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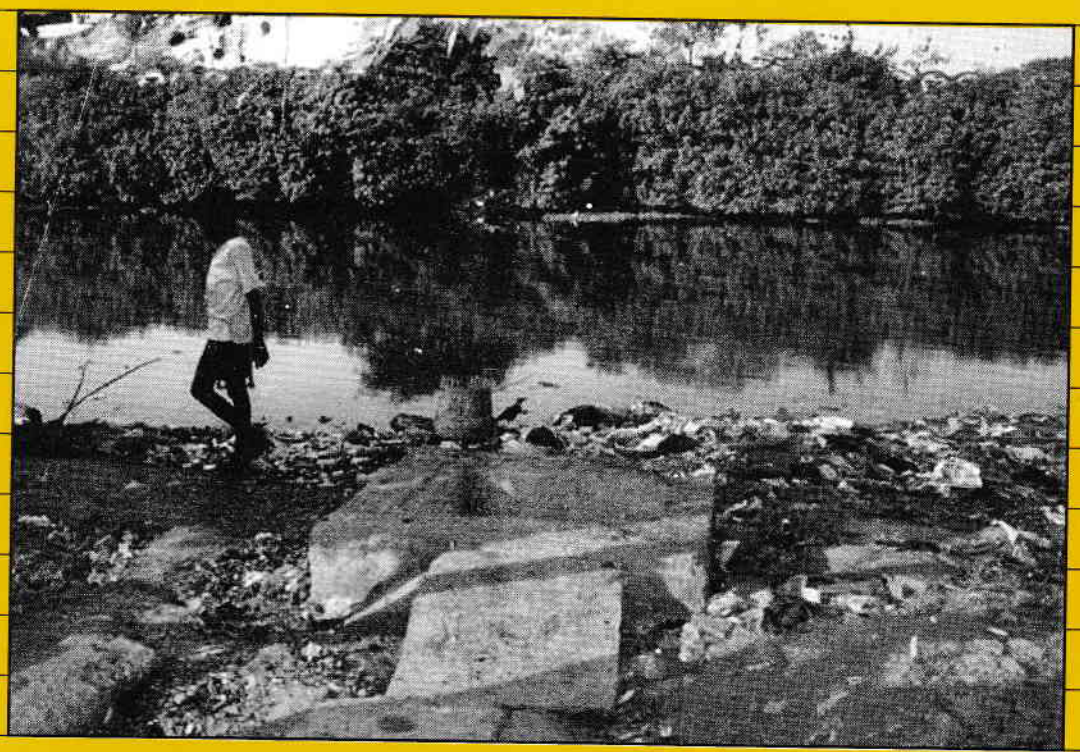

Editor : S. Subbiah

THE INDIAN GEOGRAPHICAL JOURNAL

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Plight of River Coovum in Chennai

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Email: bhattarams@airtelbroadband.in

The Indian Geographical Journal

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Editorial Introduction of the Guest Editor

Health, Environment(s) and Interdisciplinarity

Martin J. Bunch
Faculty of Environmental Studies, York University, Toronto, Canada

The World Health Organisation's classic 1948 definition of health as "a complete state of physical, mental and social well-being, and not merely the absence of disease or infirmity" (1) has wide ranging implications for the management of human health. Conceiving of health in this manner implies that health interventions must be targeted more widely than delivery of public health care, and that addressing health means also management of its environmental, social and economic determinants. Recognising these inter-relationships, Principle 1 of the Rio Declaration states that "Human beings are at the centre of sustainable development. They are entitled to a healthy and productive life in harmony with nature" (2). Thus, considerations of health are appropriate and even required to guide our management of the environment.

Health is an integrating theme that provides a vehicle to cut across the disciplinary and jurisdictional boundaries that typically constrain our approaches to understanding and managing environmental and health issues. Not only those in traditional health and medical fields, but also economists, anthropologists, geographers, urban

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planners, sociologists, ecologists and many others have expertise to bring to bear on human health. Furthermore, its management includes a wide range of governmental and non-governmental actors and stakeholders. Academic contributions might be based on multidisciplinary understanding, such that knowledge about environment and health issues are triangulated from different disciplinary treatments. Such might also be a more intentional interdisciplinary integration of knowledge generated from disciplinary concepts and methods, or trans-disciplinary work in which a fusion of disciplinary knowledge and lay expertise produces new and transcendent understanding and explanatory theory of the subject (3). The place-based and problem-oriented nature of many environment and health issues provides fertile ground for inter- and trans-disciplinary approaches, and the simple exercise of conceiving of environment and health together requires at the very least a multidisciplinary approach.

The range of approaches was demonstrated in the approximately100 papers presented in December 2003 at the 3rd International Conference on Environment and Health (ICEH), organized by the Karnataka Environment Research Foundation and hosted by the Department of Geography, University of Madras in Chennai, India. Out of the third conference, four of the papers put forward for peer-review have been selected for publication in this special issue.

The first paper by Bunch *et. al.* describes the methods and results of a multi-stakeholder workshop that was part of a trans-disciplinary action research programmme to apply an ecosystem approach to management of the urban environment for human health in Chennai, India. The workshop brought together academics, government and civil society to develop a common conceptuali- zation of environment and health in Chennai, and to direct a programmme of research into it. Issues of solid waste management, malaria, water quality, informal (slum) settlements and public participation in governance and management of environment and health were highlighted. The workshop led researchers to establish pilot projects that developed and explored a participatory community action planning approach to managing environment and health in two informal settlements in the city.

Papiya Sarkar's paper also dealt with the urban poor. Sarkar, who was at the time with the environmental NGO 'Toxic Links', describes a socio-economic and occupational health survey of informal sector workers in solid waste collection, informally known as waste or rag pickers. Sarkar's analysis of the occupational health hazards of this vulnerable group, and of their contribution to solid waste management in Delhi, allow her to comment on government programmmes oriented toward waste pickers, and to waste management in general.

The Paper by Joshi and Sharma of the National Zoonoses and Food Hygiene Research Centre in Katmandu has a focus on the quality of drinking water supply in Nepal. They describe a low-cost community-based approach to water quality monitoring in a study that tested 150 water sources in two wards in Katmandu. They found that most of the water sources used for drinking water (such as stone taps, tube wells, and piped water) was contaminated by faecal coliform bacteria. Their work led to the training of community members for a programmme of community-based water quality monitoring and treatment.

The final paper by Prashanthi Devi, B. Manickam and S. Balasubramanian presents a study that used Geographic Information Systems (GIS) to explore and model relationships between malarial incidence and mosquito habitat. Drawing on remotely- sensed and other spatial data about malaria incidence, humidity, temperature, rainfall and the presence of vegetation and water bodies, they are able to develop a predictive model for malaria incidence in Salem District, Tamil Nadu in southern India. The risk maps produced in this study should be of use to determine where to extend malaria control programmes and to implement prophylactic measures in the population, especially in places for which their study indicates susceptibility to malaria epidemics due to changes in conditions of meteorological environment that can alter the equilibrium between malaria hosts, vectors and parasites.

Taken together, these four papers cover a range of environment and health issues in South Asia related to malaria, water quality, solid waste and its management, and housing. They also span (and in some cases combine) scientific approaches to these issues with community and stakeholder-based approaches. They represent the type of inter- and trans-disciplinary work that is necessary to effectively manage environment and health issues, and which the series of ICEH conferences attempt to promote.

Acknowledgements

This peer-reviewed special issue of *The Indian Geographical Journal* has been supported by funding from the Canadian International Development Agency through their funding of the 3rd International Conference on Environment and Health. I would also like to acknowledge and thank the 19 anonymous peer reviewers, whose contribution had substantial influence on the selection and shape of the final form of the papers appearing in this issue.

References

1. WHO (1948). *Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June 1946, and entered into force on 7 April 1948.* New York: United Nations.

2. United Nations (1993). *Agenda 21: The United Nations Programme of Action from Rio*. New York: United Nations.

3. Lawrence, Roderick L (2004). 'Housing and Health: From Interdisciplinary Principles to Trans-disciplinary Research and Practice', *Futures*, 36, pp. 487-502.

Operating an Ecosystem Approach to Urban Environmental Management in Chennai, India:

Techniques and Results of a Stakeholder Workshop

Martin J. Bunch
Faculty of Environmental Studies, York University, Toronto Canada

V. Madha Suresh & T. Vasanthakumaran
Department of Geography, University of Madras, Chennai, India

Beth Finnis
Department of Anthropology, McMaster University, Hamilton, Canada

Dana Wilson
Department of Geography, McGill University, Montreal, Canada

Raj Murthy
Karnataka Environment Research Foundation, Bangalore, India

Michael J. Jerrett
Division of Environmental Health Sciences, University of California, Berkley, USA

and

John Eyles
School of Geography and Earth Sciences, McMaster University, Hamilton, Canada

This paper discusses a workshop in support of an ecosystem approach to human health in Chennai, India. The workshop brought together stakeholders to explore environment and health relationships, identify actors in managing for human health, and develop a conceptual model of environment and health in Chennai. The paper demonstrates the productive use of a stakeholder workshop within an ecosystem approach, and techniques adapted from soft systems methodology, adaptive management and participatory action research. Workshop participants developed a diagrammatic expression of environment and health in Chennai, and identified and explored themes derived from it. Participants helped identify a mixed-methods approach to address these issues. Workshop results are guiding a participatory action research programme on environment and health in Chennai.

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Introduction

Relationships exist between the biophysical environment and human health (1, 2). In developing countries such environment and health problems are particularly worrisome. Hardoy *et.al.* (3) indicate that in "many poor city districts, infants are 40-50 times more likely to die before the age of one than in Europe or North America, and virtually all such deaths are environment-related."

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Other studies show that infectious diseases related to an unfinished "sanitation agenda" continue to plague developing countries (4). Despite mounting evidence, many environment and health relationships are notoriously difficult to identify and describe. The problems may not be immediately apparent, data are poor or non-existent, and scientists disagree on the nature or even existence of such relationships. Moreover, expert and bureaucratic beliefs do not necessarily reflect the experiences and perceptions of actors living with environmental problems on daily basis. Management decisions that do not account for stakeholder understanding of the problem lead to ineffective interventions. Accommodation for such problems in the management of human affairs typically occurs *post hoc*, requiring a crisis to bring the issue to the attention of the public and policy makers.

An ecosystem approach to human health and the environment is a promising approach to such issues (5,7). This approach integrates traditional science into a more holistic means of inquiry. Ecosystem approaches recognise that problems can be usefully conceptualized as systems of inter-related elements and actors. The identification of system characteristics such as structure and processes, various levels of hierarchy (subsystems, wider systems), emergent properties and feedback loops, can be a powerful aid in understanding environmental problems (8). The ecosystem approach draws upon systems-based approaches and collaborative processes to develop a qualitative understanding of a problematic situation, including its cultural and political context. This understanding, or conceptual model of the 'system', directs further inquiry in the situation to develop knowledge about key actors, elements and relationships, and informs management and policy initiatives.

This paper presents the results of a workshop held in Chennai (formerly Madras), India in August 2002 in support of an action-oriented programme of research that compares an ecosystem approach to human health in Chennai to a similar approach in Canada. The paper is intended to highlight the use of a stakeholder workshop within an ecosystem approach, tools and techniques employed in the workshop's working sessions, and methods identified via this workshop that will be applied in the remainder of the research programme.

We present below a brief overview of the larger research programme and a description of the workshop, including its objectives, the methods employed and workshop participants. This is followed by a presentation and analysis of the material generated by workshop participants. We finish with a discussion of the workshop recommendations and conclusions.

Overview of the Research Programme

The workshop that is the subject of this paper is part of a larger research programme called "An Adaptive Ecosystem Approach to Managing Urban Environments for Human Health" funded by the Social Sciences and Humanities Research Council of Canada. Fig. 1 describes how the workshop fits into the larger programme. This research has to do with the exploration of an adaptive ecosystem approach to managing the urban environment with the aim of improving the health of city

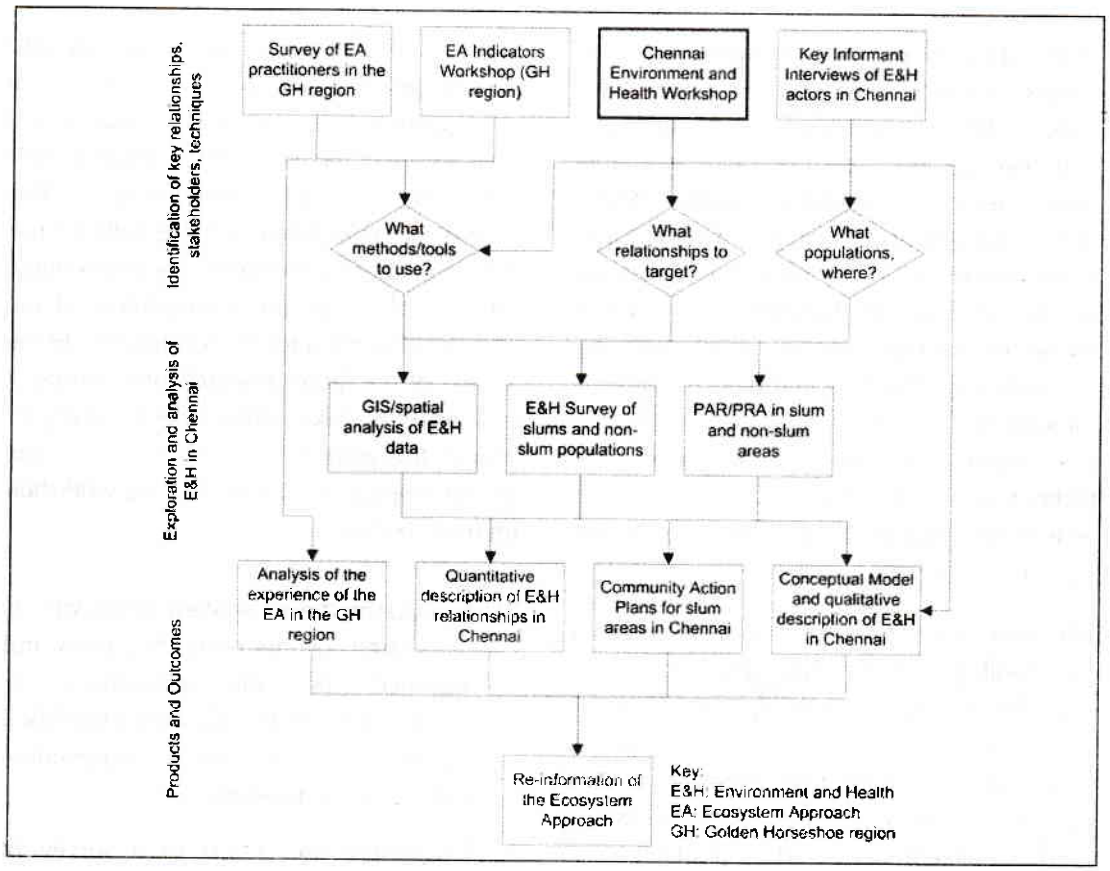

Fig. 1

The relationship of the 2002 environment and health workshop in Chennai to the larger project. The structure of the research programme presented in this diagram is largely a product of the workshop described in this paper.

dwellers. It is a comparative study that builds on the experience of the "Golden Horseshoe" region (Toronto to Hamilton) in Canada where ecosystem approaches have been applied for about 30 years, and explores the approach in the Chennai context. The research mobilizes existing agency and academic expertise, as well as lay knowledge and concerns, to develop a framework for research that will lead to a holistic and integrated understanding of environment and health issues in Chennai. It is expected to directly stimulate further work on environment and health in Chennai.

We adopt a modern conception of the ecosystem approach in which human beings are understood to be embedded in the ecosystem, and in which natural and human systems may be coupled and complex[1] (9,11).

[1]Complex systems are more than merely complicated. They exhibit characteristics such as self-organization, extreme resiliency in the face of external pressures, and (sometimes) rapid and surprising reorganization. For an introduction to complex systems see Casti J (1994). *Complexification: Explaining a Paradoxical World through the Science of Surprise.* New York, NY: Harper Collins, and Hansell R.I.C, I.T. Craine and R.E. . Byers (1997). `Predicting Change in Non-linear Systems', *Environmental Monitoring and Assessment, 46(1-2): pp. 175 - 190.*

This approach provides a framework that guides a process of problem expression, system identification, visioning of culturally and ecologically feasible and desirable futures, selection of a vision to pursue, design of an adaptive plan for its implementation, and implementation of the plan. An ongoing process of adaptive management subsumes the whole (iterative) process. At all points the ecosystem approach is informed by systems thinking and collaborative processes. Within this framework, specific methods and techniques are not prescribed, but should be responsive and appropriate to the situation and its cultural context.

The workshop discussed here helps to build the 'toolbag' of methods and techniques available to practitioners of the ecosystem approach through the development, adaptation and exploration of the use of such tools in the Chennai context. The workshop used stakeholder-based collaborative processes to undertake problem identification, system conceptualization and future visioning. Stakeholders set priorities for research and action that this action research programme will act upon. They are partners in directing the research.

Overview of the Workshop

The workshop was hosted by the Chennai Metropolitan Development Authority (CMDA) in Egmore, Chennai. Chennai is a major urban agglomeration of 6.4 million inhabitants in 2001 (12), located in southern India on the Bay of Bengal. The city is the fifth largest in India, and typifies the environment and health challenges that confront many large cities in low and middle income countries of the South.

Using a mix of paper presentations and working sessions, the workshop introduced participants to the ecosystem approach, and provided a mechanism for participants to help direct the research programme. This workshop was targeted to those with interest and jurisdiction (at the municipal and regional scale) in planning and management of the urban environment for human health. In the context of the larger research programme, a broader set of stakeholders (identified in part through this workshop) will participate. The specific objectives that guided the workshop are listed below:

1. To present the ecosystem approach (as formulated for this research project and informed by the experience of practitioners in the Golden Horseshoe region) to research programme participants in Chennai.
2. To present the results of a survey of practitioner perceptions of the ecosystem approach in the Golden Horseshoe to research programme participants in Chennai.
3. To explore the feasibility of using key tools, techniques and methods identified in the Golden Horseshoe survey in the Chennai context.
4. To develop a preliminary conceptual model of environment and health for the city of Chennai.
5. To use this model to identify key themes in environment and health in Chennai.
6. To identify key information necessary to understand (model) at least one of these key themes.

Participants

The workshop consisted of a group of 30 participants from government agencies (11), NGOs (10) and academic and other research organizations (9). Twenty two were men and eight were women. About two thirds of these comprised the core group, participating in working sessions, while others attended inaugural and valedictory sessions and paper presentations. Government agencies involved were at the municipal, regional and state levels, and included agencies mandated to coordinate development activities, develop and disseminate information about the population of Chennai, and manage both built and natural environmental contexts of that population. NGOs included those oriented toward the environment, as well as those having social and human health mandates. Researchers had environmental and health interests. Table 1 presents participants' organizational affiliations. These were

Table 1
Affiliations of Workshop Participants

Government Agencies and Departments	Non-governmental Organizations	Academic and Other Research Organizations
1. Department of Environment and Forests, Government of Tamil Nadu	1. Citizens Alliance for Sustainable Living (SUSTAIN)	1. Centre for Ecological Science, Indian Institute of Science
2. Directorate of Census Operations, Tamil Nadu, Census of India	2. Exnora, Anna Nagar	2. Department of Geography, University of Madras
3. Chennai Metropolitan Development Authority	3. Exnora International	3. Tuberculosis Research Centre
4. Tamil Nadu Slum Clearance Board	4. Mini Health Centre	4. Institute for Ocean Management, Anna University
5. Tamil Nadu Public Works Department	5. Madras Musings (Journal)	5. National Environmental Engineering Research Institute
6. Corporation of Chennai	6. Club and Alpha Institute of Akademic Excellence	6. Regional Meteorological Centre
	7. Myrtle Social Welfare	7. Department of Zoology, Loyola College, Chennai
	8. Citizens' Waterways Monitoring Programme	
	9. Asian Youth Centre	

individuals who had some role or interest in managing the urban environment. Most had earlier expressed interest in participating in the larger research programme.

Workshop Methods

Methodological Influences

While the ecosystem approach provides a general framework and guiding principles, there are several other bodies of work that influenced the choice and implementation of methods for the workshop. These are: participatory action research (PAR) (13,14); soft systems methodology (SSM) (15-17) adapted for use with the ecosystem approach [10]; and adaptive management (18-20). All three approaches emphasise (to varying degrees) collaboration and participation of stakeholders. They all explicitly operate some form of an action-experience learning cycle.

PAR describes a set of processes in which researchers and participants work in partnership to address problems by operating purposely linked cycles of action and research. Whyte (13) indicates that instead of the conventional research process starting with a literature review, generation of hypotheses, and testing of research design, PAR starts by discovering the existing problems in a situation. As researchers work with participants in the process, diagnosing and exploring the problem, they draw upon the literature and their own past experience as appropriate.

SSM is a systems-based methodology for dealing with ill-structured problematic situations involving human activity. It involves the expression of a problematic situation, the identification of key themes in the situation, modelling these as systems of purposeful human activity, and using the models to stimulate debate (and accommodation) among stakeholders for systemically desirable and culturally feasible change.

Adaptive management is an environmental management approach to dealing with situations characterized by high levels of uncertainty. Practitioners of adaptive management treat interventions in the system as if they were experiments, so as to ensure careful monitoring of system responses, and to maximize the potential for learning from surprise. It also deals with situations of multiple and conflicting values and interests by incorporating stakeholder perspectives in, for example, problem definitions and system models, and by empowering stakeholders in the governance of management programmes.

Presentations and Demonstrations

The workshop consisted of presentations, workshop exercises and demonstrations. Paper presentations were made by workshop organizers to achieve the first two workshop objectives (above). Papers were presented on the topics of: an introduction to the ecosystem approach; past experience of using ecosystem approaches, a critique of the ecosystem approach based in jurisdictional and institutional issues, and mobilization of local knowledge using participatory rural appraisal (PRA) and PAR techniques. Following the presentations there were opportunities for discussion of these topics.

Working Sessions

There were four working sessions oriented to: identification of environmental and health problems in Chennai; development of a

conceptual model of environment and health for Chennai; use of the conceptual model to identify and explore important environment and health themes; and a force field analysis, used to identify the restraining and driving forces of one objective for change identified by workshop participants.

The first exercise in the workshop consisted of a set of written responses to eight problem identification questions adapted from a UNCHS action research training material (21). Participants were first asked to identify what they thought was the most important environment and health relationship in Chennai. The following questions, oriented to problem identification and scoping helped to clarify these relationships:

1. What is the problem?
2. Why is it a problem? What would the problem look like if it were solved?
3. Whose problem is it? Who owns it?
4. Where is it a problem? Is it localized and isolated, or is it widespread and pervasive?
5. When is it a problem? (e.g., every Monday morning at 8 a.m.? Once every full moon? Continually?)
6. How long has it been a problem?
7. Really now, what is the problem? Is the problem you stated in task one: (a) a symptom of a bigger problem; or (b) a solution to what you think is the problem.
8. Finally, what would happen if nobody did anything to solve the problem?

The second working session involved the diagrammatic expression of environment and health in Chennai using a 'rich picture' technique borrowed from soft systems methodology. They describe relationships among the various actors and elements in a problematic situation. The use of diagrams such as these, that simultaneously portray multiple interacting relationships, represent one way to promote holistic thinking about the situation (17).

The third working session involved the further exploration of key themes in environment and health in Chennai. Two primary themes were pursued by workshop participants: slums and waterways. Both of these themes were cast in light of institutional and organizational contexts. Institutional and jurisdictional issues were also a main theme in the workshop. Influence diagrams, a common diagrammatic tool in systems-based approaches (and similar to the rich picture technique in form and implementation) were used to explore and express these contexts.

The fourth working session undertook "force field analysis" for a selected aspect of the problem situation (21). The exercise was intended to identify barriers (restraining forces) and bridges (driving forces) with regard to an objective that would change the current situation. A force field diagram organizes these forces in two adjacent lists, with the objective considered to lie between them. Arrows are drawn from the force toward the objective. The length of the arrows for each force represents their power: the longer the arrow, the more powerful the force. Force field analysis provides a set of targets for intervention in the situation. In particular, addressing restraining forces will often turn them into driving forces.

Workshop Analysis

Problem Identification

Responses to questions oriented toward problem identification and problem framing indicated a wide variety of environmental aspects and associated issues having to do with environment and health in Chennai. These fell into four categories: air, water, solid waste, and associated human health problems. In all, forty one problems were identified. Water quality seemed to be the most concerning. Participants identified 18 distinct problems in this category. Seven problems associated with air quality, 8 associated with solid waste, and 8 with general health hazards were identified. All four categories were indicated as long-term problems that should be a priority for management.

Air quality problems centered around emissions from a variety of activities, including cooking, transportation and unregulated industries. Participants cited both limited emission regulations and a lack of enforcement of the regulations that did exist. Additionally, burning of garbage by individuals and waste management personnel is a problem throughout the city. This is related to the poor household waste management system in Chennai, partially a result of limited funds for pickups, and limited space for city dumps.

Solid waste management was identified as a key problem resulting from several factors, such as aging infrastructure and the prevalence of open air defecation. While private homeowners will have toilet facilities, slum and street dwellers often have little access to public facilities. These facilities, where they do exist, are typically unsanitary and inadequate, discouraging individuals from using them. Sewage pipe systems throughout the city are aging, compromising waste management for private homes and offices.

The problems with solid waste are related to water contamination. Domestic drinking water often mixes with waste water. Private homeowners tend to refrain from drinking the water piped into their homes without boiling or otherwise sterilising it. Moreover, there is a lack of water supply to most slum areas, leaving citizens with limited, and often expensive options. Although water is trucked and stored for some slum areas, deliveries may be periodic, and may not even reach slum areas when trucks are waylaid by private individuals. Water trucks are aging, resulting in leaks. The same can be said for the piped water delivery system. In an area with limited access to fresh water, and annual summer water shortages, such leaks are particularly problematic. Finally, inadequate management of water was identified by participants as contributing to the breeding grounds of infectious disease vectors. Water stored by households for example, may not be properly protected to prevent mosquito breeding.

A number of human health problems were associated with these, and other, environmental problems. Asthma and other respiratory diseases, gastrointestinal problems such as typhoid, cholera, dysentery and diarrhea, and exposure to malaria-carrying mosquitoes were all listed as pressing problems. In identifying and discussing these concerns, it became clear that participants

were highlighting slum dwellers as most at risk for many environment and health problems. Discussion increasingly turned to slum communities and the interconnected issues that shape the environment and health of women and children in particular. During the rich picture exercise (Fig. 2), participants chose to further discuss slum communities.

Understanding the future that stakeholders anticipate provides valuable insight into the depth of the problems. As noted above, participants were asked what environment and health problems would look like if they were solved, and the consequences if problems remained unchecked. Interestingly, many of the responses were placed in an economic context. For example, responses to the scenario of continued water problems included the statements; "You'd pay higher prices. Maybe rationed water. Maybe Chennai won't be livable," and "It will result in total health failure of the people. Economic losses due to spending on medicine and doctors."

When thinking about solid waste management, two individuals stated, "Productivity of the people will come down because of poor health. Suffering and frustration will breed anti-social elements", and "[It would mean a] drop in the quality of living. No investors. No tourists." Quality of life, economic losses, and basic livability were high on the list of future and current repercussions of environmental problems.

In contrast, participants saw vast potential improvements if human and economic resources could be mobilized to make environmental changes. An improved situation would be characterized by; decreased infant mortality rates, more productivity and improved financial stability for all sectors of the city, the control of malaria and other mosquito-borne diseases, a lack of typhoid and other gastrointestinal diseases, a clean sky, and a neater, cleaner city. Hopes for increased tourism went hand-in-hand with many of these indicators.

Describing Environment and Health in Chennai

The second working session involved the collaborative development of a diagrammatic expression of the problem that added detail to, and began to synthesize the more general categories of environment and health concerns, placing them in their economic, political, social and management contexts. The techniques for developing and using such "rich pictures" were borrowed from SSM. By this point in the workshop slums and slum dwellers had arisen as a primary theme, and for this exercise participants chose to express the environment and health situation of slum areas. The rich picture was constructed by facilitating a discussion of important environment and health relationships, actors and elements in slum areas, and recording these on contiguous large sheets of paper (in lieu of a blackboard, or whiteboard). Fig. 2 is a redrawing of the rich picture developed during the workshop.

The rich picture does not portray all possible actors, elements and relationships. Nor does it represent all possible perspectives (such as that of slum dwellers themselves). Yet, it does

begin to portray the degree of complication in the situation and highlights some important clusters of relationships, including:

- Animal husbandry, including the role of cattle as hosts for the malaria parasite, pigs and the spread of Japanese encephalitis, animal (including human) dung and the spread (via flies) of diseases such as cholera, hepatitis, and diarrhea. This is linked to the keeping of animals in the city (as a source of income). Animals are allowed to graze in the streets and open areas, particularly along waterways where they contribute to the pollution of surface waters and the buildup of organic sludge. These waterways and other sites are breeding grounds for the Anopheles (malaria) and Culex (filariasis) mosquitos.
- Location of slums on objectionable land, such as riverside locations that are prone to flooding, and on roadsides where slum dwellers are exposed to higher levels of traffic-related pollution, dust, and traffic hazards.

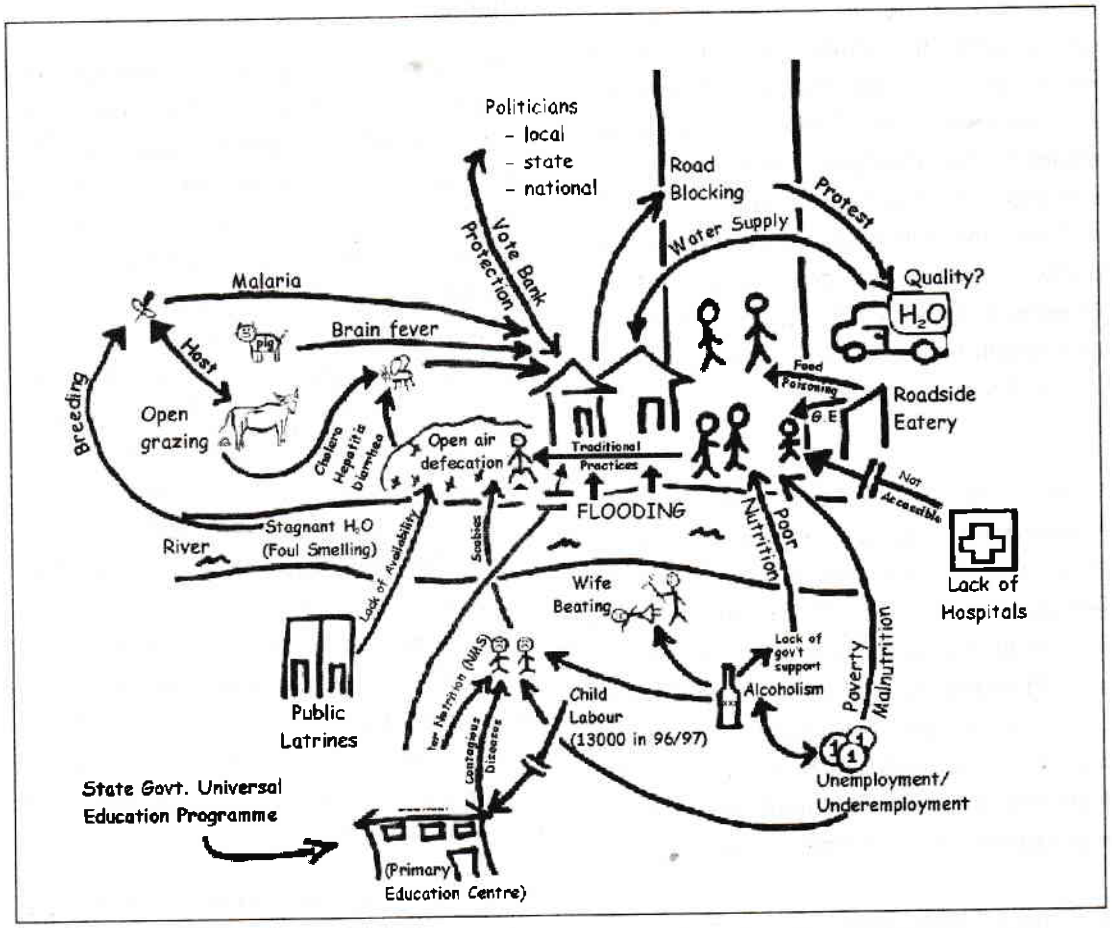

Fig. 2
A Rich Picture of the Environment and Health Situation of Slums and Slum Dwellers

- Political processes such as the use of slums as vote banks by politicians in exchange for protection and political favours. Also indicated is protest action by slum dwellers who block roads in response to water scarcity and the responding provision of water supply (of questionable quality).

- Links to the urban economic system are portrayed in indications of unemployment/ underemployment. These are linked (in the absence of adequate government support for slum dwellers) to urban poverty, malnutrition, alcoholism, domestic violence and child labour. Roadside eateries (which are affordable to slum dwellers) are implicated in gastroenteritis and food poisoning.

- Children emerge as a theme in the rich picture. Unemployment/ underemployment are portrayed as one of the causes of child labour. Child labour acts as a partial barrier to participation of children in primary education. Primary education centres improve nutrition through the noon meal scheme, but also act in the spread of contagious disease among children. Children (and others) engage in open air defecation because of lack of availability of public latrines and continuation of traditional practices in slum areas, which increases the incidence of scabies and contributes to the spread of cholera, hepatitis and diarrhea.

- Lack of urban and public amenities in slums are shown to affect health in the rich picture. For example, lack of public latrines promotes open air defecation and the spread of spread of cholera, hepatitis, diarrhea and scabies. Water supply is of questionable quality. Hospitals are not accessible to slum dwellers. Schools are not located in slums.

More than simply portraying relationships, the rich picture is a collaborative expression of the situation – something "owned" by all participants in the workshop. It is also a powerful tool to stimulate systemic understanding of the situation. Systemic understanding as the basis for management and policy intervention is an important characteristic of the ecosystem approach.

Environment and Health Themes

Two 'influence diagrams' were developed by workshop participants in the third working session. Fig. 3 explores the relationship between institutions and organizations and slums/slum dwellers in the context of environment and health. A variety of relationships were identified. For example, workshop participants indicated that slums act as vote banks for local politicians in exchange for relief benefits. Local politicians' 'strong arm' (via henchmen) make the Corporation of Chennai to provide such civic amenities to their protected slums. Access to slum dwellers was seen to be controlled by slum leaders and "Slum Lords."

Fig. 4 portrays institutions and organizations involved in managing surface waters in Chennai. The theme of surface water quality and its relationship to human health was a primary one in the workshop. Previous work in which some of the current workshop participants were involved (the Cooum River Environmental Management Research Programme) produced a rich picture of the Cooum River situation in Chennai (8,10). As does Fig. 3 with the theme of slums, this

diagram represents an exploration of organizational and institutional relationships associated with surface waters in Chennai.

In Fig.4 waterways are portrayed as locations of organic sludge (associated with pathogenic parasites and enteric pathogens) and a breeding ground for flies and mosquitos (disease vectors). Organizations and agencies depicted with stars are those seen by workshop participants to have some jurisdiction or power to change the situation. The number of stars corresponds to participants' perception of the potential for that agency to stimulate change. By this indication the most important agencies are the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) (five stars), the Tamil Nadu Public Works Department (three stars), the Corporation of Chennai (two stars) and the Tamil Nadu Slum Clearance Board (two stars). Another way to analyse this diagram is to look at the number relationships associated with entities in the diagram, and the number of other entities to which they connect. From this perspective, the Tamil Nadu Public Works Department (with nine relationships and connections to seven other entities) is the most important. This is followed by the Chennai Metropolitan Development Authority (nine relationships and connections to five other entities), the Corporation of Chennai (5/3), the CMWSSB (5/3) and the Tamil Nadu Slum Clearance Board (4/3). In light of these results, the technique may be seen as an effective way to identify the responsibilities of stakeholders,

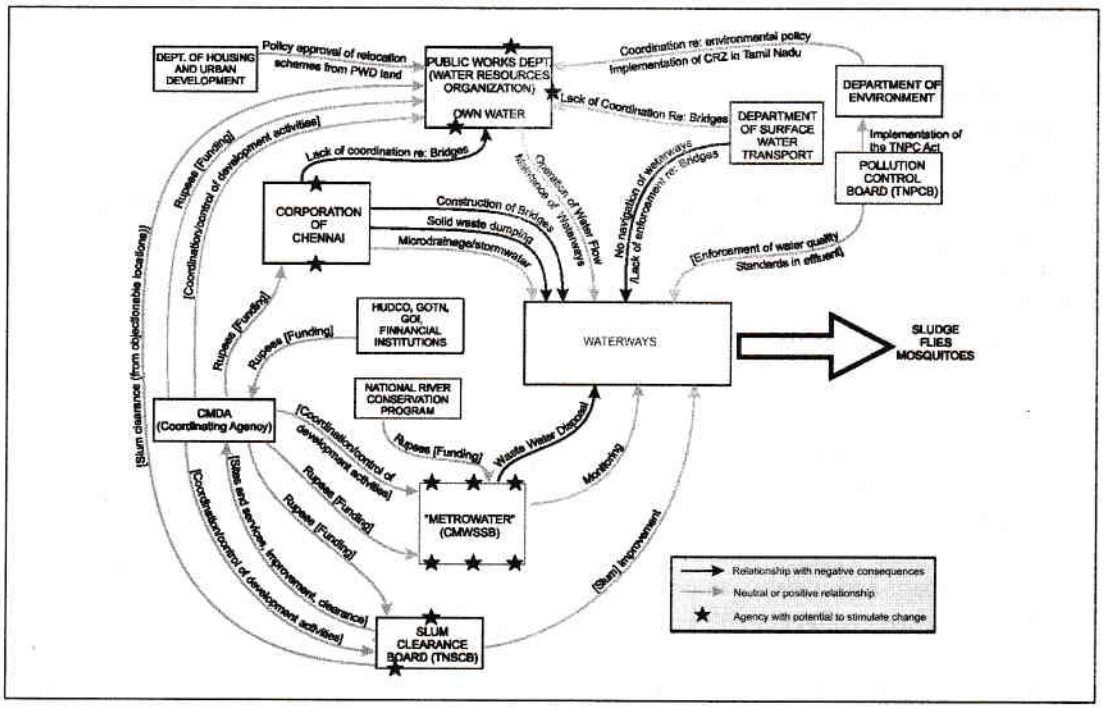

Fig. 3

A Diagrammatic Portrayal of Relationships among Institutions and Organizations and Slums and Slum Dwellers in the Context of Environment and Health

pointing out which stakeholders need to be brought to the table.

Force Field Analysis

A force field analysis diagram was generated in the fourth working session and is portrayed below in Fig. 5. In this exercise, participants chose to work on the problem of "Limited Public Participation" in management of environment and health problems. The objective was to "improve public participation."

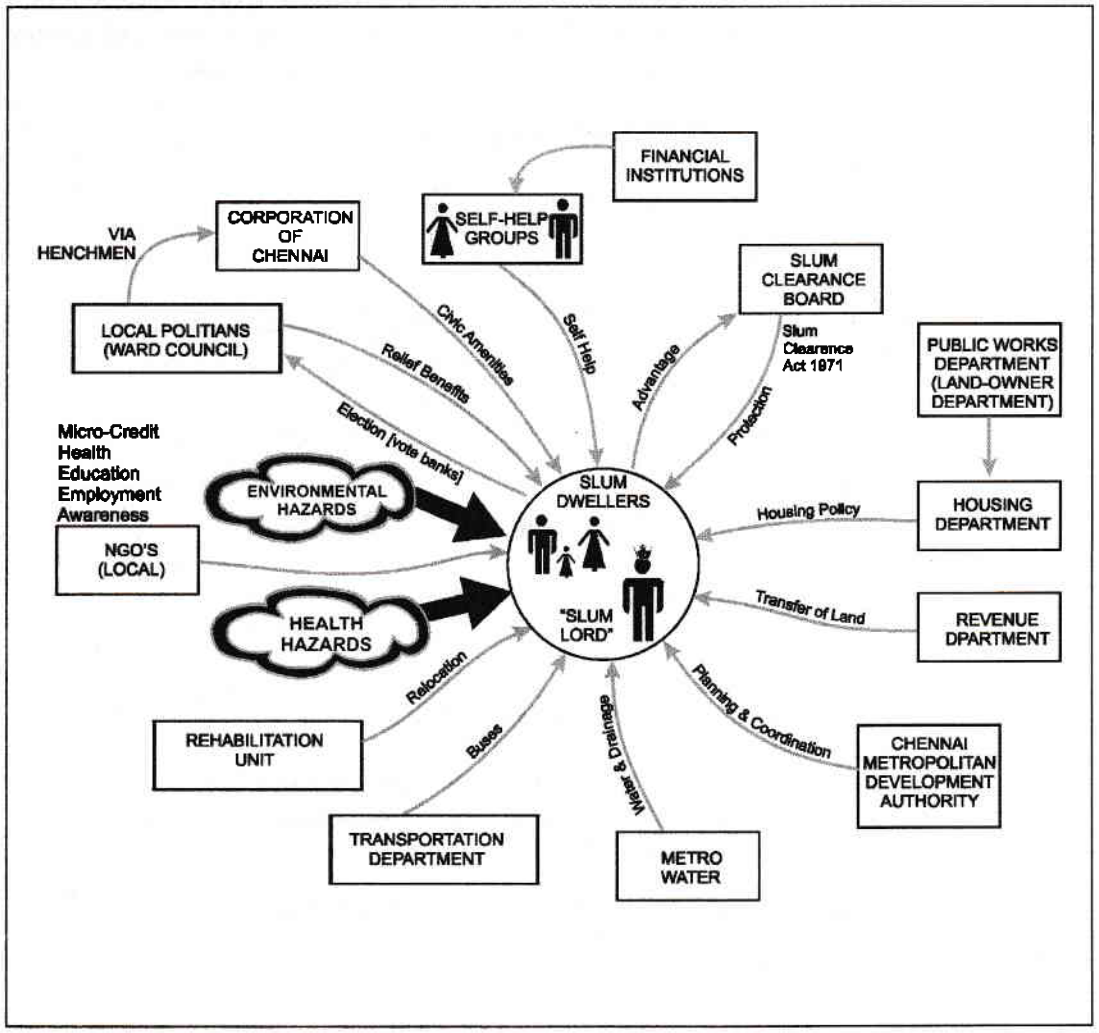

Fig. 4
Institutions and Organizations involved in Managing Surface Waters in Chennai. The Context: Human Health Relationships with Surface Water Quality. Some of the acronymns in the diagram are: CMDA (Chennai Metopolitan Development Authority), CRZ (Coastal Restriction Zone), CMWSSB (Chennai Metropolitan Water Supply and Sewerage Board), and TNPC Act (Tamil Nadu Pollution Control Act).

In this analysis, participants identified political, financial and institutional support as restraining forces. These external forces were often identified as barriers towards achieving the desired goal. There is some correspondence here with "bureaucratic rigidity" and "jurisdictional fragmentation" which are the most commonly cited barriers to successful application of ecosystem approaches. In contrast, internal forces, or those centering around individuals, their experiences and perceptions, were more commonly identified as driving forces (bridges) towards the desired goal. However, these also play important roles in the restraining forces list (lack of interest, lack of integration between education and training, not understanding the benefits).

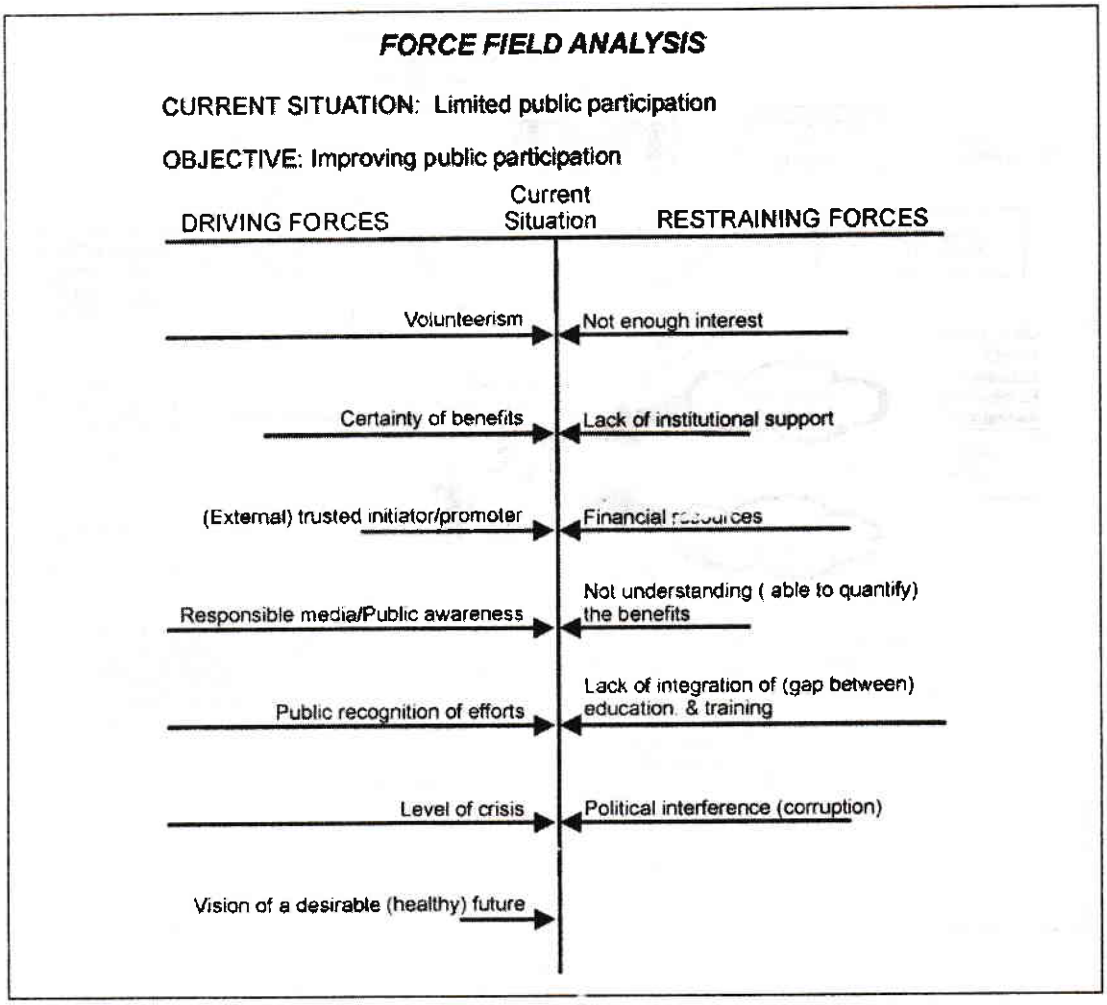

Fig. 5

A Force Field Diagram that was part of an analysis of public participation in planning and management activities in Chennai.

The length of arrows correspond to the strength of the force.

Workshop participants identified more and stronger driving forces than restraining forces. If a full arrow were to represent four force units then driving forces out-power restraining forces 22 to 17. This may indicate that participants perceive the situation to be changing in favour of increased public participation, or that the situation is poised to change.

Discussion of Workshop

Recommendations

A final session in the workshop involved a discussion of potential directions for the programme of research, possible case studies and recommendations for government. Based on this discussion, and the work undertaken in the earlier working sessions, key issues were identified that we will further explore in the remainder of this research programme. The most strongly emphasized issues were: slums as locations of most-vulnerable populations and objectionable conditions; surface water quality and water-borne disease (e.g., typhoid, cholera, diarrhea, dysentery); public participation in management of environment and health problems, and malaria. Also indicated were: air pollution and respiratory illness; lack of coordination and cooperation among government agencies/departments; poor governance; solid waste (rodent and fly breeding - gastroenteritis, etc.); tuberculosis; filariasis; and a variety of other pathogenic parasites and enteric pathogens.

In addition to the identification of key concerns, relationships, and vulnerable populations, participants in the workshop had three main recommendations:

1. Government agencies and departments must establish and operate mechanisms for meaningful citizen participation in environmental management projects and programmes in Chennai.

   Three primary reasons for this recommendation emerged in discussion throughout the workshop. First, multiple stakeholders can provide different perspectives on a problem to develop a more complete picture of issues and actors involved. Second, local knowledge exists alongside scientific knowledge about ecological and social systems and can improve environmental managers' understanding of the situation. Third, meaningful participation by stakeholders will transfer ownership of solutions and management plans to the stakeholders, and this will promote cooperation with interventions and improve the chances for success.

2. The ecosystem approach should guide sustainable development and environmental management activities in Chennai. Specifically, the Master Plan for Chennai should adopt an ecosystem approach.

   The ecosystem approach crosses many academic disciplines, requires collaboration among government agencies and departments, and ongoing meaningful participation of citizens and NGOs. This implies that it is challenging to undertake. It also offers the greatest potential for successful management of such intractable situations in the long term.

3. The CMDA should establish a Centre for Environmental Planning which incorporates the new environmental wing in the CMDA, activities carried on from the Sustainable Chennai Project (SCP), and the geographic information systems (GIS) section.

Several times throughout the workshop participants expressed their view that the CMDA, with its mandate for coordination of development activities in Chennai, was the appropriate agency to sponsor the kind of ecosystem approach necessary to address the difficult environment and health problems with which Chennai is faced. The combination of a mandate for environmental management and sustainable development in the environmental wing, the potential of SCP activities to foster collaboration among government agencies/departments and participation of NGOs and the public, and the necessary support for environmental modelling, mapping and spatial analysis that could be provided by the GIS section offers a unique opportunity to create an effective unit to apply an ecosystem approach to environmental management and environment and health problems in the Chennai Metropolitan Area.

Thus, workshop participants identified both key environment and health relationships and locations and populations at great risk in Chennai. They have also identified tools and processes that, in effect, now directs researchers and participants in the research programme to employ the three-pronged mixed-methods approach that is outlined in Fig. 1.

Conclusions

The workshop on environment and health held in Chennai in August 2002 served as a useful instrument to operationalize the ecosystem approach. It brought together stakeholders in the management of environment and health relationships to describe and explore the environment and health situation in Chennai. Participants identified key themes (such as slums as the locations of the most objectionable conditions and vulnerable populations, water quality, malaria and public participation) that the larger research programme is now addressing. This is one way that the workshop participants help to direct the research. For example, the research will now focus on environment and health in slum areas, with an emphasis on participatory processes, and dealing with issues such as water quality.

The workshop also addressed tools and techniques used within an ecosystem approach. We were interested in the suitability and appropriateness of such tools in the Chennai context. Stakeholder workshops are a common instrument used by ecosystem approach practitioners. The successful implementation and productivity of this one indicates that such workshops are appropriate tools in Chennai for the types of stakeholder that participated in this workshop. Particularly effective was the sequence of problem identification, diagraming and analysis techniques. Responses to problem identification questions and their presentation back to participants generated a prodigious amount of raw material to support participants' work in later working sessions. Diagraming techniques such as the rich picture and influence diagrams were found to be very useful to organize this material so as to express the environment and health situation in an interconnected and holistic manner, and to facilitate the identification of important themes in the situation. Force field analysis was found to be effective in the exploration

and analysis of such themes, having a positive orientation toward change in the situation.

In contrast, public participation, which is key to the successful operation of the ecosystem approach, may present a problem in Chennai. Workshop participants indicated that public participation in the management of environment and health issues in Chennai is limited. Partly because of this we have decided to pursue the collaborative development of community action plans for slum areas as a means to operate future visioning, plan development and implementation components of the ecosystem approach. These would benefit from, but not depend on, cooperation and participation with government agencies. Management processes that are closed to non-governmental stakeholders present an institutional barrier to public participation. This is an excellent example of a restraining force that through the institutionalization of mechanisms for public participation could be converted into a powerful driving force for positive change in the situation.

Acknowledgment

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References

1. Eyles J(1997). Environmental health research: setting an agenda by spinning our wheels or climbing the mountain?, *Health and Place, 3 (1) pp. 1-13.*
2. Steenland K and D.A. Savitz(1997). *Topics in Environmental Epidemiology*. New York: Oxford University Press.
3. Hardoy J.E., D. Mitlin and D. Satterthwaite (1992). *Environmental Problems in Third World Cities*. London: Earthscan Publications Ltd.
4. WRI, *World Resources, 1998-99(1998). A Guide to the Global Environment: Environmental Change and Human Health*. New York: Oxford University Press.
5. Rapport D.J, R. Constanza and A.J. McMichael (1998).'Assessing Ecosystem Health', *Tree*, 13(10), pp. 397-402.
6. Forget G and J. Lebel (2001). 'An Ecosystem Approach to Human Health', *International Journal of Occupational and Environmental Health*, 7(2). pp. S1-S36.
7. Lebel J(2003). 'Health: An Ecosystem Approach', in *Focus 100*. Ottawa, Canada: International Development Research Centre.
8. Bunch M.J (2001). 'An Adaptive Ecosystem Approach to Rehabilitation and Management of the Cooum River Environmental System in Chennai, India', *Geography Publication Series* 54. Waterloo: Department of Geography, University of Waterloo. *Geography Publication Series,54.*
9. Kay J.J *et. al. (1999).* ' An Ecosystem Approach for Sustainability: Addressing the Challenge of Complexity', *Futures*, 31(7), pp. 721-742.
10. Bunch M.J (2003). 'Soft Systems Methodology and the Ecosystem Approach: A System Study of the Cooum River and Environs in Chennai, India', *Environmental Management*, 31(2), pp. 182-197.
11. Waltner-Toews D *et. al.* (2003). `Perspective Changes Everything: Managing Ecosystems from the Inside Out', *Frontiers in Ecology and the Environment*, 1 (1), pp. 23-30.
12. Government of India (2001). *Census of India (Provisional) Tables; Cities with More than One*

Million Population; and Urban Agglomerations/Cities having Population of One Million in 2001. New Delhi: Office of the Registrar General.

13. Whyte W.F(1991). *Participatory Action Research*. Newbury Park, California: Sage Publications.
14. Parkes M and R. Panelli(2001). 'Integrating Catchment, Ecosystems and Community Health: The Value of Participatory Action Researc', *Ecosystem Health* 7(2), pp. 85-106.
15. Checkland P.B (1981). *Systems Thinking, Systems Practice*. Toronto: John Wiley & Sons, Ltd.
16. Checkland P.B and J. Scholes (1990). *Soft Systems Methodology in Action*. Toronto: John Wiley & Sons, Ltd.
17. Checkland P.B(1999). 'Soft Systems Methodology: A 30-Year Retrospective', in P.B.Checkland and J. Scholes (ed.). *Soft Systems Methodology in Action*. Toronto: John Wiley.
18. Holling C.S (ed.)(1978). *Adaptive Environmental Assessment and Managament*. New York: Wiley.
19. Lee K.N(1993). *Compass and Gyroscope: Integrating Science and Politics for the Environment*. Washington, D.C : Island Press.
20. Gunderson L.H, C.S. Holling and S.S. Light (eds.)(1995). *Barriers Broken and Bridges Built: A Synthesis*, in *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. New York: Columbia University Press.
21. UNCHS (1991). *Guide for Managing Change for Urban Managers and Trainers*. Nairobi: The United Nations Centre for Human Settlement (Habitat).

Solid Waste Management in Delhi –

A Social Vulnerability Study

*Papiya Sarkar**
New Delhi

Management of burgeoning solid wastes has become a critical issue for almost all the major cities in India. Although the responsibility of solid waste management remains primarily with municipal bodies, several other stakeholder groups play significant roles in the process. In the Indian scenario the so-called waste pickers, who come from a highly vulnerable social background, play a unique role. Waste pickers, scavengers or rag pickers as they are commonly called, eke out a living by collecting and selling recyclable materials out of municipal solid wastes. In the process they make significant contributions to environmental management in different cities and render service to local economies. This paper presents a vulnerability study of the waste pickers of Delhi with focus on the socio-economic and occupational health aspects. The paper makes use of a database, pertaining to the socio-economic profile of the waste pickers including working conditions, and their problems and expectations. This database was developed through literature review, questionnaire survey and open-ended interviews conducted by the environmental group "Srishti" from June 2001 to January 2002 to generate data on waste pickers in Delhi. Relevant policies of the Delhi Government have been examined to assess its understanding of the overall role of waste pickers, and to explore concerns and commitments of the Government towards them. Recommendations have been made to enhance the efficiency of the Government ventures in addressing the basic problems of waste pickers, such as deplorable working conditions, poor returns, exploitation and everyday harassments. Suggestions have been made to improve the design of policy initiatives aimed at integrating waste collection and disposal, incorporating the employment needs of the urban poor and migrants with adequate attention to the occupational health aspect of these people.

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The quantity of municipal solid wastes generated in Delhi has been consistently rising over the years. This can be attributed to rapid population growth, mass migration of population from rural to urban areas, increase in economic activities in general in the city and the change in lifestyle of the people. Amongst all the Indian States and Union Territories, the National Capital Territory of Delhi is most urbanized with 93 per cent urban population (3). Along with intrinsic population growth, rural to urban mass migration accounts for additional population pressure on the city. Changes in lifestyle of the people have resulted in increased wasteful consumption, leading to a change in the composition and increase in the quantity of solid waste generated.

Urban solid waste is normally a mixture of household waste, construction debris, commercial wastes, toxic industrial elements and hospital wastes. On an average, Delhi generates 8000 tonnes of municipal solid waste per day (2). A physical analysis reveals that it consists of about 32% compostable matter. The recyclable components include paper (6.6%), plastics (1.5%), and metals (2.5%) (7). Primarily the responsibility of solid

* The author was with Toxics Link, New Delhi

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waste management is vested upon several public sector agencies. However, various other stakeholder groups, such as waste pickers, waste dealers, recyclers and recycling unit workers play significant roles in the overall scheme of things.

This paper presents the findings of a survey conducted by Srishti[1] from June 2001 to January 2002 to elucidate the socio-economic profile of the waste pickers including their working conditions, and their problems and expectations.

Solid Waste Management in Delhi

Three municipal bodies - the Municipal Corporation of Delhi (MCD), the New Delhi Municipal Council (NDMC) and the Delhi Cantonment Board (DCB), are responsible for solid waste management in Delhi. MCD alone manages almost 95% of the total area of the city. The above authorities are supported by a number of other agencies. The Delhi Development Authority (DDA) is responsible for siting and allotment of land to MCD for sanitary land-filling. Delhi Energy Development Agency (DEDA) under the Delhi Administration (DA) is responsible for solid waste utilization projects aiming at bio-gas or energy generation in consultation with the Department of Non-Conventional Energy Sources (DNES), and the Ministry of Environment and Forests (MoEF), Government of India. The Department of Flood Control of Delhi Administration looks after the supply of soil to be used as cover for sanitary landfills by the MCD.

Apart from the above public agencies there are other important agents who play their part in the overall scheme of solid waste management in the city. They are private sweepers and garbage collectors employed by the people for cleaning privately-owned premises, waste pickers, waste dealers and recycling industries, which consume recyclable waste to produce recycled products.

Stakeholders involved in recycling of Solid Waste in Delhi

In the overall sequence of activities starting from collection of recyclable materials to the final disposal and recycling of waste, significant contributions are made by a range of private stakeholder groups outside the municipal authorities. These stakeholder groups are at the helm of the informal sector recycling trade activities, namely segregation, collection, sale and purchase of recyclable materials, and the actual process of recycling at recycling units.

Residents and shopkeepers sell recyclable items, such as newspaper, glass containers, tin cans etc. to *kabdiwallas* or itinerant waste collectors. The waste pickers retrieve recyclable materials from what is discarded by households, commercial establishments and industries and from municipal waste sites. Larger commercial establishments and industries sell the recyclable waste (in segregated form or otherwise) to waste dealers in bulk, who then sell it to recyclers.

Waste pickers pass on the retrieved materials to waste dealers. There are agents who

[1]Srishti is an environmental group registered as a society, involved in issues regarding environment, waste, toxicity and communities. For the past several years Srishti has been working primarily on waste and waste trade issues.

facilitate transactions between medium / large waste dealers and recycling unit owners. A typical structure of the waste trade is presented in Fig. 1.

Waste trade activities performed by these informal sector stakeholders result in very significant waste material recovery and recycling (9-15%) (4). These activities in the informal sector are crucial in the broader framework of urban waste management. Such informal sector activities require low capital investment, respond directly to local needs and demands, provide livelihood opportunities to a significant number of urban poor, and reduce the environmental burden that would have otherwise resulted due to the accumulation of solid wastes had they remained uncollected. Unfortunately, not all the stakeholders, benefit proportionately from the profits made from these activities. Amongst all the stakeholders the waste pickers, who come from highly vulnerable social backgrounds, often become victims of exploitation, despite their significant service to environment and the society at large (12).

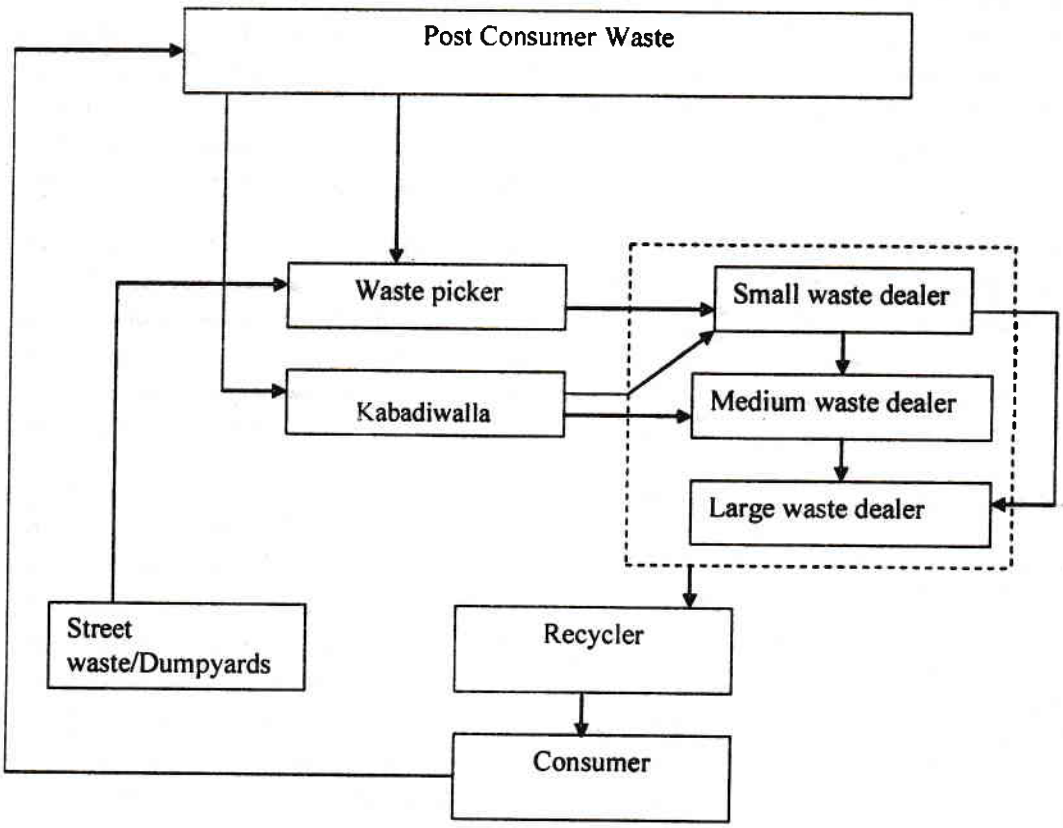

Fig. 1
Recycling and Movement of Waste through Various People involved in the Waste Trade

Methodology of the Study

The study was exploratory in nature. The initial sample size for waste pickers (approximately 200) was spread over 8 slum communities.[2] A standard Delhi map was selected as a starting point to delineate the geographical area of Delhi into manageable units. Delhi was divided into five zones – east, west, north, south and central. It was decided that around 40 waste pickers would be interviewed from each zone. A team of five people including myself undertook the survey. It was expected that, as waste pickers belong to economically weaker sections of the society they would live mostly in slums though there are some who live on railway platforms, bus depots and on the pavements. However, for the survey 12 slum areas spread over five zones were selected as potential locations where the survey was to be carried out.

The bucket sampling method was employed to identify the 8 sample slums from the 12 slum areas in Delhi. The slum areas were identified on the map and thereafter each was assigned a number from 1 to 12. The same numbers were then written on chits of paper and 8 chits were chosen randomly. The 8 slums chosen covered the five zones. In order to find survey respondents in the eight slums frequented by the survey team, questionnaires were administered randomly only to waste pickers who were found waste picking in the slum areas.

The present paper makes use of the database of one hundred and ninety eight waste pickers who were interviewed from different parts of the city between 10 a.m and 4.p.m from June 2001 to January 2002.

Socio Economic Profile of Waste Pickers

Most Vulnerable

Waste pickers, scavengers, or rag pickers as they are commonly called, constitute that segment of the society involved in the waste trade and who make a living by collecting and selling recyclable materials out of municipal solid waste. Though they play a pivotal role in the larger waste management system they remain most vulnerable in the urban society.

Due to the extremely unorganized and scattered nature of the waste picking activity it is difficult to give an accurate estimate of the population involved in waste picking. Rough estimates give the number of waste pickers in Delhi as ranging between 80,000 and 100,000 (5).

In the absence of a formal census, it is also not possible to ascertain the precise age or the sex profile of this population. We surveyed 198 waste pickers, of whom 24% were female and 76% male. Overall 24% were below the age of 16, 31% were between the ages 16 and 25, and 45% were above 25 years of age. If the survey results are taken as typical, this would reveal fewer females in the occupation. This might be because most women return to their household chores before noon and the survey

[2]While different State laws have adopted different definitions of the word slum, the Census of India 2001 has proposed to treat the following as 'Slum' areas: -

All areas notified as 'Slum' by State/Local Government and UT Administration under any Act;

All areas recognized as 'Slum' by State/Local Government and UT Administration which have not been formally notified as slum under any Act;

A compact area of at least 300 population or about 60-70 households of poorly built congested tenements, in unhygienic environment usually with inadequate infrastructure and lacking in proper sanitary and drinking water facilities

was conducted between 10 a.m and 4 p.m. There also exists area-wise variations.

However, in response to interview questions, we found on the whole apart from the Muslim community either both men and women within the household are engaged in waste picking or only the women are involved. Often the children assist their parents during waste picking. A study conducted by National Labour Institute (NLI) in 1997-1998 found waste picking to be the fourth largest occupation for street children in Delhi (1). The present study found only 24% of the waste pickers to be children. A possible reason could be that most child waste pickers take up waste picking as a family occupation and collect waste with their parents. During the survey only those children who were without their parents were interviewed.

It is not possible to arrive at religious or community profiles of the waste pickers in Delhi based on the micro surveys that have been conducted in limited areas. However, in this study 52% of the waste pickers were Muslims. Most of the Muslim families did not allow women and adolescent female members of their family to do waste picking.

Migrants as Waste Pickers

Most waste pickers are migrants from rural India. Unemployment and poverty are two prime reasons for their migration into urban areas. 97.5% of the migrants surveyed revealed that they came to Delhi looking for employment and ended up waste picking as a means to survive. We found that 10% of the waste pickers are Bangladeshi immigrants who came during the 1971 war as refugees or illegally entered India. They include both Hindu and Muslim refugees. Once in the city most of them took up waste picking as a means to survive. Moreover, the very nature of the activity, which requires no skill, no investment and no contacts or references, might be other reasons for migrants to become waste pickers.

Income of Waste Pickers

Adult waste pickers earned the meager amount of Rs 45 to 80 (about $US 0.96-1.70 in later 2001) per day. A child waste picker earned Rs 10-15 when assisting his parents. If he was working independently he earned Rs 20 and Rs 30 as he could devote more time to his activity. Waste pickers with bicycles earned Rs 50 to 80 per day and those with tricycles earned Rs 150 to 200 per day.

Waste pickers usually sell the collected waste to the local waste dealer on a daily basis, as they have no place to store the waste. Since they have little savings they depend on the waste dealer for loans and advances. The Srishti study revealed that about 75% of them are illiterate. Even after several years at waste picking they do not acquire any special skills and are hence unable to move into any other occupation. Trapped in the vicious cycle of poverty and debt they are forced to continue with waste picking.

Quantity of Different Types of Waste collected by the Waste Pickers

The most common waste material collected by waste pickers is plastic as it has wide application and is found everywhere. The quantity and kind of material collected depends on the area in which collection is done. In residential areas, mostly mixed waste items like plastic, paper and glass are

collected. In the market areas mostly packaging waste like cardboard cartons (known as *gatta* in the Hindi language) are available. On average an adult waste picker collects between 5 and 15 Kg of plastic and 10 to 15 kg of paper and cardboard per day. Additionally she/he collects some glass as well. Table 1 gives a list of different recyclable waste materials collected by waste pickers, their colloquial names and prices.

Table 1

Various Recyclable Waste Materials and Prices paid by Dealers buying from Waste Pickers in 2002

Waste Material	Colloquial Name	Price at which sold to Waste Dealer (Rs.)/Kg..)
PLASTIC		
PET bottles (coke, mineral water bottles etc.)	Raincoat	2
Plastic thread, fibres, rope, chair cane	Cane	6-7
Milk packets	*Dudh Mom*	6
Hard plastic like shampoo bottles, caps, plastic box, etc.	*Guddi*	7
Plastic cups and glasses, LDPE, PP	Fresh PP	7 - 8
PAPER		
White paper used in offices/press cutting	*Saphed* (White)	3
Mixed shredded paper	*Raddi*	2
Mixed paper	*2 No Raddi*	0.50-0.75
Cartons and brown packing papers	*Gatta*	2.50
Fresh news paper	*Gaddi*	4.50-5.00
Carton sheets	*Raddi*	4.50-5.00
Tetrapack	*Gutta Sheet*	2
ALUMINIUM		
Beer and cold drink cans		50
Deodrant, perfume bottles		50
Electrical wires		40
Aluminium foil	Foil	20
Other metals		
Steel utensils	Steel *Bartan*	20
Copper wires	*Tamba*	80
GLASS		
Broken glass	*Shisha*	0.50
Bottles (Beer)	Bottle	2

PET: Polyethylene Terepthalate
LDPE: Low density Polyethylene
HDPE: High density Polyethylene
PP: Polypropylene

*Selling prices of all items as on January 2002

Source: Srishti (2002). *Recycling Responsibility, Traditional Systems and New Challenges of Solid Waste in India.* New Delhi: Srishti.

Working Conditions and Occupational Health Hazards

The Different Kinds of Waste Pickers in the City of Delhi

There are four different kinds of waste pickers:

- Those who carry a sack on their back and collect whatever has any resale value. These street waste pickers move in their respective localities and pick up waste from streets, drains, municipal bins and open dumpings. Some waste pickers go to landfills to collect waste. They usually carry a magnet fitted with a bamboo or wooden handle to gather ferrous metals.
- Those who carry a huge sack slung in two partitions across a bicycle and keep the items separately. These waste pickers collect only specific items like glass bottles, plastic etc. and sell them separately.
- Those who use a tricycle and collect over 50 kg of waste per day. They collect mixed waste and usually travel long distances to sell it.
- Waste pickers who work for waste dealers. These waste pickers are committed to sell their daily collection to the waste dealers who employ them. Often they also sort the waste for the waste dealer. In exchange they get food and a place to sleep. Sometimes the waste dealers pay them a paltry sum of Rs 10 – 20 depending on the quantity of waste they sort.

Waste pickers have a well-coordinated method of working. They enjoy informal camaraderie that supports a self-organization of waste pickers into operating areas. That is, for waste collection some kind of informal territorial boundary exists. The waste pickers of one particular area do not encroach into other areas.

Almost all the waste pickers interviewed collect waste on an everyday basis and 85% said that they had no option but to do so as it was their only source of livelihood. Those who collect waste from markets or industrial areas take rest on the weekly closure day.

Health Hazards

The occupational health hazards of waste pickers arise from two aspects – poverty and their occupation itself. Since they belong to the poorest and most deprived section of the urban population, malnutrition, growth retardation, anemia, tuberculosis and other bacterial and parasitic diseases are very common amongst waste pickers. These make them more susceptible to occupational health hazards.

In the hope of discovering some saleable items the waste pickers rummage through putrefying waste heaps including toxic and medical waste using their bare hands and feet, and hence come in direct contact with dangerous material. Infections and infestations occur due to contact with human and animal excreta, sputum, dead animals and potentially infectious hospital waste dumped in refuse dumps. This makes them highly susceptible to a number of health hazards.

Injuries in the Form of Cuts and Bruises

Hazardous working conditions lead to frequent injury in the form of cuts and bruises from glass, metal sharps, broken bottles, etc.. Twenty eight percent of waste pickers reported experiencing such injuries once in every two days while 61% said that they got injured once a week.

Injuries from Medical Waste

The survey reveals that there exists an illegal nexus between waste dealers and hospital staff. Either the staff calls the waste pickers through the waste dealers, or dumps the waste at a place convenient for the waste pickers to collect. Twenty seven percent of the waste pickers who collect medical waste reported that they have sustained injuries from syringes, sharps, broken bottles and ampoules. Often proper medical attention is not given to these injuries, which leads to non healing ulcers. Injuries sustained from medical waste are all the more dangerous because the waste pickers may unknowingly get infected by Hepatitis B and C or HIV or other bacterial and viral infections through contaminated sharps and needles.

Many of the respondents admitted that they were aware that buying and selling of medical waste was illegal yet they indulged in the trade as there was more profit to be made from the medical recyclable items collected. Since most of the plastics in medical waste are of good quality they fetch higher prices compared to other items.

Injuries caused by Animals

In search for saleable waste material, waste pickers often visit landfills and open dumpyards. Hungry animals like dogs and pigs foraging for food also frequent these places. Rodents are attracted to dumpsites from surrounding areas or maybe delivered to the site in loads of wastes where they multiply rapidly. Sixty Eight percent of the waste pickers reported being bitten by rodents, snakes, dogs and bites and stings from other vermin once a fortnight. These animals transmit a variety of infections either by themselves or through the vectors they carry.

Air-borne Diseases

During long dry periods the surface of landfills and open dumping grounds become dry and very dusty. The waste pickers are exposed to air-borne dust, which makes their working conditions more unpleasant. Under these conditions infections and allergic disorders, especially of the respiratory tract, are common.

Chemical Poisoning

Chemical poisoning includes pesticide poisoning. Waste pickers often come across empty containers of chemicals, which they sometimes use for storing food or water, or they burn such containers as sources of heat in winter. Several anecdotal pesticide poisoning cases have been documented in children who have used discarded pesticide tins as containers for drinking water, and lead poisoning in families where discarded lead battery containers were used as fuel have been documented [6].

Other Diseases

Tuberculosis, scabies, multi-system allergic disorders, asthma, respiratory infections, ophthalmic diseases, ulcers and stomach problems are other commonly-reported diseases. The problem is acute because waste pickers are not protected by occupational health and safety measures. The survey revealed that no waste pickers used any kind of protective gear like gum boots, plastic aprons, masks or gloves. Moreover, waste pickers do not come within the purview of any labour legislation. Hence they are not entitled to any benefits or security of livelihood.

Waste Pickers who also work as Waste Sorters

Fifty one percent of the waste pickers surveyed also work as waste sorters for the waste dealers, segregating different recyclable components of the waste. Thirty five percent of the waste sorters are females and sixty five percent are males. Most of the waste pickers who work as sorters do their work in open spaces. Almost all the sorters reported occupational related health problems. Thirty percent said they had respiratory ailments. Fifty one percent had fever and skin diseases. An additional nineteen of the respondents said that they experienced all three problems. Sometimes there are sharp metal objects attached to plastic or cardboard waste, so cuts and injuries are routine. At times, waste materials maybe contaminated with various hazardous substances like chemical residues, pesticides, used syringes etc.. Only seventeen of the waste pickers said that the waste dealers either provide them with doctor's fee or some basic first aid.

The Social and Physical Cost of Waste Picking

The survey revealed police atrocities against waste pickers in all the areas. Seventy eight percent of the waste pickers said that they were troubled by the police or the municipal staff on one pretext or the other at least once a week. 10 percent said they were harassed once in a fortnight. The police interference comes in different forms. Waste-pickers are often prohibited by police from visiting high income residential areas. When there is a theft reported in any area, the police invariably target the waste pickers. Survey respondents reported that they are verbally abused and often beaten up for crimes they have not committed.

Government Initiatives and Policies

Employment requirements of increasing numbers of urban poor, and management of the vast amount of solid waste generated in Delhi are key factors that have combined to create the increasingly growing occupation of waste picking.

Waste pickers play a significant role in the entire process of waste management, and yet their services go unnoticed and issues concerning their livelihood go unaddressed. Government approaches to the needs of the waste pickers are too compartmentalized and fail to take a holistic view of their problems and requirements. It is imperative that policies be designed so that they are more responsive to the needs of waste pickers.

This section presents a review of government policies and programmes on the main factors that have contributed towards the growing occupation of waste picking.

Employment Opportunities of the Urban Poor

The number of urban poor has increased over the last three decades in contrast to the decreasing rural poverty in India. This is a well-established trend in India and other nations of the Global South that needs to be recognized and promoted to higher priority in government agendas (9, 11). In India, this phenomenon can be attributed to the fact that Indian policy makers have, for decades, focused on rural development. Over the years urban poverty alleviation got sidelined because it was assumed that the urban poor had greater access to services and

employment opportunities in urban areas and hence had less insecurity to cope with. As urban systems and poverty within it grew, urban poverty could no longer be ignored. However, so far there is no segmentation of the urban poor to determine the size of the waste pickers in urban setups for enabling exclusive interventions.

Employment-Oriented Urban Poverty Alleviation Programmes

Urban poverty as a priority area occupied the attention of the planners only in the Seventh Five Year Plan (1985-1990) when urbanization was realized as an integral part of economic development (8). In the seventh plan emphasis was given to urban employment generation as a means to tackle urban poverty. The Self-Employment Programme for the Urban Poor (SEPUP) was introduced in 1986 and Nehru Rozgar Yojana (NRY)[3] was introduced in 1989. SEPUP was the first urban poverty reduction programme with emphasis on employment. It was a stand alone, one-dose small credit intervention programme. NRY was a more comprehensive employment programme with increased number of interventions like widening the employment base for skilled as well as unskilled workers including women, through promotion of micro-enterprises (ME). Thereafter, other urban poverty alleviation programmes were also introduced.

[3] In order to alleviate the conditions of urban poor, a Centrally Sponsored programme – Nehru Rozgar Yojana was launched at the end of the Seventh Five Year Plan (October 1989) with the objective of providing employment to the urban unemployed and underemployed poor. The NRY consisted of three schemes namely (i) the Scheme of Urban Micro Enterprises (SUME); (ii) the Scheme of Urban Wage Employment (SUWE); and (iii) the Scheme of Housing and Shelter Upgradation (SHASU).

The informal sector, as a component of the development process in the economy, was first recognized in the Eighth Five Year Plan (1992-97). The National Capital Region Planning Board, the Government of India's regional planning agency, has accepted the informal sector employment generation route as a policy strategy for economic development in towns around Delhi, and to decrease levels of unemployment in the increasing migrant population in Delhi. In the nineties, two micro enterprise-oriented programmes were introduced in view of the growing urban poor. The basic objectives of these new programmes were employment generation, community empowerment and environmental improvement, giving attention to the informal sector, which was growing at a rate of 6% against the tardy growth in general employment. To provide sustenance to programmes of income generation, the Urban Basic Services for the Poor (UBSP) programme was implemented as a centrally-sponsored scheme during the Eighth Five Year Plan. Its main objective was to meet the basic physical and social needs of the urban poor through community organisation, mobilisation and empowerment.

Public intervention for employment generation was considered crucial, and the necessity of achieving full employment was a major determining factor in setting up of growth rate of the Indian economy during the nineties. The Prime Minister's Integrated Urban Poverty Eradication Programme (PMIUPEP) was launched in November, 1995. It was basically an employment generation programme which sought to address problems associated with urban poverty by building up community based organizations (CBOs) as the centre of the development process and by facilitating direct participation of the targeted groups.

In the Ninth Plan (1997-2002), it was recognized that rapid economic growth was most important to increase employment opportunities. Towards the end of the nineties, another programme, Swarna Jayanti Shahari Rozgar Yojana (SJSRY) was introduced that included all the urban programmes in existence. The programme seeks to alleviate urban poverty by converging employment components of the earlier schemes and seeks to provide gainful employment to the urban unemployed or underemployed poor by encouraging the setting up of self-employment ventures or provision of wage employment. The two schemes under SJSRY are the Urban Self Employment Programme (USEP), and the Urban Wage Employment Programme (UWEP).

The Tenth Plan (2002-07) also provides a high priority to employment growth and sees employment as a central issue in determining the growth rate of the economy.

Government Policies towards Waste Management

At the national policy level, the Ministry of Environment and Forests has legislated the Municipal Waste Management and Handling Rules, 2000. It gives details of the practices that are to be followed by the municipalities for managing urban waste. However, though the rules recommend recycling they do not say how to implement such a programme or give any direction towards promoting recycling. Indirectly, waste to energy technologies are encouraged through the formulation of technology standards.

Other policy documents include:

- Manual on Municipal Solid Waste Management, prepared by an expert committee constituted by Ministry of Urban Development, GOI, January 2000.
- Recycled Plastics Manufacture and Usage Rules, Ministry of Environment and Forests (MOEF), GOI, September 1999.
- Solid Waste Management in Class I Cities in India. Committee constituted by Honourable Supreme Court of India and headed by Mr. Asim Burman, Municipal Commissioner, Calcutta Municipal Corporation, March 1999.
- National Plastic waste Management Task Force. Committee constituted by MOEF, GOI, August 1997.
- Report of the High-powered Committee on Urban Solid Waste Management in India, headed by Prof B.S. Bajaj, Member, Planning Commisssion. Constituted by Planning Commission, GOI, 1995.
- Waste to Energy Policy as promoted by the Ministry of Non Conventional Energy sources (MNES), 1995.

The policies lack a holistic approach towards management of waste in urban India. The waste management as it presently occurs involves many people for whom it is a source of livelihood. Hence policies should be so directed as to integrate the employment requirements of the urban poor with managing waste in an environment-friendly manner. Clear policy directions towards recycling will not only help in resource conservation but also strengthen the role played by the waste pickers, ensuring their livelihood.

Conclusion and Recommendations

Though industrialization has created jobs, the

increase in employment opportunities in urban centers has failed to maintain a balance with the increased availability of unskilled labour in the population. Despite various government programmes and policies directed towards poverty alleviation in urban areas, lack of gainful employment even in the informal sector still remains a key area that needs immediate attention. Rather than a holistic approach the thrust of urban policies so far have been disjointed and compartmentalized.

A typical example is the management of Solid waste in Delhi involving various stakeholders. The most vulnerable among them are the waste pickers who are engaged in this occupation, with abysmal working conditions, solely as a means to survive. In the process they address a basic societal need for waste management by removing waste from the waste stream, thereby substantially reducing amount of the uncollected waste. This saves on municipal expenditure and minimizes the environmental impacts of uncollected waste in cities.

The contributions of waste pickers remain unacknowledged and waste pickers continue to suffer due to various occupational health hazards arising out of abysmal working conditions. Moreover they receive extremely low economic returns and are victims of harassment from the police, municipal workers and the general population.

Institutionalizing Waste Picking

Waste pickers' need for employment and decent lifestyle needs to be accommodated with the existing system of waste management and recovery of material for recycling. Taking cognizance of the extremely poor working conditions, very low monetary returns, exploitation and harassment and the potential of the waste pickers to make better contributions towards urban waste management, there seems to be a need to legitimize their role. Institutionalizing their activities would enhance the scope of their work and at the same time provide better working conditions. They could be organized with the help of civil society groups around micro enterprises related to recycling. Apart from assuring their livelihood, this would also help restore their self-esteem.

Integrated Approach towards Waste Management

Institutionalizing waste picking would necessitate a change in urban waste management practices. There is a need to build up public awareness on the social and environmental component of waste management. Only then will the waste pickers get due recognition in the society. There is a need for information dissemination and creating awareness on the importance and need to recycle. This awareness would generate changed waste handling habits of households. An approach towards changed waste dealing habits could be achieved by providing households with monetary incentives for segregating waste. Presently such a practice exists for glass bottles and newspapers. It can be implemented for all recyclable materials. The waste pickers can then directly collect the recyclable waste materials from households who will in turn benefit from practicing segregation. The working conditions of the waste pickers would then automatically improve.

Dual Role of Collection of Both Recyclable and Biodegradable Waste

Waste pickers may also be engaged in the collection of the biodegradable component of municipal waste as well. They could play an active role in facilitating decentralized composting in specific urban pockets. Such an approach would not only ease the burden of municipalities but also legitimize their work providing them with social and economic security.

Encouraging Recycling

Recently, waste to energy technology propagated by private industries is slowly gaining a foothold as a method to manage urban waste. This may replace traditional systems of waste management based on reuse and recycling and threaten the livelihood of waste pickers. The waste to energy policy with the objective of promoting waste solely as an energy source, supported by the Ministry of Non Conventional Energy Sources (MNES), needs to be reviewed. There is a need to encourage recycling as a viable option of waste management through subsidies on recycled products. This will in turn safeguard the livelihood of the various stakeholders involved in the waste trade, most importantly the waste pickers.

Setting up of Co-operatives

Presently, though waste pickers contribute substantially towards recovery of recyclable materials, they work and live under extremely unhygienic conditions. It is essential to improve their living and working conditions. The waste pickers could be organized to set up cooperatives with the help of NGOs. The waste pickers could then collect waste directly from households instead of foraging in garbage dumps. This would reduce the occupational health hazards providing them with better working conditions and also better economic returns. In the process their contribution towards waste management will be recognized in the society.

References

1. Barman, Asim *et. al.* (1999). *Solid Waste Management in Class 1 cities in India.* New Delhi: Supreme Court.
2. Central Pollution Control Board (2000). *Status of Municipal Solid Waste Generation, Collection Treatment and Disposal in class – 1 cities.* New Delhi: Central Pollution Control Board.
3. Census of India (2001). 2001 *Census Results.* [online]. Available from: http://www.censusindia.net/ [Accessed 12 November 2005].
4. Chaturvedi, Bharati (1998). *Public Waste Private Enterprise.* New Delhi: Heinrich Boell Stiftung.
5. Chaturvedi, Bharati (2000). *Polybags: The Enemy Within.* New Delhi: Oxford and IBH Publishing.
6. GOI (1995). *Urban Solid Waste Management in India.* New Delhi: Planning Commission.
7. IIIEE (2004) Analysing Plastic Waste Management in India . [online]. Available from: http://www.iiiee.lu.se/Publication.nsf/$webAll/7502CC39F791FAA6C1256BE90031BE75 [Accessed 25 November 2005].
8. India Infoline (2005). *Economy Database.* [online]. Available from: http://www.indiainfoline.com/econ/andb/plan/plan3.html [Accessed 28 November 2005].
9. Ravallion M (2001). *On the Urbanization of Poverty.* Working Paper No. 2586. Washington, DC: The World Bank

10. Srishti (2002). *Recycling Responsibility, Traditional Systems and New Challenges of Solid Waste in India*. New Delhi: Srishti.

11. UN Millennium Project (2005). *A Home in the City. Final Report of the UN Millennium Project Task Force on Improving the Lives of Slum Dwellers*. London: Earthscan.

12. Venkateswaran, Sandhya (1994). *The Wealth of Waste: Waste Pickers, Solid Wastes and Urban Development*. New Delhi: Friedrich - Ebert - Stigtung.

Community- based Monitoring and Urban Drinking Water Quality in Kathmandu, Nepal

Durga Datt Joshi & Minu Sharma
National Zoonoses and Food Hygiene Research Centre, Chagal , Kathmandu, Nepal

Rapid urbanization and population growth in Kathmandu impedes the ability of the Nepal Water Supply Corporation (NWSC) to provide an adequate supply of safe water to the city. A large portion of the population depends on unprotected and hygienically unsafe water sources. In 2001-02, an inventory and testing of water sources in the wards was carried out. Policy makers of the city and health authorities were sensitized, simple water testing technologies were transferred to the wards' health clinics, and water quality monitors from the respective wards were trained. Over 150 different water sources were monitored using a low-cost bacterial test (H_2S). Half of sample replicates were also tested for Total Coliforms and E.coli as quality control. High bacterial contamination was detected during spring and monsoon periods in most water sources. The stone tap water was less contaminated than tubewells. While there is no significant difference between NWSC supplied direct tap water and NWSC supplied stored water, the water in the distribution system was slightly better. A water treatment strategy was initiated, including the promotion of safe storage and handling practices, and chlorination. Several stone taps were rehabilitated with funding from the city government. The programme effectiveness and sustainability will be evaluated in the coming project phase.

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Access to safe drinking water is a basic human need that remains unmet for millions of people worldwide. According to the world Health Organization (WHO), more than 1.4 billion people around the world consume water that is unsafe because of contamination with potentially harmful microorganisms or toxic substances. Each year diseases associated with dirty water are responsible for two million deaths. Humans can acquire bacterial, viral and parasitic diseases through direct body contact with contaminated water as well as by drinking water. Diarrhoeal diseases, arising mainly from unhygienic drinking water and unsanitary conditions of the water environment, account for nearly 1/3 of all child deaths. Approximately 30,000 children under five die of diarrhoea each year (17, 3). Many individual, social, economic, epidemiological, and environmental factors complicate the issue (15).

Water provides a habitat for a wide variety of organisms including micro organisms of medical significance. Those known to have occurred in contaminated drinking water include strains of *Salmonella, Shigella,* enterotoxigenic *Escherichia Coli (E. coli), Vibrio cholerae, Yersinia enterocolitica* and *Campylobacter fetus*. These organisms may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal dysentery, cholera or typhoid. Potable water used for drinking and bathing, if it contains excessive numbers of organisms such as *Pseudomonas, Flavobacterium, Acinetobacter, Klebsiella* and *Serratia*, may produce a

variety of infections involving the skin and mucous membranes of the eye, ear, nose and throat (18).

Faecal pollution of water supplies may lead to the introduction of a variety of intestinal pathogens or enterobacteria that cause water borne diseases [6]. Coliform are a well recognized indicator of bacteria for faecal contamination. Microbiological potability standards for drinking water in most developed countries rely on the detection of total Coliform and *E.coli* (a Coliform itself) as markers for human pathogens. The Coliform test can, therefore, serve as an indicator of treatment efficiency or the integrity of a distribution system. *E.coli* is the most discriminating marker for faecal contamination, and is therefore the microbiological indicator of choice for drinking water potability and safety. Drinking water safety dictates that no *E.coli* should be present (8).

Rapid urbanization and population growth in Kathmandu impedes the Nepal Drinking Water Supply Corporation (NWSC) to supply adequate and safe water to the city. Because of limited and insecure water availability, a large portion of the population depend on unprotected and hygienically unsafe water sources for domestic and commercial use (including ward hotels, restaurants, butcheries and slaughtering houses). Community residents in Wards 19 and 20 of Katmandu, and our research team on urban ecosystem health, considered improving the quality of drinking water essential to sustainable community health.

In 2001-02, with funding from IDRC, Ford Foundation and Winrock International, we undertook an inventory and testing of water sources in the wards. The objective of this research was to examine urban drinking water quality of Kathmandu City and develop a control plan for its treatment. As part of the work, policy makers of the city and health authorities were sensitized, simple water testing technologies were transferred to the wards' health clinics, and water quality monitors from the respective wards were trained. Over 150 different water sources were monitored, including traditional community taps (stone taps), household connections, shallow wells, deep wells, and household water storage tanks, using a low-cost bacterial test (H_2S) prepared locally. Tests for Total Coliforms and *E. coli* were used as quality control.

This paper presents the low-cost, community-based approach to water quality testing that we employed, and the results generated by its application in Wards 19 and 20 in 2001-2002, and discusses implications for the control of drinking water quality in Katmandu.

Water, Sanitation and Health in Nepal

In Nepal, water and hygiene related diseases are responsible for 8% of all deaths in the general population. According to the country profile by the Ministry of Health for 1997 [10], infective and parasitic diseases constituted the largest single (31.27%) cause of morbidity in the general population. Diarrhoeal diseases, arising mainly from unhygienic drinking water and unsanitary conditions of the water environment, account for nearly 1/3 of all child deaths. Disease arising from the ingestion of pathogens in contaminated water have the greatest impact worldwide. In the

national context, the under 5 years mortality rate was 118.3 per 1000 lives births; among them 1279 deaths (10.29% Case Fatality Rate (CFR) under 5 years were only from diarrhoeal diseases) (4, 5, 9).

There is plentiful water supply in Nepal but much of poor health of the communities in the country is due to lack of safe and potable drinking water. The incidence of water borne diseases in the country is high. Outbreaks of typhoid and amoebic dysentery occur quite frequently and parasitic infections are common. Sanitation is poor, resulting in faecal matter entering into the water supply. Several studies (1, 2, 11) indicate that one third of the deaths of children under 4 years of age in rural areas are due to water borne diseases.

Drinking water is commonly collected from unsafe surface sources outside the home. Water may become contaminated after collection, either during transport or storage in the homes. Even municipal piped-well water is unsafe because of inadequately maintained pipes, low pressure, intermittent delivery, insufficient chlorination, and clandestine connections. As noted in surveys conducted by the WHO, contamination of water even from treated and protected sources may also occur during household storage (18). They observed that drinking water taken from the piped supply was stored for cooling in earthen jars that were faecally contaminated. Faecal Coliform concentrations were generally and sometimes dramatically, higher in stored water than in source water.

In urban households a common water source is tap water. The Department of Drinking Water Supply HMG/Nepal and the Nepal Water Supply Corporation are responsible for supplying drinking water and sewerage service to the municipal areas of Kathmandu. NWSC collects water from 17 spring sources located in the hills surrounding the Kathmandu valley. According to their records there were a total of 97,711 connections with 76,050 metered connections (77.8%), and 20,386 non metered connections (20.9%) and 1,275 stand post connections (3%) during July-August 1997 (14, 16). However, the existing water supply service is not equitable. Some consumers in low-lying areas and near transmission mains enjoy 24 hours supply, whereas most of the consumers receive only a few hours supply in a day. Consumer surveys reported that only about 34% of the total 97,711 connections have either good or sufficient water flow (16). This statistic is in line with the results of our survey in Wards 19 and 20 during the period 1999 under the urban ecosystem health project (4, 5). It is due to this insufficient and inequitable water supply from NWSC, that people also rely on other sources of water for their daily needs (e.g., drinking, washing, bathing and toilet use). Other important sources of water are stone taps, tube wells and wells (Fig. 1).

Methodology

Twenty-four community research volunteers were selected out of 12 stakeholder groups to participate in this water testing programme. The volunteers were of different working classes (e.g., sweepers, street vendors, employees/owners of small tea shops, butchers, meat sellers, ward secretaries, staff at urban health clinics and local clinics, and squatters). These stakeholders were responsible to collect water samples from different water sources (such as stone taps, NWSC supplied taps, wells, tubewells and

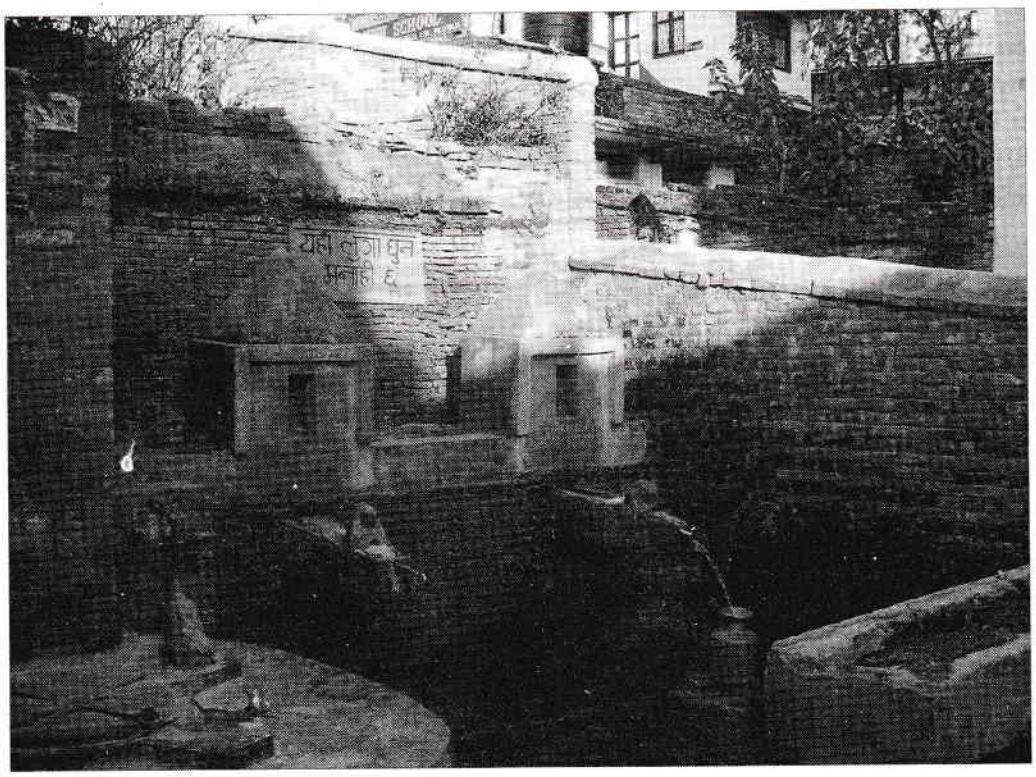

Fig. 1: Stone Tap Water used for Drinking Purposes in Kathmandu Valley

stored rainwater). These samples were then tested in a community laboratory using the H_2S paper strip test. Volunteer water quality monitors received one week of training in water quality testing and treatment, and made a commitment to participate in the programme for two years (under the urban ecosystem health project phase - II supported by the International Development Research Centre (IDRC), Ottawa, Canada and implemented by the National Zoonoses and Food Hygiene Research Centre (NZFHRC)).

This programme employed the hydrogen sulphide (H_2S) paper strip bacteriological test to detect the presence of certain micro-organisms in the water. Some of these microorganisms might be harmful to the health of people. The hydrogen sulphide (H_2S) test indicates the presence or absence of H_2S-producing bacteria (such as coliform bacteria) in water samples by promoting the growth of H_2S-producing bacteria inside test tubes. The H_2S method does not specifically and consistently measure the presence of coliform bacteria. However, the other common H_2S-producing bacteria that can lead to positive H_2S test results are also commonly associated with the intestinal tracts of warm-blooded mammals (19). Thus, a positive result on the H_2S paper test can be taken to indicate fecal contamination, though it cannot indicate whether the contamination is of animal or human origin. The WHO (19)

concluded that :

``The H_2S method in various modifications has been tested in many places in different waters and produced results reported as indicating it to be a reasonable approach for testing treated and untreated waters for faecal contamination. It offers advantages including low cost (estimated at 20% of the cost of coliform assays), simplicity and ease of application to environmental samples''.

A water sources inventory of Wards 19 and 20 of Kathmandu Metropolitan City (KMC) was prepared by a transect walk with community stakeholders. The emphasis was placed on water sources that people frequently use in their daily life. Test tubes and bottles were sterilized and H_2S paper strips were prepared in the test tube and bottle. Water samples were collected from all the water sources identified by stakeholders. H_2S tests were performed on all samples collected.

The pollution levels were measured on the basis of bacterial indication in the incubated sample for up to five days if temperature remained below 30°C, and if temperature was between 30 – 39°C the measurement of pollution level was taken within three days. If the sample didn't indicate the presence of H_2S within the allocated time period, the sample tests were considered to have a negative result.

In addition to the H_2S paper strip tests, almost half of the samples were quality control tested, using colistrip and coliplate methods. Coliplate and colistrip specific antigen coated commercial plates (Canadian Products) were used.

The colistrip is a convenient test for a quantitative measure of total coliform and *E. coli* density. The test is designed to test surface water, recreational water, processing water and wastewater. The colistrip contains selective media to provide nutrients to stimulate the group of coliforms and *E. coli*. The media also contains inducers and chromagenic/fluorogenic substances. These substances react with specific enzymes indicative of coliforms and *E. coli* to provide color change to blue/green and fluorescence by coliforms and *E. coli* respectively. Colistrips contain only 16 wells, while coliplate contains 96 wells. This test is fast and the most sensitive one for detection of hydrogen sulfide producing bacteria, as well as bacteria which don't produce hydrogen sulfide gas such as *E. coli*. This is a completely enzyme-based test by which results can be obtained within a maximum of 24 hours. The samples should be incubated at 35°C (not below 30°C and not higher than 39°C).

Results

Water Quality Status of Ward 19

Among the various water sources identified in Ward 19 within the project period, a total of 78 different water sources were tested. The results the H_2S revealed that 47 samples showed positive results (i.e. presence of faecal contamination) on the second day while a further 23 samples tested positive on the first day. Ninety per cent of water samples tested positive. The indication of positive results within the first and second day demonstrates a high level of contamination of the water samples with hydrogen sulfide - producing bacteria of human and animal faecal origin, and the water is not safe to drink unless treated.

Most of the ground water and surface water

sources showed positive results within the first or second day, indicating high levels of contamination. Moreover, there is a problem with water from household taps, which remains stored in the household for consumption purposes. Twenty five of 27 such samples tested positive with the H_2S test.

Among 78 different water sources tested by H_2S method, 48.7% of them were further incubated by colistrip or coliplate method to detect coliforms and *E. coli* densities. In Ward 19, most of the samples contained <100 bacteria as a whole but most of the tube well water contained coliform densities in between 100 and 500. One stone tap water source was found to contain more than 500 bacteria per 100 ml of the water sample, while most of the 3 open wells were found to be heavily polluted. In one of the samples the *E. coli* bacteria level was found to be dangerously high (e.g., <16-1696 per 100 ml). Bacteriological pollution levels in different water sources of Ward 19 are presented in Table 1.

Water Quality Status of Ward 20

In Ward 20, among the 75 different water sources tested with the H_2S method, 24% of samples tested positive for feacal contamination within 24 hours, a further 44% tested positive in the second day of culture. Overall, 83% of samples showed positive. This result indicates that most of water samples tested were moderately polluted. There were a few sources (13 of the 75 samples) that did not show positive results for the hydrogen sulfide test.

Regarding the source-wise pollution in Ward 20 a large proportion of ground water and surface water sources in the community are heavily polluted with faecal coliforms. In the case of the stone taps, each of the 5 stone taps were found to contain high levels of pollution compared to other ground water sources. All of the stone taps showed positive results within 24 hours of incubation. It is an important fact that most people in this ward frequently use these water sources for their daily activities including drinking, even in households having protected water supply (tap water). Moreover, people who live in tenements around the stone tap area completely depend upon the stone tap water sources. Bacteriological pollution levels

Table 1
Bacteriological Pollution Level in Different Water Sources of Ward 19

Sources	Number of 100 ml samples	+ result for H_2S	% of faecal contamination	Coliplate/colistrip results	
				Coliform MPN Range	*E. Coli* MPN Range
Tube wells	26	23	88	<16 - 405	<16 - 938
Well (open / closed)	10	9	90	<16 - 1696	<16 - 964
Stone Tap	9	9	100	<5 - 469	<5 - 307
NWSC (direct)	6	4	67	<5 - 28	<5 - 16
NWSC (stored))	27	25	93	<5 - 938	<5 - 938
Total	78	70	90		

in different water sources of ward 20 are presented in Table 2.

Most samples of tube well water (31 out of 34) were also found to be bacteriological-polluted and not safe for drinking. In contrast, water supplied from the Nepal Drinking Water Supply Corporation was found to be comparatively safe for drinking purposes. Only 1 of 3 NWSC-supplied water samples tested positive for hydrogen sulphide (though admittedly, the sample size was very small) whereas, for the same water coming from stored sources, only 8 of 21 samples were uncontaminated.

Total coliform level and *E. coli* densities revealed during the analysis were in the range of <5 – 1696 cells. The indication of positive results within the first and second day has indicated a high level of contamination of the water samples with hydrogen sulfide producing bacteria of human and animal fecal origin, and the water is not safe to drink unless treated.

During the project period a total of nine sets

Table 2
Bacteriological Pollution Level in Different Water Sources of Ward 20

Sources	Total sample tested	+ result for H_2S	% of faecal contamination	Coliplate/colistrip results	
				Coliform MPN Range	*E. Coli* MPN Range
Tube wells	34	31	91	<5 - >1696	<5 - 240
Well (open / closed)	12	12	100	>938	>938
Stone Tap	5	5	100	146 - >1696	<5 - 1696
NWSC (direct)	3	1	33	<3 - 102	<3 - 5
NWSC (stored))	21	13	62	<3 - 275	<3 - 938

Table 3
Sourcewise Total Coliform and *E. coli* Densities measured by Coliplate and Colistrip in Wards 19 & 20

Sources	No.of samples tested	Pollution level detected					
		Total coliform detected			Total E. Coli detected		
		< 100	100 -500	> 500	< 100	100 -500	> 500
Tube well	30	18	9	3	23	6	1
Open/Closed well	6	3	1	2	2	1	3
Stone tap	9	2	6	1	5	4	--
NWSC(Direct)	5	4	1	--	4	1	--
NWSC(Stored)	26	20	5	1	24	--	2

of experiments in ward 19 and ten sets of experiments in ward 20 were performed both by using the H_2S test. Overall, a total of 153 water sources were tested, among them 132 showed a positive result for the H_2S test which showed very high incidence of contamination levels in the community water sources. All the stone tap water samples collected from different localities of both of the wards showed positive results for the H_2S test. 54 tubewells out of 60, and 21 open wells out of 22 showed positive results for this test.

Coliform and *E. coli* densities of the water sources play a very important role in a water quality monitoring system. Among the total 153 water samples tested in both of the wards, 49.7% of them were incubated in coliplate or in colistrip method. The result showed that 47 of the examined samples showed coliform levels below 100 cells per 100 ml of the water, 22 samples showed moderate levels of pollution (100-500 cells per 100 ml) while 7 samples were found to contain densities greater than 500 coliforms. 12 samples showed *E. coli* levels of 100 – 500 cells per 100 ml of water samples, and 6 samples were found to contain *E. coli* densities greater than 500 cells. Total coliform and *E. coli* densities measured by coliplate and colistrip in Wards 19 & 20 are presented according to source in Table 3.

Water Treatment Strategy applied in the Community

Water treatment demonstration training was organized separately for the community leaders, ward members, consumers and the ward chairman in ward 19 and 20. For this purpose, 500 litre plastic water tanks, clorinometers and other supplies were distributed to the ward office. Water experts from NWSC and four monitors demonstrated the method of chlorination and testing of clorinated water.

35 participants from different stakeholder groups participated in the training. It has been assumed that they will start treating the water resources in their community where pollution has been found. Bleaching powder for water purification/chlorination has been provided to the ward urban clinics and ward offices. A follow-up study on these activities will be carried out as usual from National Zoonoses and Food Hygiene Research Centre (NZFHRC) in Katmandu.

Discussion

In Wards 19 and 20 of Kathmandu, all natural water sources, including ground water sources like tube wells and deep wells, and surface water sources like stone taps, are neither treated for bacteriological contamination nor protected properly. In some locations some of the personal tube wells remain protected, closed from outside but the waste water drainage pipe is not far from the wells and tube wells, leading to risk of contamination. We did not measure turbidity, but it was obvious that most of the tube well water was contaminated with the soil and sand particles and was not entirely transparent. There are a few tube wells found in some locations of both wards which look clear and have no odour but are bacteriologically unsafe. Only the tap water supplied from the Nepal Drinking Water Supply Corporation is treated (by chlorination).

The problem is in the distribution system where most of the drinking water pipelines are

brought parallel to that of the waste water drainage pipelines. During the rainy season most of the drainage pipelines break down and contaminate their surroundings. Contamination of drinking water happens due to the use of un-repaired old pipeline systems for distribution, and irregular supply of the drinking water in the pipeline. When drinking water is not supplied in the pipeline they remain filled with air. If there is waste water around them, very easily the waste water is sucked in to the drinking water pipeline. This is known to the community. Most people complain that they can see fecal matter in the drinking water at times (12, 13). All of the information regarding the water sources and water supply system indicate that the possibility of drinking water getting microbiological or faecal contamination is high.

During our bacteriological study of water samples, test results have revealed that 86% of total samples tested by H_2S methods showed positive results. Of this, 54 out of 60 tube wells tested in both wards showed they were microbiologically not safe for drinking purposes. All the stone taps and 19 deep wells out of 22 showed positive results. This result indicates that most ground and surface water sources in the community are not safe for drinking. The people who are using such water are at high risk.

The tap water was found to be less polluted, but still these samples were not free from contamination. Drinking water remains a problem because it is supplied sometimes once a day or even sometimes only once in two days or less.

Conclusion

We have found that the method of application of the H_2S paper strip test, as described above, is a reasonable approach for testing treated and untreated water samples for faecal contamination. Previous studies carried out by Joshi *et. al.*, (4, 5) have indicated intermittent service, so one would expect, in situations of parallel drinking water delivery and sewerage systems, to find some contamination. Our bacteriological study of water samples in Wards 19 and 20 of Katmandu confirms this. Most of the water samples tested from these two wards showed high levels of bacteriological contamination (more than 100 bac/100 ml water).

Rapid urbanization and concentrated population in KMC areas through migration especially in cities like Kathmandu Valley are creating terrible environmental problems. In Kathmandu valley, about 5000 to 6000 houses are built every year (7). This rapid growth of urbanization has caused shortage of drinking water, and increases in demand for solid waste and sewerage disposal. Currently municipalities treat drinking water by adding chlorine as a disinfectant. This is a simple solution to a very serious public health problem throughout the water distribution system. Chlorine is still used because it is able to kill pathogens throughout the distribution system.

Our research has led to training of community members for a programme community-based water treatment using chlorine. The stakeholders will monitor the water supply sources in both wards 19 and 20 of KMC regularly. They will perform H_2S testing with the collaboration of urban clinics, which have been trained and equipped by the project. The efficacy of that programme will be evaluated in future research.

References

1. ADB (1985). *Nepal Water Supply and Sanitation Sector Profile*. Manila: Asian Development Bank (ADB).
2. Collins C(1985). 'Water Quality Monitoring of Kathmandu City Water Supply: Final Report'. Kathmandu: Health Education and Source Project Services, DISVI.
3. Dold C (2001). 'Water and Health, Hand – in Hand for a Day', *Bulletin of the World Health Organization*, 79 (5).
4. Joshi D. D, M.Maharjan and M.Sharma(1999). 'Public Health-related Indicators observed in Ward 19 and 20 of Kathmandu Metropolitan City, Urban Eco-system Health Project 1999 to 2001', *Zoonoses and Food Hygiene News, 5 (6)*.
5. Joshi D. D, M.Maharjan, N.P.Ghimire and M.Sharma(1999). *Urban Ecosystem Health Status in Wards 19 and 20 of Kathmandu*. Kathmandu: National Zoonoses and Food Hygiene Research Centre.
6. Joshi D. D (1986). 'Health Aspects of Water Supply and Sanitation', *Journal of Nepal Medical Association*, 24(4): Issue 81, pp.45-48.
7. Joshi D.D, H.Joshi, B.R.Heron *et. al.*, (2001). 'Drinking Water Supply and Water- borne Diseases in Nepal', *Zoonoses and Food Hygiene News*, 7(1), pp.1-2.
8. Kravitz J. O, M.Nyaphisi, R. Mandel and E.Petersen(1999). 'Quantitative Bacterial Examination of Domestic Water Supplies in the Lesotho Highlands: Water Quality, Sanitation and Village Health', *Bulletin of the World Health Organization*. 77(10), pp.829 – 833.
9. Maharjan M, D.D.Joshi and H.Joshi (2001). *Water Quality Status of Kathmandu under Aquatox 2000 Programme in Nepal*. Kathmandu: National Zoonoses and Food Hygiene Research Centre.
10. Ministry of Health (1999). *Annual Report of Department of Health Services HMG/N 1998/99*. Kathmandu: Ministry of Health, HMG/N.
11. New Era (1984). *Sanitation Education in Khokana: a Report on the Baseline Survey*. Kathmandu: UNICEF.
12. NZFHRC (2001). *Training Manual for Community- based Water Quality Monitoring and Drinking Water Management Training for Selected Ward Members of KMC, Nepal*. Kathmandu: National Zoonoses and Food Hygiene Research Centre.
13. NZFHRC (2002). *Community-based Water Quality Monitoring and Drinking Water Management: A Pilot Project in Ward 19 and 20 of KMC*. Nepal. Kathmandu: National Zoonoses and Food Hygiene Research Centre.
14. SILT Consultants (P) Ltd. and Development Research and Training Centre (DRTC) (1997). *Draft Final Report on Consumer Survey (Urban Water Supply and Sanitation Rehabilitation Project)*. Kathmandu: HMG/N MHPP, Nepal Water Supply Corporation.
15. Thompson J & S.Cairncross (2002). 'Drawers of Water: Assessing Domestic Water Use in Africa', *Bulletin of the World Health Organization*, 80 (1), pp.61-73.
16. Tiwari B. N(1999). 'Affordability and Willingness to pay of Water Users in Kathmandu Valley', *The Economic Journal of Nepal*, 22(2): Issue 86.
17. UNICEF (1997). *Children and Woman of Nepal: A Situation Analysis*. Kathmandu: UNICEF.
18. WHO (1984). *Guidelines for Drinking Water Quality. Vol. 1,2 and 3*. Geneva: World Health Organziation.
19. WHO/WDE/WSH/02.08 (2002). *Evaluation of the H_2S Method for Detection of Fecal Contamination of Drinking Water*. Geneva: Water, Sanitation and Health Department of Protection and the Human Environment World Health Organization.

Use of Remote Sensing and GIS for Monitoring Environmental Factors associated with Vector-borne Disease (Malaria)

M.Prashanthi Devi & S. Balasubramanian
Department of Environmental Sciences, Bharathiar University, Coimbatore, India

and

B. Manickam
ISRO Head Quarters, Bangalore, India

An epidemiological and ecological study has been conducted to determine malarial incidence in Salem district of Tamil Nadu, India. Causal environmental factors like temperature, rainfall, and humidity in association with forest cover and water bodies were enumerated to predict malaria incidence. Primary data were collected from the Directorate of Health under the Government of Tamil Nadu Health Ministry. Survey of India toposheets at 1:250,000 scale and IRS IC LISS III imagery captured on February 26th, 1999 were used for digitization of forest cover and water bodies. GIS was used to overlay and analyse parameters contributing to malaria transmission by creating layers representing epidemiological, environmental and ecological data. Monthly scale analysis was done using environmental variables and malaria cases to find the optimum temperature, humidity and rainfall patterns contributing to maximum disease incidence. Multiple Linear Regression (backward elimination method) was used to analyze environmental factors related to malarial incidence. The resultant fitted model was used to prepare a prediction map. The results reveal that temperature, water bodies and the interaction of rainfall and forest cover play a major role in vector propagation. Further, a risk map to identify zones where the meteorological and environmental conditions may favour the vector was prepared so that epidemic control strategies may be effectively implemented in these areas.

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Vector-borne diseases like Malaria, Filaria, Japanese Encephalitis and Dengue/ Dengue Hemorrhagic Fever (DHF) affect the populace of India. These diseases inflict heavy losses to the country due to high morbidity. Of these diseases, malaria continues to be the greatest threat to public health. Every year the country reports about 2.5 million cases with a few thousand deaths. Several attempts have been taken in the last decades to control malaria with the use of insecticides to kill vector mosquitoes and with treatment of malaria parasites. Though these control strategies worked well in the initial phases, the precipitation of resistance in the vectors increased alarmingly (17).

Malaria is caused by infection with the plasmodium parasite, transmitted principally by mosquitoes in tropical and subtropical regions of the world. Epidemics may arise through changes in ecological equilibrium, mass migration, importation of exotic vector species, and favourable environmental

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conditions. Among these factors the most common cause of malaria epidemic is change in meteorological environmental conditions, which temporarily alter the equilibrium between malaria hosts, vectors and parasites. This type is termed a "true epidemic" (14). In contrast, "resurgent outbreaks" result from control failure where inadequate health care infrastructure and increasing insecticide drug resistance enable malarial epidemics in regions where it has previously been under control.

The current global malaria control strategy emphasizes the need for efforts to control the disease, rather than eradication. An integrated approach using various methods of malaria control together is presently favoured.

Spatial aspects of the epidemiology of infectious diseases arise when considering locational surveillance data, distribution of human and animal hosts and vectors, spatial determinants of disease transmission, landscape constraints, spatial association of risk factors and disease, targeting of control efforts and questions related to the origin of diseases and outbreaks (10).

The potential application of Remote Sensing and Geographical Information Systems (GIS) to epidemiological studies has been shown (4, 8, 18, 19). GIS is an important set of tools for environmental epidemiology but a few applications have been made, even though epidemiological data clearly has spatial components. GIS permits analysis of both spatial and non- spatial information and hence is an excellent framework for disease monitoring and control. Clarke *et. al.*, have reviewed the use of GIS in surveillance and monitoring of vector-borne diseases, water borne diseases, environmental health and exposure to electromagnetic fields, lead hazards in a neighbourhood area, child pedestrian injuries and the analysis of disease policy and planning (4). The present study uses GIS and Multiple Linear Regression to identify potential zones of malaria incidence in Salem district in Tamil Nadu, and to prepare a risk map.

Study Area

Salem district is located in the south Indian state of Tamil Nadu. It extends over of 5173 Km^2. The climate is tropical monsoon with a rainy season from June to November/December with a normal average rainfall of 729.56 mm/year[1]. The average daily temperature ranges between 22.5°C and 35.08°C.

Materials and Methods

Malarial case data were collected by health workers from the Directorate of Health under the Government of Tamil Nadu through a number of Primary Health Centres (PHCs) in the district. Monthly malarial incidence in both the rural and urban areas was confirmed through microscopic examination. Among the blood smears tested for malaria, positive cases were recorded in ward registers from January 1996 to June 2001 (both months inclusive). Case numbers in each area were treated as incidence figures. The data were collected from 70 Primary Health Centres randomly distributed in the rural area and 4 centres in urban areas (Salem, Mettur, Attur, and Edappadi). Digitised maps were prepared of the District and Taluk boundaries from the

[1]This average rainfall was calculated from the rainfall data collected at the taluk headquarters through out the district for this study

Survey of India topographical map sheets at 1:250,000 scale using MapInfo 6.0. Villages having Primary Health Centres were located in the map. The recorded malaria cases (in dBase III plus) were imported into MapInfo 6.0 (Fig. 1) to further prepare thematic maps.

Monthly meteorological data such as temperature, humidity and rainfall pertaining to the study area were collected from the Department of Meteorology, Govt. of India. Forest and vegetation cover and water bodies corresponding to the coordinates of each of the study villages were extracted from IRS 1C LISS III (February 26th 1999) remotely-sensed images.

Based on the approach reported by Hay *et. al.*, (2000) for Gambia, a temporal variability analysis for Salem District of Tamil Nadu was done [9]. To determine the predictor variables affecting the presence and the incidence of malaria, Multiple Linear Regression analysis using the backward elimination method was performed. For this model, all the PHCs that tested positive for malaria cases were used in the analysis. Variables were subjected to natural logarithm transformation to obtain approximately normal distributions (1). The linear regression models resulting from the analysis were used to prepare predicted maps for malaria cases.

For disease mapping or prediction, geostatistical or variogram approaches have been used occasionally (3, 13, 15, 16). These authors have suggested the use of 'ordinary kriging' to interpolate disease prevalence as incidence rates across a map, based on the recorded values at known locations. A semivariogram is used to model spatial dependence in the observed data. Based on

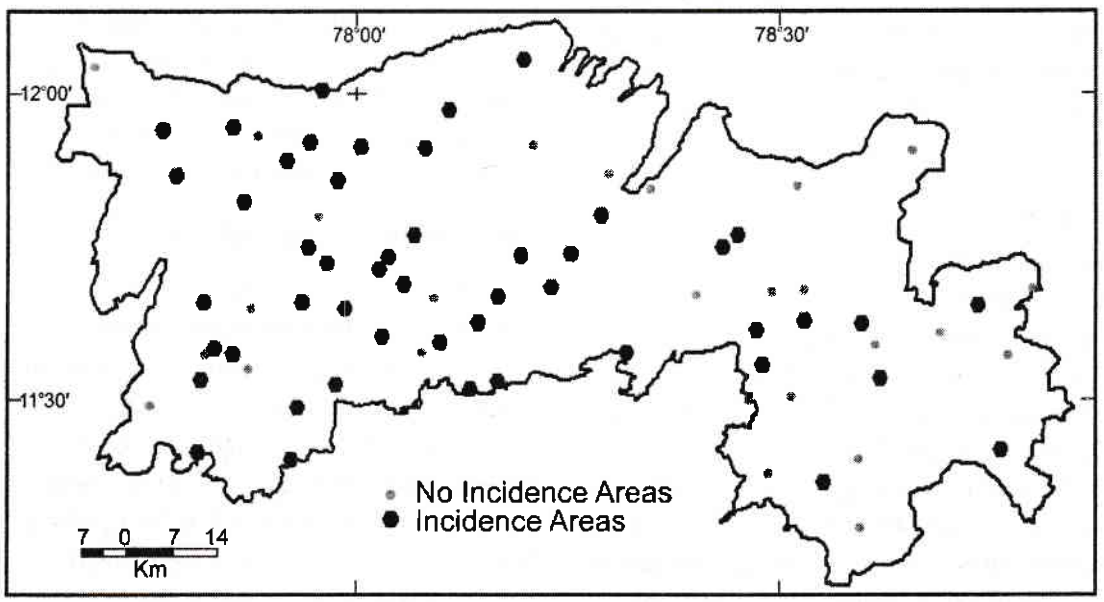

Fig. 1. Study Area and Recorded Malaria Incidences : Salem district

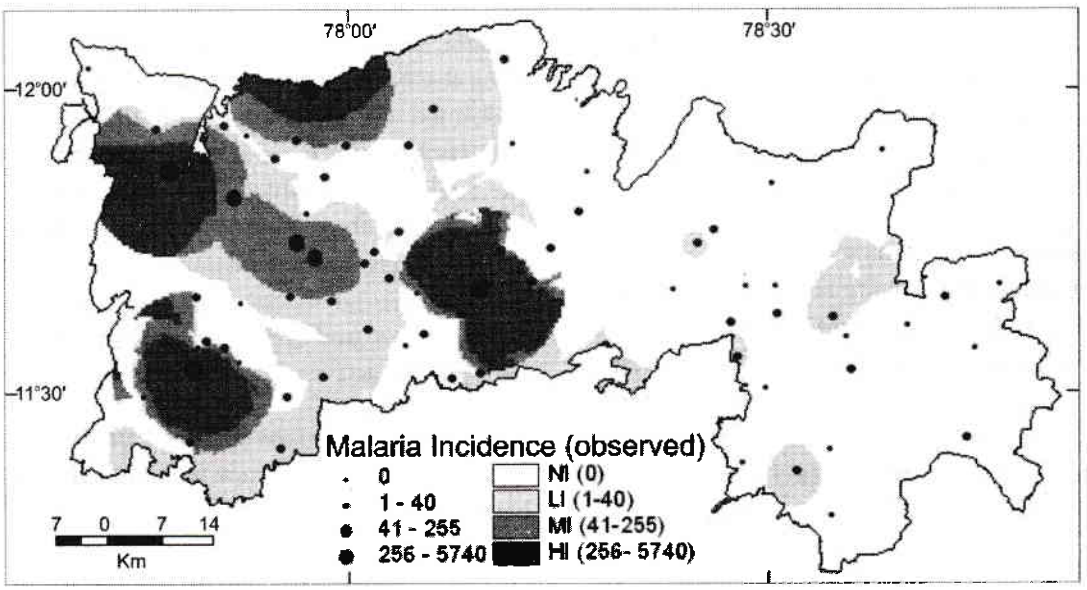

Fig. 2. Interpolation of Recorded Malaria Incidences in Salem district

this, for each variable in the model, an image was produced in Arc View 3.2a using GWA SA Kriging Interpolator (an extension tool). Ordinary kriging method was used to estimate the semivariogram based on the Linear with sill method, with a lag distance (γ) of 0.1 km and a search radius of 0.2 km.

Results

Thematic Factors

Recorded malaria cases from the PHCs were used to prepare a thematic map classifying the infected areas as high (256-5740 cases), moderate (41-255 cases) and low (1-40 cases) (Fig. 2). No incidence cases were recorded in 25 PHCs. The remaining 49 PHCs had positive cases. Out of the 49 PHC areas recorded for positive cases, three areas of high incidence were recorded at Vellar, Mettur and Salem. Areas of moderate incidence were recorded at four locations; Tharamangalam, Sedapatty, Kedaiyur and Nangavalli. The remaining 42 locations were designated as low incidence areas.

From the distribution of malaria cases, it can be said that the high incidence areas are clustered in the central and northern parts of the district whereas the 'no incidence' areas are clearly distributed in the eastern zone.

Analysis of Meteorological Factors

Temperature and Humidity

Cross *et. al.*, (1996) have studied temperature and relative humidity patterns in relation to incidence location, and considered that these factors are related to high probability of malarial occurrences (5). In this study, the day temperature ranges from 30°C to 36°C, where the occurrences of incidence were noted. In areas of lower temperature of around 20°C (Nagalur, Valavanthi and Pachamalai) malarial cases were not reported. Related humidity data were also collected for Salem

district to correlate with malaria incidence. In this study, the average relative humidity was recorded as 74% for the years 1996 to 2001.

Rainfall

As mosquito species are also temperature - bound, they are also rainfall dependent. For most species, the number of breeding sites is proportional to the amount of rainfall and its pattern. Extreme conditions restrict mosquito proliferation; low rainfall creates fewer breeding habitats; and high rainfall flushes mosquito eggs. Between 1994 and 2000, the average rainfall recorded in the district was 506.36mm (6)[2].

Analysis of Environmental Factors

Vegetation Cover and Water Bodies

Evergreen forest is reported to be favourable habitat for malaria vectors. Rainfall is a major factor contributing to forested areas and hence the classification of forests mainly depends upon intensity of rainfall (2). In the GIS layers derived from the toposheets, vegetation cover is mainly classified into mixed jungle, scrublands, plantations and unclassified reserve forests. The overall area of forest cover was 1196.68 sq.km.

The *Anopheles* larva is aquatic and needs relatively quiet water to grow. Perennial water bodies were digitized from the IRS 1C LISS III imagery. A digitized layer from the imagery was overlaid on the GIS layers to present a common map for forest cover and water bodies.

[2]This figure shows the average rainfall in the district throughout the study period 1994 – 2000. At the start of the study, the district included Namakkal, Thiruchengode and Rasipuram taluks (dry regions that contribute relatively little rainfall). These taluks were later separated from the Salem district to form the Namakkal District. Thus, during the later part of the study, these three taluks were not included.

Malaria Incidence Seasonality

Mapping of malaria seasonality is an important goal because the distribution of the vector (mosquito) depends on the seasons. Since India is a vast country and has diverse environments, the prevailing conditions may be useful to help optimize the time of insecticide spraying, for restricted distribution of anti malaria drugs to periods of known disease risk, and to reduce the time required to provide logistically and financially demanding chemo prophylaxis.

Meteorological data such as rainfall, temperature and humidity were used for mapping malarial seasonality. The collected monthly malarial incidence (in percentage) at 49 PHC wards was used to correlate these environmental variables. The correspondence between the mean maximum day temperature, rainfall, humidity and malaria incidence is illustrated in Fig. 3 for high, moderate and low incidence areas detected from the incidence map of Salem District (Fig. 2).

In low and high incidence areas, the maximum malarial incidence was reported in July and August. In the moderate incidence areas, the maximum percentage of incidence occurs in February. The temperature ranges between 32°C and 34°C in the high, moderate and low incidence areas. The rainfall ranges from 0.85 mm to 23.68 mm in high incidence areas, 1.12 mm to 48.90 mm in moderate areas and 1.82 mm to 79.45 mm in low incidence areas. The relative humidity ranged from 68.16% to 84.5%. From the above results, it is inferred that moderate rainfall with optimum temperature and relative humidity is most favourable for the prevalence of malaria. From the figures it is inferred that,

i) At optimum temperature (32°C – 34°C), the rate of incidence is high.

ii) During months of high rainfall, the incidence rates were low, but increased during the subsequent months.

iii) High humidity is a favourable condition for increasing malaria incidence

These results lead us to hypothesize that environmental variables (temperature, precipitation and humidity) are acting in a similar manner in all the three derived incidence categories. It is understood that in addition to these environmental variables some other factors like vegetation cover and the presence of water bodies play an important role for the incidence of malaria. The interaction of the factors influencing mosquito incidence has a formidable complexity.

Incidence Prediction Model

A number of models have been proposed by Klienbaum *et. al.,* to predict vector-borne disease (12). Among those models, the backward elimination method of the Multiple Linear Regression Model (MLR) was identified as the best interpreter for incidence of malaria. This is represented in the form,

$$Y = \beta_o+\beta_1X_1+\beta_2X_2+.....\beta_kX_k+E \qquad (1)$$

where Y is the total malarial cases, X_1- X_k are predictors, β_o is a constant and β_{1-k} are coefficients.

Confounding and interaction of variables are two methodological concepts relevant to attaining this goal. Kleinbaum *et. al.,* describe the context of epidemiological research, which typically addresses this question (11). Mathematically, one way to represent the interaction effects is,

$$Yy/(X_1...X_k)= \beta_o + \beta_1X_1 + \beta_2X_2 ++\beta_kX_k + \beta X_1X_k \qquad (2)$$

The proposed model to interpret the relationship between malarial incidence and the related environmental factors such as vegetation cover, rainfall, water body, temperature and humidity is,

$$Y = \beta o+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6 +\beta_7X_7+\beta_8X_8+\beta_9X_9+\beta_{10}X_{10}+E \qquad (3)$$

Where Y is the Total Incidence, X_1 is the Rainfall in millimetres, X_2 is the Temperature (C), X_3 is the Humidity (%), X_4 is the extent of Vegetation cover in sq. km, X_5 is the extent of Water body in sq. km, X_6 is the Interaction of Rainfall * Temperature, X_7 is the Interaction of Rainfall * Humidity, X_8 is the Interaction of Rainfall * Vegetation cover, X_9 is the Interaction of Vegetation cover * Water Body, X_{10} is the Interaction of Rainfall * Vegetation cover * Water Body.

A log transformation was used to stabilize the variance of Y (total incidence) to normalize the dependant variable (7). A summary of the backward elimination method of multiple linear regression analysis is presented in Table 1a where six models are presented. The R (multiple correlation) value decreases only slightly from model 1 to model 6 and the contribution of the 4 predictors are significant in model 6 at the 0.05 level and the dummy variable (presence of water bodies) at 0.01 level. The analysis of variance for log malaria incidences regressed on environmental and ecological variables is presented in Table 1b. Model 6 includes only four variables (temperature, extent of water bodies,

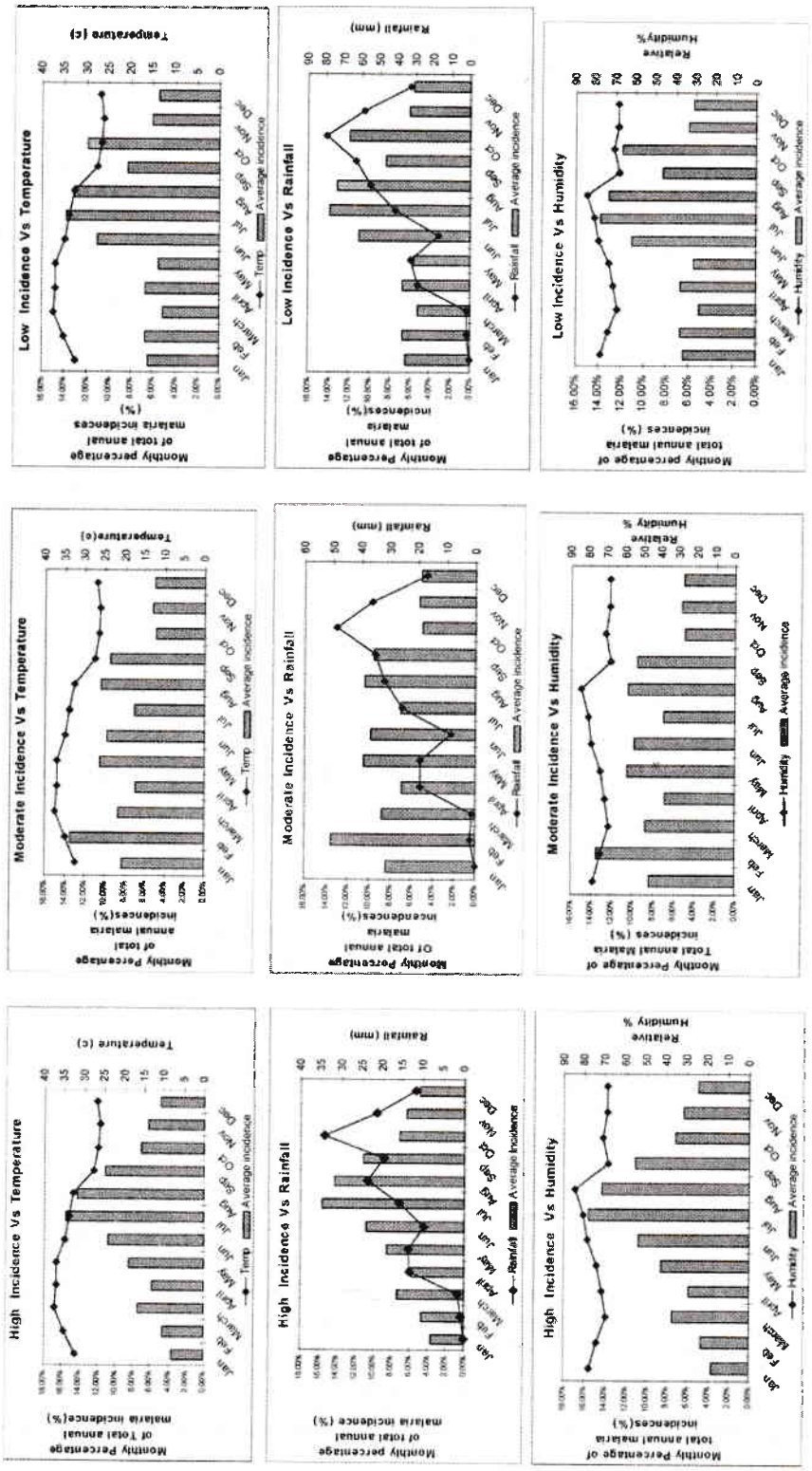

Fig. 3 Graphs show the Monthly Mean Percentage of Malarial Incidence (bars) for the High, Moderate and Low Incidence Areas of Salem District along with the Environmental Factors Temperature, Rainfall and Humidity.

Table 1a

Summary of the Tests of the Backward Elimination Method of the MLR

Regression details

Model		Unstandardised coefficients		Std. Coeff-icients	t	Sig.	95% coincedence Interval for B		Correlation			Colinearity Statistics	
		B	Std. Error	Beta			Lower bound	Upper bound	Zeroth order	Partial	Part	Toler-ance	VIF
1.	(Constant	-13.861	7.473	.285	-1.855	.071	-28.976	1.254					
	Temp. MA	.231	.207	.074	1.119	.270	-.187	.649	.111	.176	.089	.097	10.305
	Humid M/	.319E-02	.092	-.594	.794	.432	-.113	.260	.064	.126	.063	.726	1.377
	Water BC	9.95E-03	.017	.091	-.591	.558	-.044	0.024	.154	-.094	-.047	.006	60.769
	Forest	583E-04	.005	1.232	.099	.921	-.009	0.010	-.230	.016	.008	.008	31.665
	X_6	1.85E-03	.002	1.305	-.744	.461	-.007	0.003	-.025	-.118	-.059	.002	135.452
	X_7	.173E-04	.001	-.395	.786	.437	-.001	0.003	-.025	.125	.062	.002	138.032
	x_8	3.47E-05	.000	.395	-.473	.639	.000	0.000	-.241	-.076	-.038	.009	10.673
	X_{10}	.511E-07	.000	.891	.397	.694	.000	0.000	.020	.063	.031	.006	57.416
	Z_7	1.367	.184		7.416	.000	.994	1.740	.818	.765	.588	.436	2.292
2.	(Constant	-13.723	7.252		-1.892	.066	-28.380						
	Temp. J/1A	.230	.204	.284	1.130	.265	-.182	.933	.111	.176	.089	097	10.289
	Humid JV1	.241E-02	.091	073	.798	.430	-.111	.642	.064	.125	.063	.731	1.367
	Water BC	1.06E-02	.015	-.636	-.703	.486	-.041	.256	.154	-.110	-.055	.008	33.271
	X_6	1.86E-03	.002	-1.236	-.756	.454	-.007	.020	-.025	-.119	-.059	.002	135.240
	X_7	.077E-04	.001	1.290	.790	.434	-.001	.003	-.025	.124	.062	.002	134.247
	x_8	2.80E-05	.000	-.319	-.958	.344	-.000	.003	-.241	-.150	-.075	.055	18.075
	X_{10}	444E-07	000	.438	.496	.623	-.000	.000	.020	.078	.039	.008	127.256
	Z_7	1.372	.175	.894	7.820	.000	1.018	1.727	.818	.778	.613	.470	2.128
3.	(Constant	-14.708	6.910		-2.128	.039	28.664	-.752					
	Temp._MA	.278	.178	.343	1.564	.126	-.081	.637	.111	.237	.121	.125	7.987
	Humid W	672E-02	.089	.067	.748	.459	-.113	.247	.064	.116	.058	.743	1.345
	Water BC	3.17E-03	.001	-.189	-2.139	.038	-.006	.000	.154	-.317	-.166	.769	1.300
	X_6	2.40E-03	.002	-1.598	-1.103	.276	-.007	.002	-.025	-.170	-.086	.003	48.200
	X_7	.002E-03	.001	1.600	1.071	.290	-.001	.003	-.025	.165	.083	.003	570.385
	x_8	1.40E-05	.000	-.159	-1.933	.060	-.000	0.00	-.241	-.289	-.150	.888	1.126
	Z_7	1.316	.031	.857	9.983	.000	1.049	1.582	.818	842	.775	.818	1.223
4.	(Constant	-11.473	5.362		-2.140	0.038	-22.294	-.652					
	Temp._MA	.337	0.159	.415	2.119	0.043	0.016	.657	0.111	.311	.164	.155	6.442
	Water BC	3.18E-03	.001	-.190	-2.160	0.037	-.006	.000	.154	-316	-.167	.769	1.300
	X_6	2.92E-03	.002	-1.940	-1.419	0.163	-.007	.001	-.025	-.214	-.110	.003	513.504
	X_7	226E-03	.001	1.957	1.390	0.172	-.001	.003	-.025	.210	.107	.003	532.624
	x_8	1.36E-05	.000	-.155	-1.893	0.065	0.000	.000	-.241	-.280	-.146	.893	1.120
	Z_7	1.305	.130	.850	10012	0.000	1.042	1.568	.818	.839	.773	.827	1.209
5.	(Constant	-4.690	2.243		-2.091	0.042	-9.213	-.167					
	Temp._MA	.134	.065	.166	2 082	0.043	.004	.265	.111	.303	.163	.960	1.042
	Water BC	3.57E-03	.001	-.213	-2.440	0.019	.001	.001	.154	-.349	-.190	.798	1 254
	X_6	6.56E-05	.000	-.044	-.534	0.596	.000	.000	-.025	-.081	-.042	.914	1.094
	x_8	1.33E-05	.000	-.152	-1.837	0.073	.000	.000	-.025	-.270	-.143	.894	1.119
	Z_7	1.341	.129	.874	10.380	0.000	1.080	1.601	.818	.845	.810	.861	1.162
6.	(Constant	-4.984	2.157		-2.311	.026	-9.330	-.637					
	Temp._MA	.139	.064	.171	2.187	.034	.011	.267	.111	.313	.169	.976	1 024
	Water BC	3.44E-03	.001	-.206	-2.404	.20	-.006	-.001	.154	-.341	-.186	.819	1.221
	x_8	1.40E-05	.000	-.159	-1.966	.056	-.000	.000	-.241	-.284	-.152	.918	1.089
	Z_7	1.333	.127	-.868	10.472	.000	1.076	1.590	.818	.845	.811	.872	1.147

Table 1b - Analysis of Variance Tables for Log, Malaria Incidences regressed on Environmental and Ecological Variables

Model	Variables	Sum of Squares	df	Mean Squares	F	R^2
1.	Regression Residual Total	24.812 8.077 32.888	9 39 48	2.757 0.207	13.312**	0.869
2.	Regression Residual Total	24.810 8.079 32.888	8 40 48	3.101 .202	15.355**	0.869
3.	Regression Residual Total	24.760 8.128 32.888	7 41 48	3.537 0.198	17.841**	0.868
4.	Regression Residual Total	24.649 8.239 32.888	6 42 48	4.108 0.196	20.941**	0.866
5.	Regression Residual Total	24.649 8.239 32.888	5 43 48	4.854 0.200	24.219**	0.859
6.	Regression Residual Total	24.213 8.675 32.888	4 44 48	6.053 0.197	30.701**	0.858

** Significant at 5 per cent level

interaction of rainfall and forest cover and a dummy variable Z) apart from the constant. Relative humidity was not significant and hence was removed in the model. A dummy or indicator variable is any variable in a regression equation that takes on a finite number of values so that different categories of a nominal variable can be identified. The term dummy reflects the fact that the values taken on by such variables (usually values like 0, 1 and -1) do not indicate the meaningful measurements but rather the categories of interest. In this analysis the dummy variable is a binary indication of the presence, or not, of water bodies. Therefore model 6 is used for predicting the malarial incidence.

The selected final model is

$$Y = -4.98 + 0.14 \text{ (Temperature)} - 3.44 \times 10^{-3} \text{ (Water body)} - 1.40 \times 10^{-5} \text{ (Interaction of Rainfall and Forest cover)} + 1.33(Z) \quad (4)$$

The fitted regression model (the fitted equation 4) is diagnostically checked to assess the accuracy of the computations. For this model, we have focused the residual analysis method as a diagnostic tool.

The cumulative residuals were plotted and presented in Fig. 4a. Careful study of the figure reveals that there are no marked blatant departures from the normality assumption. The 45° straight line of the normality plot confirms the adequacy of the model. From this check, it is inferred that model 6 is the best

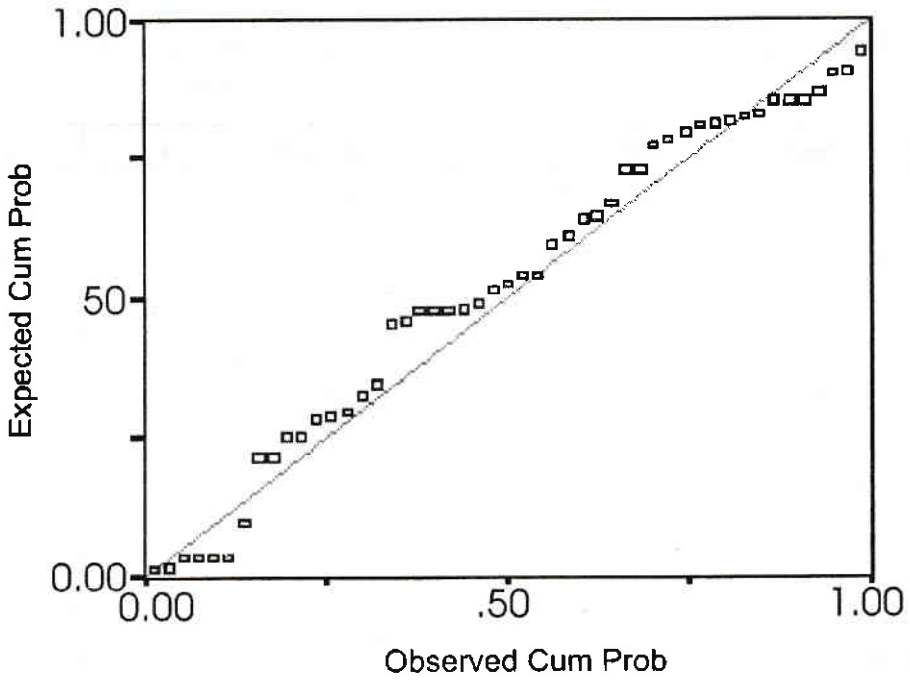

Fig.4a Normal Probability Plot of the Residuals for MLR fitted for Mosquito Incidence with Environmental and Ecological Variables

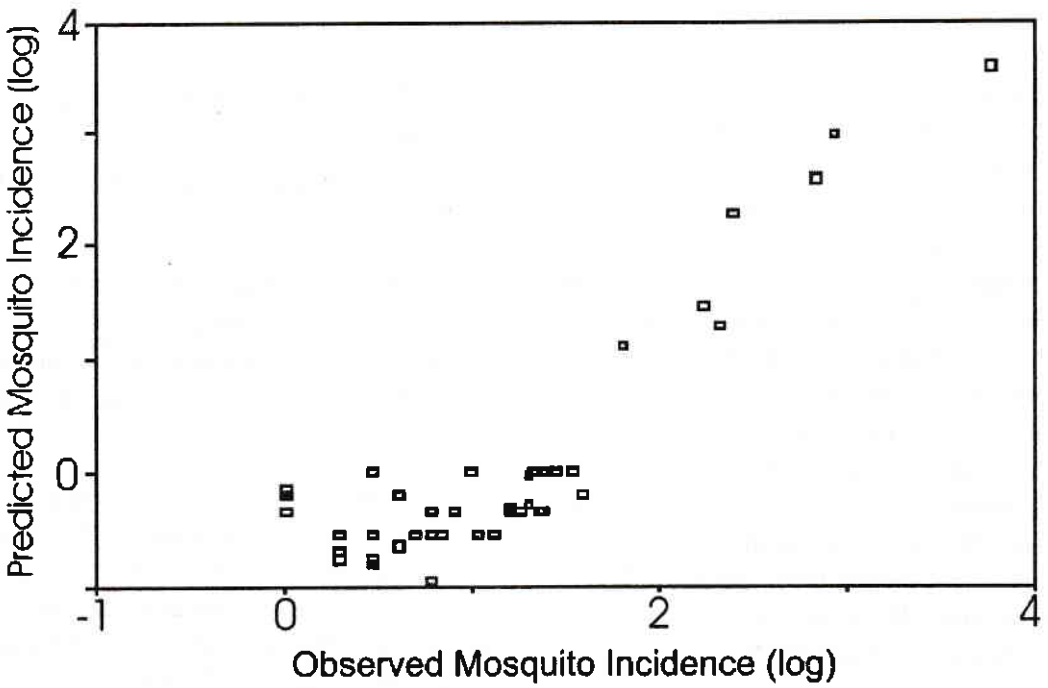

Fig. 4b The Observed and Predicted Malaria Incidences in Salem district

model (the residual plots of the other five models are not included).

Predicted and observed values that were used for correlation analysis are presented in figure 4b. The correlation coefficient of this is 0.858 and the coefficient of determination (R^2) is around 73.1%. From the results of the correlation analysis and the significance of the correlation coefficient, the prediction is judged to be good. The predicted values were used for preparing a visualization map of predicted malaria incidence.

A thematic map of the predicted values was created that presents predicted malarial intensity zoned as high, moderate and low areas (Fig. 5). From this map, it was observed that high incidence areas were predicted at four areas where the predicted cases ranged from 256 to 5740 cases, moderate incidence were predicted at three areas ranging from 41 to 255 cases and low incidence predicted at 42 locations ranging from 1 to 40 cases. These results were compared with that of the thematic map of incidence. As this study was more concerned with environmental influence on malaria distribution, population distribution was not considered here, but is a factor for consideration in the next part of the study.

1) On comparing the Figs. (2) and (5), we have distinguished, based on the prediction of cases, three zones:

   - Areas where environmental variables are favourable for malaria distribution,
   - Areas where environmental variables are not favourable for malaria, and
   - Areas where the environmental condition may or may not favour occurrences of malaria. In such cases, a rapid

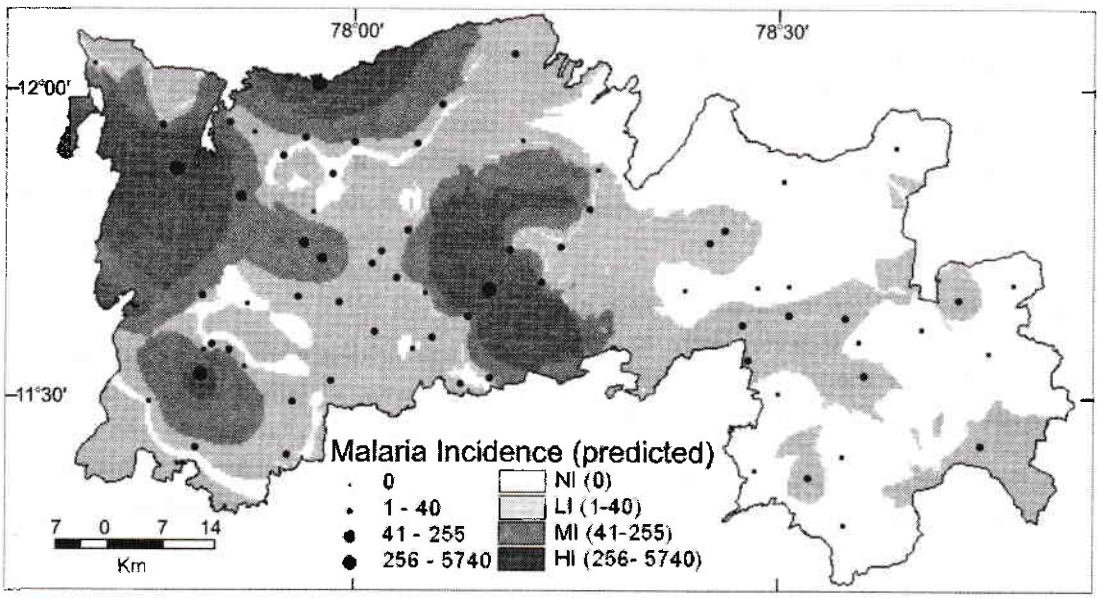

Fig.5 Interpolation of Predicted Malaria Incidences in Salem district

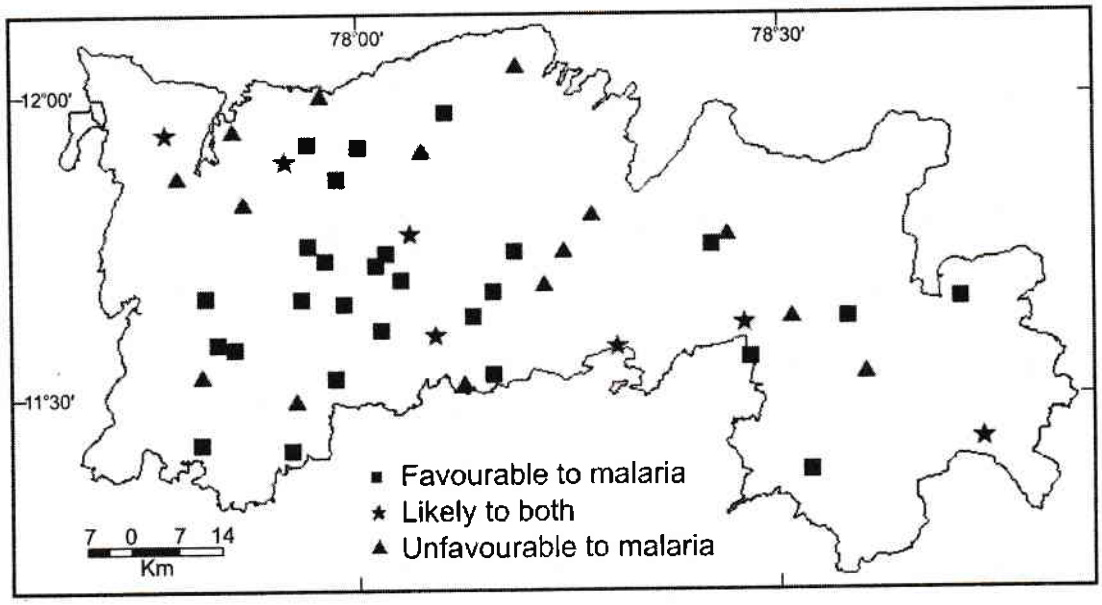

Fig. 6 Areas in which Conditions are Favourable or Unfavourable to Malaria, and in which Favourability is likely to be affected by Change in Climatic Conditions.

change in any climatic factor may influence the disease transmission.

2) If the conditions of environmental factors are favourable but actual incidence is restricted, the same anti-malaria measures employed there may be implemented in other areas so as to decrease malarial distribution.

Using the predicted malarial cases, a map depicting areas that were likely to favour occurrences of the disease, in Salem was prepared to support control strategies (Fig. 6).

In the predicted map (Fig. 5), the same 42 locations were observed in low incidence areas. Out of the 42 locations 15 areas were predicted to be unfavourable for future malarial incidence. In eight areas, conditions were likely for both. These areas were likely to switch between the two. Favourable conditions for malarial incidence were predicted to occur at 19 locations. In these areas, environmental factors most favour the occurrence of malarial incidence. Similarly in moderate incidence areas, two locations (Sedapatty and Tharamangalam) were seen to be favourable to malaria, and Nangavalli was unfavourable.

In high incidence areas, Kedaiyur, Mettur and Vellar were classified as unfavourable and Salem was highly favourable with a predicted value of 3932 incidences. (This predicted value is lower than the observed value of 5737 cases).

Conclusion

The prediction model developed in this study

provides detailed mapping of malaria incidence classified into high, medium and low incidence locations in Salem district. The fact that this model was derived from meteorological and environmental variables gives us a chance to produce a risk map of the disease and predict its burden in areas not covered by the initial data. The risk maps produced from the study should be of great value for planning and improving locations of treatment centers, for finding appropriate places for human settlements, and to decide where to extend control programmes. Although the model was based on local data pertaining to Salem district, it provides good prediction of malaria cases, and so the study can be suggested for extension in other malaria- prone areas.

References

1. Abeku T.A, S.J. Devlas, G.J.J.M.Borsboom, A.Tagede, Y.Gebreyesus, H.Gebreyohannes, D. Alamirew, A. Seifu, N.J.D.Nagelkerke, and J.F.D.Habbema(2004).' Effects of Meteorological Factors on Epidemic Malaria in Ethiopia: A Statistical Modeling Approach based on Theoretical Reasoning', *Parasitology,* 128, pp. 585-593.
2. Aruna Srivastava, B.N.Nagpal, Rekha Saxena and S.K.Subbarao (2001). 'Predictive Habitat Modeling for Forest Malaria Vector Species', *Current Science,* 80(9), pp.1129-1134.
3. Carrat F and A.J. Valleron A (1992). 'Epidemiological Mapping using the 'Kriging' Method Application to Influenza-like Illness Epidemic in France', *American Journal of Epidemiology,* 135(11), pp.1293-1300.
4. Clarke.K.C, S.L.McLafferty and B.J.Tempalski (1996). 'On Epidemiology and Geographic Information Systems: A Review and Discussions of Future Directions', *Emerging Infectious Disease,* 2, pp.85-92.
5. Cross E.R, W.W. Newcomb and C.J.Tucker (1996). 'Use of Weather Data and Remote Sensing to predict the Geographic and Seasonal Distribution of *Phlebotomus papatasi* in Southwest Asia.', *American Journal of Tropical Medicine and Hygiene,* 54, pp.530-536.
6. Department of Meteorology, Indian Meteorological Division, Salem Collectorate(2000). Personal Communication.
7. Elnaim D.A, J.Schorscher, A.Bendall, V.Obsomr, M.E.Osman, A.M.Mekkawi, S.Conner, R.W.Ashford and M.Thomson (2003). 'Risk Mapping of Visceral Leishmaniasis: The Role of Local Variation in Rainfall and Altitude on the Presence and Incidence of Kala-azar in Eastern Sudan', *American Journal of Tropical Medicine and Hygiene,* 68(1), pp. 10-17.
8. Hay S.I, S.E.Randolph and D.J.Rogers (2000). *Remote Sensing and Geographical Information Systems in Epidemiology*. London: Academic Press.
9. Hay S.I, R.W.Snow and D.J.Rogers (1998). 'From Predicting Mosquito Habitat to Malaria Seasons using Remotely-sensed Data: Practice, Problems and Perspectives', *Parasitology Today,* 14(8), pp.306-313.
10. Kitron U (1998). 'Landscape Ecology and Epidemiology of Vector-borne Diseases Tools for Spatial Analysis', *Journal of Medical Entomology,* 35(4), pp.435-445.
11. Kleinbaum D.G, L.L.Kupper, K.E.Muller and A.Nizam(1998). *Applied Regression Analysis and Other Multivariate Methods.* Pacific Grove: Duxbury Press.
12. Kleinbaum D.G, L.L.Kupper and H.Morgenstern (1982). *Epidemiologic Research: Principles and Quantitative Methods.* Belmont, California: Lifetime Learning Publications.
13. Kleinschmidt I, M.Bagayoko, G.P.Y.Clarke, M.Craig and D.Le Sueur (2000). 'A Spatial Statistical Approach to Malaria Mapping',

International Journal of Epidemiology 29 (2), pp.355-361.

14. Nájera J.A, R.L.Kouznetzsov and C.Delacollete (1998). *Malaria Epidemic: Detection and Control, Forecasting and Prevention*. Geneva: World Health Organisation, WHO/ MAL/98.1084.

15. Nicholson M.C & T.N.Mather (1996). 'Methods for evaluating Lyme Disease Risks using Geographic Information Systems and Geospatial Analysis', *Journal of Medical Entomology*, 33, pp.711-720

16. Oliver M.A, K.R.Muir, R.Webster, S.E.Parkes, A.H.Cameron, M.C.G.Steven and J.R.Mann (1992). 'A Geostatistical Approach to the Analysis of Pattern in Rare Disease', *Journal of Public Health*, 14(3), pp.280-289

17. Sharma V.P (1991). 'Environmental Management in Malaria Control in India', in G.A.T.Targett (ed.). *Malaria waiting for the Vaccine*. Chichester, England: John Wiley & Sons. pp. 49–63.

18. Thomson M, D.A.Elnaim, R.W.Ashford and S.Conner (1999). 'Towards a Kala-azar Risk Map for Sudan: Mapping the Potential Distribution of *Phlebotomous orientalis* using Digital Data of Environmental Variables', *Tropical Medicine & International Health*, 4, pp.105-113.

19. Thomson M and S.Connor (2000). 'Environmental Information Systems for the Control of Arthropod Vectors of Disease', *Medical and Veterinary Entomology*, 14, pp.227-244.

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Contents

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On the Use of Environmental Variables to Help Estimate Human Population Distributions

Petra A. Zimmermann
Department of Geography, Ball State University, Muncie, Indiana, USA

An environmentally -based model for distributing human populations over high spatial-resolution grids is developed and tested in California. The model is based on habitability, the ability of a place to sustain a fixed human population. Within the model, population densities are influenced by elevation, topographic accessibility and river proximity. Model estimates of the 1990 population distribution are compared to 1990 U.S. Census block group data. Using three independent variables, the model establishes the general pattern of settlement in California. Results show that this is a promising way to estimate population distributions in the absence of spatially high-resolution census data.

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The physical environment is often assumed to influence where people live. For example, Diamond argued that the east-west expanse of the Eurasian land mass (and by extension, relatively uniform climates) permitted *in situ* food production and fixed human settlements (4). Small, Gornitz, and Cohen showed that a large percentage of the world's population lives within short distances of open water (20), while Small and Naumann linked settlement to volcanic soils (21). These human-environment relationships, however, are usually understood qualitatively rather than quantitatively. A quantitative understanding, in contrast, would yield additional benefits, including a clearer

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picture of the interactions between human settlements and their ambient physical geography.

Much global change research focuses on changes attributed to anthropogenic causes, such as the role of humans in climate change. It is not only important to know what changes have been made, but it is important to have knowledge about where the changes occurred and continue to occur. This implies a need for geo-referenced population data that can be used with some confidence. Unfortunately, few high-quality population data are available at high spatial resolutions. This is especially true for developing countries or for historical time periods. The establishment of quantitative connections between human settlements and the ambient physical environment may help by providing another means to estimate where people live and have lived.

Our objective, then, is to explore the potential roles of environmental information in estimating the spatial distribution of a region's population. We approach this first by introducing an environmentally -based model which can resolve a region's total population onto a spatially high-resolution grid. The model rests on the concept of habitability, a term denoting the population-supporting potential of a place. In order to quantify habitability, we examine relationship(s) between selected aspects of a place's physical environment and its potential to support fixed human settlements

Population Enumeration

Estimated or counted population data already exist and are being used by the research community. The spatial reliability of many of these data is questionable, however. Perhaps the most familiar of these are censuses, which have a long history. The United States, for example, has conducted a census decennially since 1790. Other very useful population archives can also be found at varying spatial resolutions (e.g. 25). Most of these datasets, however, are static, representing only one point in time. On occasion a "static" dataset has been prepared with data from different time periods, such as Li's (12). Remotely-sensed imagery has been used to estimate population as well (23). Such estimates have been limited by the availability of population data and typically can only be utilized for contemporary time periods.

Global Population Datasets

Among the available global population datasets is Lerner, Matthews, and Fung's 1° x 1° gridded dataset, based on 1984 population and developed at NASA's Goddard Institute of Space Studies (GISS) (11). Another 1° x 1° dataset is Li's Global Population Distribution (GPD), which improved the accounting of situations in which multiple countries share a given grid cell (12). The GPD used 1990 data as a foundation. The Gridded Population of the World (GPW) dataset, a 5′ x 5′ population archive, is perhaps the best-known of the global datasets (24). Tobler *et. al.*, recognizing the resolution discrepancies between generally available population and environmental data, developed the more finely resolved GPW (24). They acknowledged the spatial and temporal inconsistencies with their input data. Version 2 of the GPW featured higher quality input data, which were incorporated onto a 2.5′ x 2.5′ resolution grid (1).

The LandScan global population database was created at Oak Ridge National Laboratory (5). Not only were its human populations resolved on a 30-arc second grid, but the daily spatial movement of people (using probability coefficients) was factored in (based on roads, slope, land cover, night time lights, and documented populations). Although quality control issues existed, Dobson *et. al.*'s (5) approach was particularly useful in describing contemporary societies within which mobility is an important characteristic.

Population Estimation from Remotely-sensed Imagery

Aerial photography has been used to help count human populations (15, 17, 28, 14). Among the techniques used are the house-counting method (13) and the land-area method (16). Aerial photography is attractive because of its relatively low cost. However, enumeration methods based on it have accuracy issues.

Satellite imagery has been used to examine population for over two decades (29). These data are spatially extensive, but their use is limited to the time periods for which the satellite data are available. Sutton *et. al.*, for instance, used a Geographic Information Systems (GIS) and satellite data to estimate population density across the globe at a 1 sq.km resolution. They correlated night-time "city lights" imagery with known population data and employed distance decay functions (23). Sutton improved upon this approach by incorporating Gross Domestic Product (22). Doll, Muller and Elvidge also achieved good results by correlating urban populations and lighted places (6). Such datasets and methods are valuable instruments, particularly when representations of contemporary populations are desired; however, their lack of basic demographic principles (rules) limits their applicability, especially when sufficient calibration data or satellite imagery is unavailable.

Urban Growth Modeling

Modeling the process wherein humans settle in concentrated groups has been another approach. These models attempt to forecast concentrations of human populations by predicting the extents of urbanized areas. Plutzar, Grübler, Stojanovic, Riedl, and Pospischil used a cellular automaton (CA) within a GIS to determine future urbanization in China; their scenarios became the basis for predicting energy demand (18). Other urban growth models, such as Landis's California Urban Futures models I and II (9, 10) have taken more statistical approaches. Clarke, Gaydos, and Hoppen, recognizing the need for tools with which to study the linkages between urbanization and local climate, developed an urban growth model (3). Their model used a CA approach to forecast land-cover changes, rather than explicitly predicting population (3). Clarke and Gaydos applied the model to both San Francisco and the Baltimore-Washington area (2). Other urban simulation work and analysis includes Europe's SCATTER (Sprawling Cities and Transport: From Evaluation to Recommendation) project, which examined policy impacts on Brussels, Stuttgart, and Helsinki (7). These model-based approaches serve as valuable planning tools in that they are useful in estimating the geography of future urban growth.

An Alternate Approach to Mapping Human Population Distributions

Our approach begins with the development of a rules-based model, with the "rules" predicated on the environmental characteristics of a place. To establish relationships between human settlement and the physical environment, we try to link the local (physical) geography to the potential size of the resident human populations. The key assumption is that human settlement is influenced by the physical environment to some degree. Our "rules"—definitions of environmental traits favourable to fixed settlements—describe the capabilities of a place to support a population. We call this "habitability".

Habitability

Like the concepts of carrying capacity—the number of people able to be supported by a given area (8)—and the ecological footprint—the area of land and water needed to sustain a given environment (27)—our habitability concept is an attempt to define limits and determine population pressures on the physical environment. Our habitability concept, while similar to these, differs in that it is a relative depiction of a place's suitability for supporting fixed human settlement, compared to other places within a region of interest.

Quantifying Habitability

Certain environmental characteristics, such as elevation or distance to a perennial stream, affect the habitability of a place, as well as its desirability with respect to humans wishing to locate there. Each of these characteristics is modeled separately as a dimensionless number that varies between 0.0 and 1.0. Our overall habitability *(H)* of a place is then defined as the product of several of these individual-variable habitability functions. Our overall *H* also is a dimensionless number that varies between 0.0 (minimum habitability) and 1.0 (maximum habitability). It is a dimensionless assessment of the aggregate population-supporting potential of a place.

Estimating Spatial Population Distributions from Habitability

Our overall habitability function *(H)* does not explicitly place people across space. Rather, it forms the basis upon which population is apportioned spatially. Habitability, then, tells us where we expect to find higher (or lower) populations or population densities. A location with a high *H* should attract or be able to support more people than a comparable location with a lower *H* value.

If we start with our estimated *H* field and a known total population for the entire region of interest, our next step is to link that total population to the habitability field. In doing this, it is important—after distributing the population across all grid cells in a given region R—to be able to integrate the estimated, gridded population-density field and obtain the same number of people as in our original, regional population total. We observe this "conservation of people" constraint by assigning the population to a grid cell based on the proportion that the grid-cell *H* contributes to the region's total *H*. This is accomplished by solving

$$\hat{P}_i = P_i(R)\left[\frac{H_{i,j}A_{i,j}}{\sum_{i=1}^{n_i}\sum_{j=1}^{n_j}H_{i,j}A_{i,j}}\right] \quad (1)$$

where t is the estimated grid-cell population at time t, i is the longitude, j is the latitude, A_{ij} is the grid-cell area, $P_t(R)$ is the total population of region R at time t, and $H_{i,j}$ is the estimated grid-point habitability. The summation of t over all grid cells, in other words, will equal the total population, $P_t(R)$, thus "conserving" people.

A Sample Application of the Habitability Model

Our model—implemented with only three environmental variables—is applied to California. Once again, the independent variables are elevation, topographic accessibility, and river proximity. An individual-variable, habitability function represents each environmental variable, and California's 1990 population (census) total is apportioned spatially onto a high-resolution grid, based on habitability (H). Following this, the model estimates are compared with observed, block-group population data.

California as A Test Case

Using California as a test region has several advantages, which arise primarily from its highly variable geography. California is spatially extensive, covering an area of approximately 410,000 square kilometers. It also has a wide variety of landscapes and climates. There is a broad spectrum of elevations, with some Sierra Nevada mountain peaks exceeding 3000 meters, and sub-sea-level elevations found in Death Valley. The density of river networks, too, varies throughout the State. Its settlements vary dramatically as well, ranging from mega-cities such as Los Angeles to sparsely populated rural areas. Just as importantly, high-resolution data for both environmental variables and population are available for California. Without such data, evaluating the performance of our model would be difficult.

California's Observed Population

In 1990, California's population was 28,858,477 people, and they resided within more than 21,000 census block groups. Since the block groups are irregularly shaped, we converted the block group ("observed") totals into a gridded population field by assigning each grid-cell centroid that fell within a block group population density of the block group. This ensured spatial compatibility with the gridded environmental data. The gridded, "observed" population field that emerged is shown in Fig. 1.

Elevation as a Component of Habitability

Elevation is selected as one of the environmental variables that can influence the habitability of a place. Small and Cohen, for example, show a relationship between elevation and population and, indeed, even cursory examinations of population maps seem to corroborate this (19). Perhaps the most noticed effect of elevation on the environment is the decrease in surface air temperature with increase in elevation. Precipitation increases or decreases can result from changes in elevation as well, but the changes are not always monotonic. Changes in air temperature and precipitation can, in turn, affect the vegetation and soils.

Our habitability function for elevation (h_z) assumes an exponential decay, and is represented by

$$h_z = \begin{cases} 1.0, & \text{when } z < 100 \text{ m} \\ e^{\frac{-(z-100)}{1000}}, & \text{when } z \geq 100 \text{ m.} \end{cases} \quad (2)$$

We assign maximum habitability for all elevations (h_z) below 100 m, based on Small and Cohen's work (19). They discerned noticeable drops in population density with increases in elevation, but especially in elevations greater than 100m. Our gridded elevation data are drawn from the GTOPO30 30-arc second Digital Elevation Model (DEM), which is available from the United States Geologic Survey (26).

Incorporation of Topographic Accessibility and Proximity to a River

Habitability, if estimated from elevation alone, is not sufficiently comprehensive to estimate adequately a population field. For this reason, two additional variables—topographic accessibility and proximity to a river—are added to the model.

Topographic accessibility (*TA*) is an index that describes the ease with which people can reach a given place (grid cell) from neighboring places (grid cells). Here, we solve for *TA* using a 3 × 3 grid-cell matrix, with the center grid cell being the cell of interest. It is assumed that it is easier to move down slope than up slope, and only those grid cells with elevations lower than the cell of interest restrict accessibility. Initially, we calculate the local inaccessibility (*LI*) according to

$$LI = \frac{\sum_{i=1}^{n_i}\sum_{j=1}^{n_j} w_{i,j}(z_{2,2} - z_{i,j})}{\sum_{i=1}^{n_i}\sum_{j=1}^{n_j} w_{i,j}}, \quad \forall z_{i,j}(z_{i,j} < z_{2,2}) \tag{3}$$

where Z_{ij} is the elevation of a neighboring grid cell and is an inverse-distance weight associated with the distance between the center of the cell of interest (2,2) and the center of the neighboring cell (i,j). Calculating the maximum *LI* that occurs within the region in question (LImax) allows for the computation of TA as

$$TA = 1 - \frac{LI}{LI_{\max}}. \tag{4}$$

Topographic accessibility (*TA*) varies between 0 (least accessible) and 1 (most accessible) and, for our purposes, *TA* and the individual-variable habitability function for topographic accessibility (h_{ta}) are the same.

The influence of proximity to a river on habitability (h_r) is expressed as a linear function, with closer locations deemed more habitable than those farther from a stream. River-proximity-based habitability (h_r) decreases linearly with distance up to 20 km. This habitability is calculated according to

$$h_r = \begin{cases} 1.0 - \dfrac{d_r}{20.0}, & \text{when } d_r < 20.0 \text{ km} \\ .01, & \text{when } d_r \geq 20.0 \text{ km} \end{cases} \tag{5}$$

with d_r representing the distance (km) to the closest perennial stream.

Estimating California's Population Distribution from Habitability

With these three individual-variable habitability functions specified, overall habitability (*H*) can be written as

$$H = (h_z)(h_{ta})(h_r). \tag{6}$$

The gridded *H* field (where H_{ij} is *H* evaluated at grid node *i,j*) forms the surface onto which

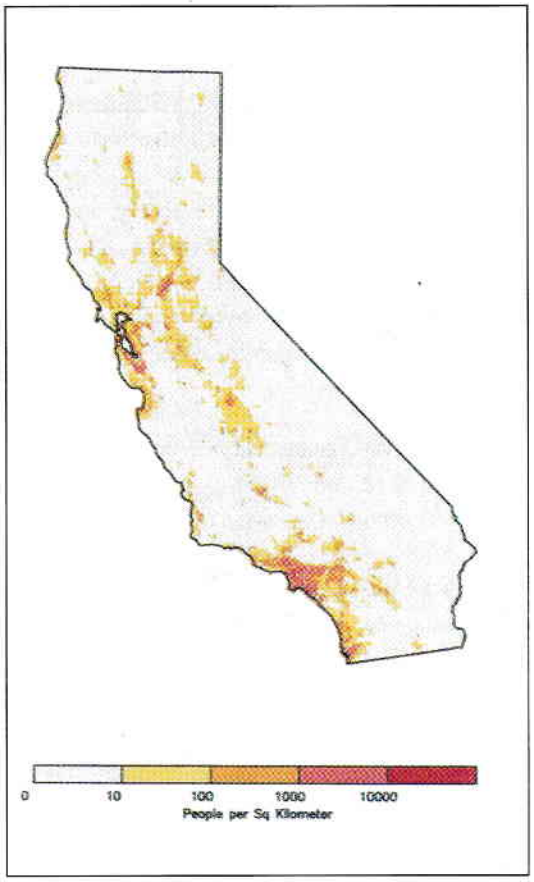

Fig. 1

California's "observed" total population is apportioned. Solving Equations (1) and (6), yields the model-estimated population field (Fig. 2).

Estimated population densities range from 0.0 to approximately 250 people per sq. km (Fig. 2). Within the State's southern half, high densities are estimated within the Central Valley. The Imperial Valley (in the extreme south-central region), as well as along the Pacific coast and the Colorado River, also show high estimates of population density. Owing to a paucity of perennial streams, the lowest densities are associated with California's desert southwest (e.g., the Mojave Desert). Within the southern Sierra Nevada mountains, higher elevations foster perennial streams which allow for mid-range population densities to be estimated. Mid-range population densities, however, do not occur within this mountainous terrain; and low population densities are typical. A similar pattern appears in northwest California (home of the Klamath mountains) and north-central California (where the Cascades are located). Model estimates exceed the observed populations; indeed, the estimated populations along Northern California river valleys show considerably higher population densities than are observed (Fig. 2).

Relatively high population densities are estimated for several of California's large metropolitan regions (e.g., Los Angeles, San Diego, and the San Francisco Bay Area); however, the estimated magnitudes are much lower than the observed populations (Fig.1).

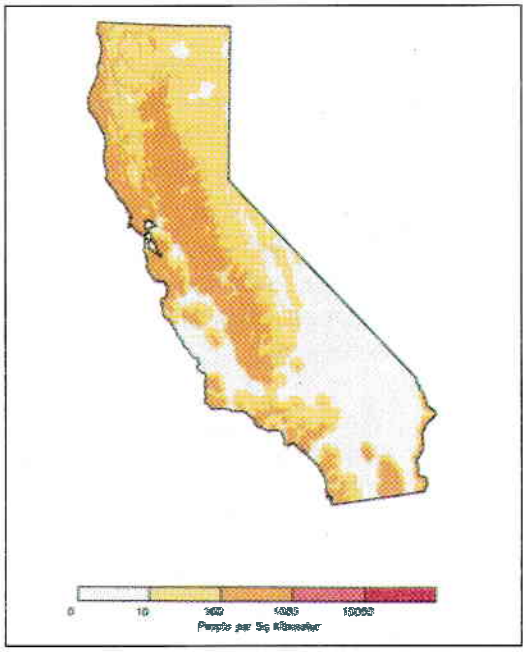

Fig. 2

Nonetheless, it is encouraging that an environmentally-based model can identify geographic areas that tend to attract large numbers of people. Low elevations, proximity to perennial streams and high levels of accessibility are all present in California's more populated coastal areas and, acting in concert, they force the model to estimate high population densities there.

Interpretation

Habitability-based modeling is a promising approach to estimating the spatial distributions of human populations. Our simple, three-variable model did not produce a perfect match between model-estimated and observed populations within California; nonetheless, our results illustrate that it is possible to meaningfully apportion human populations over space, especially when accurate, high-resolution population data are unavailable (e.g., for historical time periods). Our model was able to estimate the overall pattern of settlement in California, even though it tended to overestimate population in rural areas and underestimate it in urban areas. It is significant that our environmentally-based model was able to identify (correctly locate) the urban centers of Los Angeles, San Francisco-Oakland, and San Diego. The incorporation of additional variables, especially human-geographic factors, should improve substantially the model's performance.

Evaluating our environmentally based model within California was advantageous because of the availability of high-quality, high-resolution population and environmental data. However, there also were disadvantages, which stem from contemporary California's modern, wealthy, and technologically progressive society. California residents increasingly are able to overcome environmental obstacles to settlement, the same obstacles that presented insurmountable barriers to people living in other places or historical time periods. It is likely, in other words, that California may be an especially challenging region within which to test a model based solely on environmental factors. A model like ours may perform better is less developed regions.

Two additional caveats about the form of our model should be mentioned. Our model assigns a comparable range of influence (0.0 to 1.0) to each of our independent variables; that is, to elevation, topographic accessibility, and river proximity. This may, in fact, not be optimal, and the individual-variable h functions may require refinement, both in terms of their ranges of influence on H and their functional structures. A re-examination of the individual-variable h functions, with some refinement of them, could rectify this, as could the addition of more functions. Another aspect of our approach which should be kept in mind is that our habitability fields are, in essence, potential settlement fields, rather than actual ones. As a consequence, when our model is applied to a rapidly growing population and evolving settlement geography—such as in California—it is likely to over- and under- estimate within sub-regions, which it does. Models such as ours would be expected to work better in more demographically stable places and regions.

Conclusions and Future Directions

The idea that the environmental attributes of a place can influence human settlement has considerable value and this is reflected in the structure and performance of our habitability-

based, population–distribution model. Though our model is not perfect, it sufficiently resolved to estimate the spatial distribution of California's 1990 population for us. This simple, three-variable model was able to identify reasonably where people in California lived (in 1990) or could live and, just as importantly, where they did not or could not live. This demonstrates that environmental information about places can be used meaningfully to help estimate and map human populations in regions wherein population data are either inadequately resolved or non-existent.

It is likely that our three environmental variables do not describe fully the range of habitabilities within California and elsewhere. The incorporation of additional environmental characteristics (e.g., navigable water or protected anchorage proximity, slope, and soil quality) may improve our model's performance. Refinements to our model also should include one or more human-geographic variables that may be more influential within regions that are less topographically diverse than California. Still, our approach represents a useful way to distribute and map human population, as well as an alternate way to examine the connections between human settlement patterns and the ambient physical environment.

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References

1. CIESIN (2000). Center for International Earth Science Information Network (CIESIN); International Food Policy Research Institute (IFPRI); and World Resources Institute (WRI). Gridded Population of the World (GPW), (Version 2) Palisades, NY: CIESIN, Columbia University, http://sedac.ciesin.org/plue/gpw.
2. Clark K and L. Gaydos (1998). 'Loose Coupling a Cellular Automaton Model and GIS: Long-term Growth Prediction for San Francisco and Washington/Baltimore', *International Journal of Geographical Information Science*, 12(7), pp. 699-714.
3. Clark K, L. Gaydos and S. Hoppen (1997). 'A Self-Modifying Cellular Automaton Model of Historical Urbanization in the San Francisco Bay Area', *Environment and Planning B* , 24, pp.247-261.
4. Diamond J (1999). *Guns, Germs, and Steel: The Fates of Human Societies*. New York: Norton.
5. Dobson J, E. Bright, B. Coleman, R. Durfee, and B. Worley (2000). 'LandScan: A Global Population Database for Estimating Populations at Risk', *Photogrammetric Engineering and Remote Sensing*, 66, pp. 849-858.
6. Doll C, J. Muller and C. Elvidge (2000). 'Night-time Imagery as a Tool for Global Mapping of Socioeconomic Parameters and Greenhouse Gas Emissions', *Ambio*, 29(3), pp. 157-162.
7. Gayda S, F. Boon, N. Schaillée, M. Batty, E. Besussi and N. Chin (2003). *The SCATTER Project—Sprawling Cities and Transport: From Evaluations to Recommendations*. Paper presented at the European Transport Conference 2003, Strasbourg, France. Retrieved May 24, 2004 from http://www.casa.ucl.ac.uk/scatter/papers.html
8. Hayden B (1975). 'The Carrying Capacity Dilemma: An Alternative Approach', in Swedlund (ed.). *Population Studies in Archaeology and Biological Anthropology: A Symposium. American Antiquity*, 40, pp. 11-21.
9. Landis J (1994). 'The California Urban Futures Model: A New Generation of Metropolitan

Simulation Models', *Environment and Planning B* 21, pp.399-420.

10. Landis J and M. Zhang (1998). 'The Second Generation of the California Urban Futures Model: Model Logic and Theory', *Environment and Planning* B, 25, pp.657-666.
11. Lerner J, E. Matthews and I. Fung (1988). 'Methane Emissions from Animals: A Global High-Resolution Database', *Global Biogeochemical Cycles*, 2, 139-156.
12. Li Y (1996). 'Global Population Distribution Database'. A Report to the United Nations Environmental Programme, UNEP Subproject FP/1205-95-12, March 1996.
13. Lindgren D (1971). 'Dwelling Unit Estimation with Color IR Photos'. *Photogrammetric Engineering*, 37, pp.373-377.
14. Lo C.P (1986). 'Automated Population and Dwelling Unit Estimation from High-Resolution Satellite Images: A GIS Approach', *International Journal of Remote Sensing*, 16(1), pp. 17-32.
15. Lo C.P and H.F. Chan (1980). 'Rural Population Estimation from Aerial Photographs', *Photogrammetric Engineering and Remote Sensing*, 46, pp. 337-345.
16. Olorunfemi J (1982). 'Applications of Aerial Photography to Population Estimation in Nigeria', *Geojournal*, 6, pp.225-230.
17. Olorunfemi J (1984). 'Land Use and Population: A Linking Model', *Photogrammetric Engineering and Remote Sensing*, 50, pp. 221-227.
18. Plutzar C, A. Grübler, V. Stojanovich, L. Riedl and W. Pospischil (2000). 'A GIS-bsed Approach for Modeling the Spatial and Temporal Development of Night-time Lights', in J. Stroble, T. Blaschke and G. Griesebner (eds.) *Angewandte Geographische Information sverarbeitung XII, Beiträge zum AGIT-Symposium Salzburg 2000.* Heidelberg: Wichmann Verlag.
19. Small C and J. Cohen (1999). 'Continental Physiography, Climate, and the Global Distribution of Human Population'. *Proceedings of the International Symposium of Digital Earth*. Beijing, China.
20. .Small C, V. Gornitz and J. Cohen (2000). 'Coastal Hazards and the Global Distribution of Population', *Environmental Geosciences*, 7, pp. 3-12.
21. Small C and T. Naumann (2002). 'The Global Distribution of Human Population and Recent Volcanism'. Http://www.ldeo.columbia.edu/~small/PopVol.html. (accessed May, 25, 2002).
22. Sutton P (2000). 'Census from Heaven: Estimates of Human Population Parameters Using Nighttime Satellite Imagery', Paper presented at Annual Meeting of the Association of American Geographers, Pittsburgh, Pennsylvania.
23. .Sutton P, D. Roberts, C. Elvidge and J. Meij (1997). 'A Comparison of Night-time Satellite Imagery and Population Density for the Continental United States', *Photogrammetric Engineering and Remote Sensing*, 63, pp. 1303-1313.
24. Tobler W, U. Deichmann, J. Gottsegen and K. Maloy (1995). The Global Demography Project, NCGIA Technical Report TR-95-6.
25. United States Bureau of the Census, Population Division, International Programs Center. *Global Population Database*. Distributed by CIESIN and available from http://www.ciesin.org/datasets/cir/gpopdb-home.html (accessed January 13, 2002).
26. United States Geological Survey (2002). *GTOPO30 Digital Elevation Model (Data File)*. Available from http://edcaac.usgs.gov/gtopo30/gtopo30.asp.
27. Wackernagel M and W. Rees (1996). *Our Ecological Footprint: Reducing Human Impact on the Earth*. Gabriola Island, British Columbia, Canada: New Society Publishers.
28. Watkins J. F and H. A. Morrow-Jones (1985). 'Small Area Population Estimates using Aerial Photography', *Photogrammetric Engineering and Remote Sensing*, 51, pp. 1933-1935.
29. Welch R (1980). 'Monitoring Urban Population and Energy Utilization Patterns from Satellite Data', *Remote Sensing of the Environment*, 9, pp. 1-9.

Globalisation, Business Outsourcing and Regional Development in India

A.C. Mohapatra
Department of Geography, North-Eastern Hill University, Shillong

India during post-1991 has been witnessing a rapid and widespread growth in the service sector especially in the IT and ITES (BPO) sectors. This sector has been growing at a CGR rate of 30-40 per cent a year. What implications this has in terms of regional economic development in India? Indications are that since the mid-eighties there have been fresh impetus on increasing regional economic disparities (6) — "divergence" is the norm. With economic deregulations of early nineties, the locational scene changed drastically responding to external economies of scale arising out of responses to the global (trade) relations as well as, the internal locational advantages, which favour broadly the western and southern states of the country. The paper intends to assess the locational shift in industrialisation in recent times and its profound implications on the regional economic development of India. The process entails (i) political fall-out in terms of lagging regions which cannot capitalise on the new technology and investments on service industries; (ii) large-scale migration of young manpower to employment opportunities in the fast growth regions; and (iii) accentuation of income differentials and social welfare standards. The difficulty in this exercise arises in terms of poor database on what has been going on for the past one and half decades. Still it is attempted to explore the scenario with available information on IT and ITES sectors with specific reference to employment generation and implications on regional economic disparities.

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Reduction of regional disparities, be it per capita income or other social indicators, has remained an important objective of Indian planning, right from the First Five Year Plan. However, with accentuated deregulation of the economy of the country from 1991, the character of planning has changed from "directive" to "indicative"; perhaps, more appropriately to "policy making". The implementation has been left to the realm of market forces, to "the hidden hand", for that matter. Unlike the 1950s or 60s, the State cannot be an instrument of industrial decentralisation; the public sector is no more the "temples of new India"; and thus, at least in the sphere of manufacturing, the State cannot promote (regional) economic justice by reducing economic disparities between regions of India, its avowed policy of half-a-century. Indeed, a number of studies indicate that 60s was the only time in the history of Independent India, regional disparities did come down (6,7).

Industrial Revolutions

Industrialisation of India cannot be viewed away from global industrialisations, though there may be time-lags as well as differences in the pace and impetus in industrialisation, even the implications. The First Industrial Revolution that started in Britain at the end of 18th Century and then spread to the rest of Europe, and then to the colonies 'rode on the wings of coal and reached out by the steam propelled railways'. Whereas the First Industrial Revolution rode on the wings of coal

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and railways, especially a European enterprise, the Second Industrial Revolution (1920s) that was based on organisational changes and scale economies, "rode on the wings of steel and motor car"—the Fordist Enterprise (or as some would prefer to call, Fordist Industrialism, or simply, Fordism), necessarily an American one (14). It lasted for half a century (till, early 1970s). The Third Industrial Revolution was about electronic technology, miniaturisation and consumer (white) goods; was visible in early 1970s but from unexpected quarters, Japan and other East Asian nations like South Korea, Taiwan etc. This revolution that lasted for two decades (probably, continues as Post-Fordist industrialisation) was largely based on "foot-loose" industries, seeking markets and consumers than natural resources. Electronic skills, designing and marketing skills were the defining principles with large cities as the bases of production and consumption as well. Global trade was important to its progress and prosperity. The new Industrial Revolution referred to as the Fourth Industrial Revolution started happening in early 1990s, and is not so much about production and sale of manufactures, but "production of services" catching on what is now referred to as the "quaternary sector"[1]—technology and skill education, R and D and service industries based on IT and communication technology (11). It started with the PC revolution in the early eighties (in the Silicon Valley, US[2]) and rapidly expanded to the telecommunication, integration of IT networks, satellite communication technologies, and the Internet that created enormous demand for skilled engineers and technocrats and also made it possible for large trans-nationals to cash on cheap skilled labour in many developing countries through "call centre services", Business Process Out-sourcing (BPO), and host of other technology-oriented services. Once more, "Leontief Paradox" became relevant. Developing countries like India, China, Brazil, Russia and many other East European countries (also, Israel) now export services in significant ways not to areas they are thought to have comparative advantage, but to highly skilled professional services to the West, especially the rapidly expanding businesses in the United States. Though, theoretically this revolution like the preceding post-Fordist, electronics revolution is foot-loose (can be located anywhere, or can be moved), and in practice, it has and will have profound implications for regional economic development, in many of the developing countries like India, China or Brazil. Clearly in the process, the lagging regions would lose out in the race.

The Fourth Industrial Revolution

In the last fifteen years or so, in India there have been dramatic changes in economic policies towards economic deregulation, scraping the 1956 Industrial Policy and what otherwise, is known as the "License *Raj*". And, nearly concomitant to these important policy changes in India, what apparently was happening in the outer-world, the "IT Revolution", more involving the "code writers", the "wire-men" and the "tele-communicators" along with hardware innovations and up-gradations. With a large pool of trained English speaking artisans of modernity, India took an early start in providing low-cost on-site code-writers and fixers (of services) to principally US clients and

[1] The term "quaternary sector" has been in currency for the past two decades to denote, essentially higher education, R & D, and other technology and scientific sectors

[2] Notice, The astronomical rise of Microsoft

quickly earned reputation of "quality". Within a decade, the industry grew at a rate of nearly 50 per cent per annum, compounded from a few million USD (service exports) in early nineties to currently over 10 billion and expected to reach 50 billion in another decade. Then, it was quickly realised by the clients to receive services at Indian bases that will be cheaper than their home country bases, cashing on satellite communication technologies and explosion in telecommunication access riding on the liberalised licensing regime and falling costs of telecommunication. Other services like medical transcription, accounting back offices and banking, customer calling services, consultancies etc., were added and grew fast indeed, providing substantial employment opportunities to young skilled professionals, from an "unending pool of surplus labour" of India. This had multipliers in other sectors too, particularly in the electronic media industry and entertainment industry.

Undoubtedly, all this is very good for the country as a whole. However, there arose significant increases in concentration of incomes, between the rural and the urban at one hand, and between incomes accruing to the old-economy and the new (service) economy[3]: but most significant for our point of view; is this situation neutral[4] to location and regional economies?[5]; theoretically, IT services are supposed to be location neutral, therefore footloose; but in practice there appears strong agglomeration economies and (skilled) labour locations, especially locations with a head-start, like Bangalore, Chennai, Hyderabad, Pune-Mumbai and to a limited extent in Delhi region. Most beneficiary regions are in the Western and Southern India, and the least affected by these new service industries is the Eastern and North Eastern regions and also the North-Central regions of Madhya Pradesh, U.P. and Bihar (including Jharkhand). Though no clear data in this regard is available, it would be safe to assume that in this service sector revolution, probably 80 percent of enterprises and employments are located in the west and the south. The medium term forecast would be only for a further regional concentration of the service industries and "divergence" of regional incomes, due to differential rates of SDP growth and service sector employment growth.

As pointed out earlier, the industrialisation of the fifties and the sixties did diversify and decentralise manufacturing in India and led to some reduction in regional income inequalities. During the seventies, regional inequalities started growing again, but entirely from a different logic; the highly regional centred "Green Revolution" created widening of SDP growth rates between the agriculturally progressive and lagging regions (8). During the recent times (from early nineties) the process of accentuation of regional income disparities has continued, partly emanating from the "liberalised economic regime" (6) and the forces of the "hidden-hand", and partly, as we would ascribe to the (Quaternary) Service Sector Expansion (or Revolution).

Empirical Analysis

A database of around 670 companies

[3]Like cosmetics the demand responses to prices works in the reverse way. People prefer to go to the most expensive doctors, or lawyers, further pushing up their prices; governments prefer to hire the most expensive consultants, so also dinners to most expensive restaurants if not for quality of food but for fad and the brand. This may be true for the IT services, where price does not matter—though hard wares are price sensitive like any other commodity.

[4]Transport cost is distance neutral, if not zero.

[5]External economies of scale arising out of closer physical proximities, (locations), knowledge and skill spread-effects

(including the Public Sector Enterprises, PSE) was used (based on CMIE and other sources including the Annual Reports filed by the companies) for 1999-2000 to 2002-03, especially keeping in view of the employment generated, sectoral classifications and regional locations.

As seen from Table 1, 70 per cent of all enterprises are located in the western and southern regions and the North Eastern and the Central regions are the least industrialised accounting for less than 4% of the enterprises.

Table 1[6]

Overall Region-wise Location of Enterprises

Regions	No. of Enterprises	Per cent
North Eastern Region	4	0.60
Eastern Region	81	12.13
Southern Region	177	26.50
Central Region	20	2.99
Western Region	289	43.26
Northern Region	97	14.52
Total	668	100.00

[6]Location refers to HQ of the companies. There is no location database by factories/ establishments available.
North East Region: Assam, Arunachal, Meghalaya, Manipur, Tripura, Nagaland, Mizoram & Sikkim
Easternn Region: West Bengal, Orissa, Jharkhand, Bihar
Southern Region: Adhra Pradesh, Tamil Nadu, Pondicherry, Andaman & Nicobar Ils, Kerala & Karnataka
Central: Chattishgargh, Madhya Pradesh and Uttar Pradesh
Western Region: Goa, Maharshtra, Gujarat and Rajasthan
Northern Region: Uttaranchal, Delhi, Haryana, Punjab, Himachal Pradesh and Jammu & Kashmir

As indicated from Table 2, the Eastern Region (Calcutta) and the Western Region (principally Mumbai) dominated the industrial scene of India prior to 1951 (i.e, around the pre-Independence time). The Southern region barely had any presence. During the first decade (1951-61) the presence of the South and the West increased sharply as against the East and North.

Table 3 indicates the regional location of enterprises, broadly in three periods, i.e., 1951-81, a period characterised by continuation of Fordist enterprises; 1982-91 characterised by a transitional phase; and 1992-2002, by post-Fordist enterprises, which is the period of economic deregulation and de-licensing of enterprises. Clearly, the influence of the Eastern Region declines from 13.55 per cent in 1951-81 to 7.89 per cent during the 1992-02, whereas the importance of the South and the West grows to over 70 per cent.

Table 2

Regional Distribution of Enterprises by Year of Incorporation

Year / Region	North East Region	Eastern Region	Southern Region	Central Region	Western Region	Northern Region	Total
Before 1955	10	12	1	0	12	1	26
1951-1961	0	12	26	0	46	12	97
1962-1971	0	9	17	1	31	14	72
1972-1981	2	17	28	1	46	18	112
1982-1991	0	12	57	10	84	32	195
1992-2002	2	9	37	7	45	16	116
Unspecified	0	10	11	1	25	4	51
Total	4	81	177	20	289	97	668

Table 3

Region-wise Location of Enterprises by Periods of Incorporation

Regionwise locations	1951-1981		1982-1991		1992-2002	
	No. of Com. Incorp.	%	No. of Com. Incorp.	%	No. of Com. Incorp.	%
North Eastern Reigion	2	.80	0	0	2	1.75
Eastern Region	34	13.55	12	6.15	9	7.89
Southern Region	67	26.60	57	29.23	37	32.46
Central Regrion	1	.40	10	5.13	7	6.14
Western Region	106	42.23	84	43.08	44	38.60
Northern Region	41	16.23	32	16.41	15	13.16

Table 4

Incorporation of Enterprises by Industry Groups

Industry Type	1951 - 1881		1982 - 1991		1992 - 2002	
	No. of companies incorporated	%	No. of companies incorporated	%	No. of companies incorporated	%
Biotech	3	1.36	3	1.68	1	0.92
Builders	0	0.00	0	0.00	1	0.92
Chemical	38	17.27	21	11.73	3	2.75
Consultancy	1	0.45	3	1.68	1	0.92
Energy	14	6.36	2	1.12	3	2.75
Electronics	1	0.45	3	1.68	0	0.00
Engineering	49	22.27	40	22.35	9	8.26
Finance	0	0.00	2	1.12	0	0.00
Food	14	6.36	4	2.23	12	11.01
Home Products	2	0.91	2	1.12	0	0
IT	1	0.45	11	6.15	25	22.94
IT Communications	9	4.09	15	8.38	13	11.93
Manufacturing	16	7.27	12	6.70	8	0
Mineral	30	13.64	18	10.06	5	4.59
Motor	5	2.27	6	3.35	0	0
Oil Products	1	0.45	0	0.00	1	0.92
Personal Care	7	3.18	10	5.59	7	6.42
Petro-chemical	6	2.73	10	5.59	7	6.42
Pharma	7	3.18	9	5.03	8	7.34
Printing and Publishing	1	0.45	1	0.56	0	0.00
Textiles	15	6.82	7	3.91	5	4.59
Total	220	100.00	179	100.00	100.00	100.00

Table 5
Employment by Industry Groups (2000 to 2003)

Industry Group	2000	2001	2002	2003	% Change 2000-04*
IT**	22989	49921	42162	50880	121.32
Food/Beverage	83894	109993	173243	166826	98.85
Textiles	103802	94477	209423	197605	90.37
Pharmaceutical	25603	32323	39714	40546	58.36
Biotech	2280	1870	3447	3581	57.06
Personal Care	13426	14688	17500	17280	28.71
Consultancy	1630	1874	2563	1899	16.50
Manufacturing	67477	68497	71043	77822	15.33
Mineral	634736	564459	762379	729064	14.86
Electronics	14951	14291	13722	13996	-6.39
Engineering	251574	217690	2262211	231803	-7.86
Petro-chemical	53498	52823	226211	46990	-12.16
IT Communication	49155	43751	44279	42871	-12.78
Automobile	65465	59276	48192	54021	-17.48
Chemical	90626	75659	76853	74129	-18.20
Energy	283194	316273	186458	180669	-36.20
Total	1764300	1717865	1979119	1929982	9.39

* The yearly data refers to FY ending to that given year, generally by March 31, but for some companies June, September or December, may be the end of the FY.

** IT does not include BPO and ITeS for which no reliable emplyment data base as yet, though these segments are gaining importance.

Table 4 indicates a broad grouping of the enterprises into types of industries during the said three phases of industrial development of India. During the Fordist phase, engineering, chemical and mineral groups of manufacturing dominated; during the transitional phase, dominance of engineering still remained, though chemical and mineral groups somewhat declined. There was some presence of IT and tele-communication, but was still marginal. During the post-Fordist phase (the last decade), IT and tele-communication emerged the largest and strongest groups, 22.94 and 11.93 per-cent, respectively. Pharmaceuticals, petro-chemicals and personal-care groups assumed importance, whereas the traditional chemical, engineering and mineral groups declined in importance.

Employment figures were available (some companies estimated) for the past four financial years (2000, 01, 02 and 03), ending at March 2000 (and in other cases ending in June, September or December)[7]. Table 5

[7]It may be noted that under the Indian Company's Act, whereas it is mandatory to file the Annual Statement with SEBI and other agencies, filing employment figure is not mandatory

Table 6

Wages and Salary Costs and Employment in Industry Groups (2000-2003)

Industry Groups	2000		2001		2002		2003	
Industry	W/Sal. Cost*	%**	W/Sal. Cost*	%	W/Sal. Cost*	%	W/Sal. Cost*	%
Biotech	39.36	0.12	22.16	0.06	58.81	0.15	65.82	0.15
Chemical	1809.1	5.65	1881.35	4.88	1881.73	4.68	2035.10	4.66
Consultancy	38.05	0.12	45.56	0.12	45.62	0.11	51.62	0.12
Electronics	343.34	1.07	397.07	1.03	366.87	0.91	370.55	0.85
Energy	6009.65	18.78	7772.49	20.18	7221.53	17.95	8044.05	18.43
Engineering	4654.05	14.55	5772.85	14.99	5058.49	12.57	5417.77	12.41
Food/Beverage	1039.31	3.25	1126.41	2.92	1226.94	3.05	1299.45	2.98
IT	960.88	3.00	2046.45	5.31	3052.60	7.59	3909.46	8.96
IT Communication	925.12	2.89	923.29	2.40	1015.10	2.52	1011.80	2.32
Manufacturing	1215.96	3.80	1340.57	5.48	1305.56	3.24	1481.95	3.40
Mineral	10437.98	32.63	12097.39	31.41	13593.95	33.78	14233.53	32.61
Automobile	1126.16	3.52	1231.61	3.20	1287.50	3.20	1364.96	3.13
Personal Care	250.2	0.78	266.92	0.69	312.64	0.78	344.41	0.79
Petro-chemical	1082.81	3.38	1305.79	3.39	1525.97	3.79	1502.02	3.44
Pharmaceutical	487.97	1.53	663.69	1.72	818.01	2.03	962.57	2.21
Textiles	1572.79	4.92	1623.42	4.21	1469.54	3.65	1547.66	3.55
Total	31992.73	100.00	38516.62	100.00	40240.84	100.00	43642.72	100.00

* in Rs. Crores in current prices

** Percentages of all industries

shows the year-wise and industry-group-wise employment figures for the four recent years. Within the three-year period maximum increase in employment was found in IT sector followed by sectors of food processing, textiles, pharmaceuticals and biotech. The marginal decline in sectors like petro-chemicals, telecommunication and automobile sectors may be due to restructuring and reassignment of sectoral employment.

Table 6 shows the yearly wages and salary costs and employment by industry groups and the percentage share by industry groups for the available data for the largest 677 reporting

Table 7
Industry Groups by Periods of Incorporation

Ind. Group	Unspecified	< 1951		1951-1961		1962-1971		1972-1981		1982-1991		1992-2002		Total
	No.	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
1.	0	0	0.00	0	0.00	1	1.39	0	0.00	3	1.51	1	0.83	5
2.	0	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.83	1
3.	1	2	7.69	11	11.46	11	15.28	16	14.16	20	10.05	3	2.50	64
4.	0	0	0.00	0	0.00	0	0.00	1	0.88	3	1.51	1	0.83	5
5.	1	1	3.85	7	7.29	3	4.17	4	3.54	2	1.01	4	3.33	22
6.	0	0	0.00	1	1.04	0	0.00	0	0.00	3	1.51	6	0.00	4
7.	7	5	19.23	26	27.08	16	22.22	25	22.12	40	20.10	9	7.50	128
8.	0	0	0.00	0	0.00	0	0.00	0	0.00	2	1.01	2	1.67	4
9.	3	5	19.23	5	5.21	2	2.78	8	7.08	4	2.01	12	10.00	39
10.	1	0	0.00	1	1.04	0	0.00	1	0.88	2	1.	0	0.00	5
11.	0	0	0.00	0	0.00	1	1.39	0	0.00	0	0.00	0	0.00	1
12.	0	0	0.00	0	0.00	0	0.00	1	0.88	11	5.53	25	20.83	37
13.	1	0	0.00	5	5.21	1	1.39	5	4.42	15	7.54	13	10.83	40
14.	10	2	7.69	15	15.63	7	9.72	5	4.42	11	5.53	8	6.67	58
15.	5	4	15.38	10	10.42	8	11.11	14	12.39	18	9.05	5	4.17	64
16.	0	1	3.85	3	3.13	1	1.39	2	1.77	6	3.02	1	0.83	14
17.	0	0	0.00	1	1.04	0	0.00	1	0.88	0	0.00	1	0.83	3
18.	0	2	7.69	1	1.04	2	2.78	4	3.54	10	5.03	7	5.83	26
19.	0	0	0.00	1	1.04	5	6.94	0	0.00	11	5.53	7	5.83	24
20.	2	0	0.00	3	3.13	2	2.78	1	0.88	9	4.52	8	6.67	25
21.	0	0	0.00	0	0.00	1	1.39	0	0.00	1	0.50	0	0.00	2
22.	4	4	15.38	1	1.04	6	8.33	9	7.96	7	3.52	5	4.17	36
23.	16	0	0.00	5	5.21	6	8.33	3	11.50	21	10.55	9	7.50	70
Total	51	26	100.00	96	100.00	72	100.00	113	100.00	199	100.00	120	100.00	677

enterprises. It may be noted that the mineral processing sector is still the largest, followed by employment in engineering group (12%), energy (around 10%, on a decline mode), and textiles (10%). But, employment, as indicated earlier in IT, telecommunication, pharma etc., are fast getting significant in overall employment scene, though still hovering around 3% each. Table 7 provides a periodisation of number of enterprises in industry groups and percentages for all the 677 enterprises from prior to 1951 till 2002.

As pointed out earlier, the industrialisation of the fifties and the sixties was characterised by diversified and decentralisation in manufacturing industries, leading to a decline in regional income inequalities to some extent. During the seventies, regional inequalities started growing largely due to the highly regionally-centred "Green Revolution" that widened SDP growth rates between the agriculturally progressive and lagging regions (8). The process of accentuation of regional income disparities continued in 1990s partly due to, "liberalised economic regime" (6), the forces of the "hidden-hand" and partly, the (Quaternary) Service Sector expansion. It appears that the regional income disparities and employment opportunities may get accentuated further between the Western and Southern states and those of the East, Central, North-Eastern states of India.

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References

1. Bagchi A.K (1975). *Private Investment in India (1900-1939).* Mumbai: Orient Longman.
2. Chattopadhyay B and Moonis Raza (1975). `Regional Development: Analytical Framework and Indicators', *Indian Journal of Regional Science* 7(1), pp.1-35.
3. Hobsbwm Eric J.E (1968). *Industry and Empire.* London: Penguin.
4. Krugman P (1991). *Geography and Trade.* Leuven: Leuven University Press.
5. Mathur A (1983). `Regional Development and Economic Disparities in India: A Sectoral Analysis', *Economic Development and Cultural Change, 31(1).*
6. Mathur A (2003). `National and Regional Growth Performance in the Indian Economy: Sectoral Analysis', in A.C.Mohapatra and C.R.Pathak (eds.). *Economic Liberalization and Regional Disparities in India.* Shillong: Star Publishing House, pp. 1-41.
7. Mohapatra A.C (1978). `An Alternative Model of Measuring Divergence-Convergence Hypothesis: A Study of Regional Per Capita Incomes in India', *Indian Journal of Regional Science,* 10(2), pp.39-50.
8. Mohapatra A.C (1982). *Regional Inequality in India (1960-61 to 1978-79).* Shillong: North Eastern Hill University (Unpublished Ph.D Thesis)
9. Mohapatra A.C and J. Dey (2002). `Location, Economic Growth and Trade: Revisiting Economic Geography of South Asia', *National Seminar on Globalisation, Trade and Economic Development of North-Eastern Region of India,* Shillong, November 21-23, 2002 (forthcoming seminar proceeding).
10. Mohapatra A.C and C.R Pathak (eds.)(2003). *Economic Liberalization and Regional Disparities in India.* Shillong: Star Publishing House.

11. Mahopatra A.C (2006). `The Fourth Revolution: Industrial Location and Regional Development in India - Implications for the Eastern India', in P.M. Passah (ed.). *In Defence of Regional Economic Development of India. A Case for the North East.* New Delhi : Akanshya Publishing House, pp. 137 - 148.

12. Munshi S.K (1981). `Evolution in Concepts and Practices in Region Formation in India', *Annals of the National Association of Geographers, India*, 1(1), pp.18-28.

13. Nair K.R.G (1982). *Regional Experience in a Developing Economy*. New Delhi: Wiley Eastern.

14. Nicolas A. Phelps (2002) `When was Post-Fordism? The Uneven Institution of New Work Practices in a Multinational', *Antipode*, 34(2), pp. 205-226.

15. Sengupta P and G. Sdasyuk (1968). *Economic Regionalisation of India*. New Delhi: Census of India (Monograph No. 7).

Segregation, Concentration and Integration

Critical Reflections on Policies and Perceptions

Sako Musterd & Wim Ostendorf
Department of Geography, Planning and International Development Studies
University of Amsterdam, Amsterdam, The Netherlands

Over the last decades, segregation, concentration and integration have become widely discussed concepts in literature as well as in society. Segregation and/or concentration are often seen as a problem because it is assumed that there is a negative association with integration. In this discussion it has become unclear what the concepts of segregation, concentration and integration really stand for. This paper tries to clarify these three concepts with the help of experiences in Dutch and European cities.

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Segregation, a concept initially used for the description of unequal spatial distributions of certain population categories, has, over the decades, developed into a metaphor, which is usually meant to express 'problematic' population compositions in certain areas. In political jargon the reference is to the spatial separation of people with and without opportunities to realise full participation in society. More recently and increasingly, however, debaters also directly refer to 'ethnic' segregation as a problem. The metaphoric use of the concept implies an increased fuzziness, which may also have contributed to the construction of the idea that the 'already dangerously high levels of segregation' are continuously increasing. The main reason to label the fuzzy concept of segregation as being problematic is related to the negative effects assumed to be associated with it. Certain levels of segregation (or homogeneity or concentration) would reduce the opportunities to participate and integrate in society at the required level. This is also the reason why national and local politicians tend to develop policies aimed at changing the population composition in certain neighbourhoods. But also many academics assume that segregation results in negative effects and therefore requires countering initiatives.

In this contribution we will discuss and reflect upon the perceptions, assumptions and policy responses with regard to segregation, concentration and integration of certain population categories. We will investigate the prevailing discourses with regard to these concepts and the dominant ideas about the relations between the concepts. This will be done with reference to Dutch and other European experiences and debates. In the sections to come we start with addressing the conceptualisation. We briefly go into theoretical ideas about which factors would produce segregation and concentration, as

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well as into the question about the effects of segregation and concentration on integration and levels of participation. Then empirical data are shown to illustrate actual levels of segregation and concentration and dynamics in European cities, with a special focus on Amsterdam when discussing concentration dynamics. The differences between cities will be interpreted referring to the theoretical framework presented. In the next section, we relate the segregation and concentration debate to issues of integration and present findings from European research aimed at measuring neighbourhood effects on the level of participation in society. Finally, the findings will be confronted with prevailing policy ideas regarding social and 'ethnic' (immigrant) spatial inequalities, and some conclusions will be drawn.

Concepts and Theories regarding Segregation, Concentration and Integration

Before we will investigate the relations between the concepts mentioned in the introduction, we will first pay attention to the conceptualisation proper. As familiar among segregation researchers, but not so much among those who are operating in other fields, *segregation* refers to the relative distribution of a population category across sub areas in a city relative to another population category or relative to the rest of the population. In discussions the focus usually is on social, or income segregation and 'ethnic' segregation. Frequently the Segregation Index is used to quantify the unequal spatial distribution (6). This index indicates the share of the population category that has to move to another sub area of the city in order to reach equal distribution. So, an index score of 0 means that there is no segregation, i.e. in every sub area of the city lives the same share of the category is considered. But an index score of 50 means that there is a substantial segregation: half of the category has to move to another sub area in order to reach a situation of no segregation at all. There is no necessary relation between the level of segregation and the share of a population category in the city as a whole. A population category with a share of only 3 per cent in the city can result in similar segregation index scores as a population category with a share of 30 per cent in the city; it just depends on the distribution over the sub areas of the city as equal or less equal. In the case of segregation of immigrant categories it is important to realise that immigration does not per se result in increasing segregation. Often it will, but only if the newcomers settle in the sub areas where already many immigrants live; if the newcomers would settle in sub areas that had no immigrants so far, the index score will even go down, despite the immigration.

The concept of *concentration* refers to a different situation in which the share of the population category in the city in fact is important. However, this is once more an unclear concept in its wider use. Concentration refers to those areas that show a serious share of a certain population category. Of course the term serious does not accurately indicate a precise share. In fact opinions on what is a serious share do differ and can change over time. In some cities a share of 20% immigrants in a neighbourhood can be considered as a concentration; in other cities with many immigrants a share of 30% may not be seen as a concentration. However, while

segregation refers to relative numbers (small population categories can have a very high segregation) and expresses the level for the entire urban system under consideration, concentration also refers to absolute numbers and often is used with reference to single spatial units within the urban system. An increasing share of a certain population category in the city, say immigrants, will increase the chance that a neighbourhood will show a concentration by passing the relevant threshold of, for instance, 30%. Another difference is related to the spatial patterns. Since adjacent areas may or may not show serious shares of the same population category, concentrations may be in larger combined areas or in small areas. So, immigrants for instance can have a high segregation and can live in different parts scattered over the city. But they can also live in a particular part of the city, for instance, in the western part, where all or many neighbourhoods show a serious concentration.

In practice the concepts just described are mixed up with each other. A rising share of a certain population category in the city may already result in perceptions and statements about increasing segregation, which is not necessarily true, or about increasing concentration, which is not necessary either. Also, increasing concentrations are often interpreted as increasing segregation, whereas this may not be true if in situations of an increasing share of the population category in the city the relative spatial distribution of this category remains unchanged. In many debates about segregation effects, it is generally argued that effects are expected to get related to certain sharing of and absolute levels of a population category in neighbourhoods in the city. Despite the frequent use of the word segregation, it is frequently referred to mean concentrations.

The concept of *integration* is perhaps even more complicated. This refers to all spheres of life: the economic, social, political and cultural domains are involved. A practical operational form to measure integration is through participation in the labour market, in education, in politics, in social networks and in cultural dynamics. Inter-generational measurements may or may not reveal stronger integration over time. A common view is that the economic sphere is the most important and that economic success will encourage other spheres to follow. However, others believe that spheres as the social and cultural domains are not dependent, but independent instead; that social and cultural integration can go down, even in situations when economic integration is increasing. Such a view is confusing in particular for people who believe that economic success will result in complete integration in all spheres of life. Apart from this, the concept of integration is also used in different and more implicit meanings, which seem to be based in resentment. In those contexts the concept seems to be reduced to a call for rapid social and cultural assimilation. Expressing that there is a lack of integration, then, is regarded to be similar to saying that 'the other' is insufficiently behaving 'like us'.

If there would be a significant relation between segregation and concentration on the one hand and integration on the other, a theoretical interpretation of that relation would have to support these insights. In terms of intervention strategies it would also be

helpful to know what kind of factors, according to the literature, are supposed to determine different levels of segregation and concentration. Many politicians believe that a change of housing stock may change the levels of segregation and concentration. Does that idea match the theoretical knowledge that is available?

Starting with various theoretical interpretations (structural, behavioural, institutional) for the variation in factors that influence segregation and concentration it can be argued that there is no simple relation between these spatial outcomes and housing stock change. If we try to understand urban inequality in European cities, interpretations must include references to globalisation and economic restructuring processes. These processes might induce more polarised urban populations, declining middle classes (19), increasing numbers of low skilled unemployed (21), mismatches in terms of skills demanded and skills supplied, and the resultant increase in social inequality, which eventually could also be expressed in terms of spatial inequality. However, not just globalisation and economic restructuring should explain segregation and inequality. Many cities experience more or less similar globalisation and economic restructuring processes; yet, these places do not all show similar trends in segregation and concentration processes. Inequality may be filtered or reduced in some contexts. The educational system and the attraction power of cities might result in a rapid change of the professional structure. That structure is not necessarily polarised (11). The (spatial) mismatches in terms of the demand and supply of certain new skills may also be reduced through better transportation opportunities. The intervention power of specific welfare states and the institutional structures that are associated with them may also provide substantial input for either an increase or a reduction of social inequality and thus impact upon the segregation and concentration outcomes (15). Here we have to think about the level of redistribution of wealth, intervention in the health system, housing market and education, labour market access and exit opportunities, for example. Again others have asked attention for differences in terms of social and cultural capital, which may exist between cities and which may influence labour market opportunities and thus social inequality. Finally, the historically grown urban and social structures may or may not be helpful in catching up with the actual changes in society. The local, the place, seems to have gained a stronger role over recent years in understanding urban change due to the fact that other relevant factors in the spheres of mobility and (telecommunications and other) connections are available now almost everywhere and therefore not differentiating dimensions any more. The different economic opportunities Amsterdam and Rotterdam are experiencing today, and the different impact that has on social and eventually also on spatial inequality in these cities, may be partly ascribed to the different urban histories of these cities. Both cities are part of the same national institutional system. Yet Rotterdam seems to be hindered by its stronger manufacturing past, whereas Amsterdam seems to profit from a past that was characterised by trade, finance and services; higher unemployment of under-skilled inhabitants in Rotterdam, but a more polarised post-industrial job structure in Amsterdam seem to be associated with that (3).

Segregation patterns and specific concentrations of certain population categories must be interpreted referring to these different backgrounds. Social inequality will differ along with them. An important and classic insight is that the social spatial patterns are primarily reflections of social inequality in society. The sorting processes are very strong. Segregation and concentration patterns are thus primarily related to the social inequality in general and of the drivers behind that. There is, however, also a cultural factor, which may stimulate both mentioned processes. The literature tells us that especially in the initial phases of entry in new cities, immigrants tend to form enclaves or colonies. They function as a port of entry with sufficient support systems available, and often are a springboard to the wider society (2). Some share the idea that these enclaves develop into ghettoes, whereas others believe they will finally disappear. One reason for a persistent existence of these 'ethnic' neighbourhoods may be that continuous negative experiences in the outside world drive immigrant categories together in neighbourhoods where they can be themselves and where they can escape from xenophobic reactions in the wider world. The French integration specialist Hamida Ben Sadia recently expressed this fear in an interview with a Dutch newspaper (NRC 29 July 2004) in relation to the alarming 'Muslim reports' the French authorities published. These reports address the 'radicalisation' of Muslims in poor neighbourhoods. She argues that these reports tend to blame all Muslims and that they stimulate, instead of helping to reduce segregation, exclusion, stigmatisation and discrimination.

Theoretical considerations with regard to the factors producing segregation and concentration are relevant; but there should also be theoretical ideas about the mechanisms through which segregation and concentration impact upon integration and levels of participation. In the literature on neighbourhood effects there appears to be some consensus that population compositions of neighbourhoods may impact on individuals in these neighbourhoods via at least three mechanisms: socialisation processes through which commonality of norms may be reached, which is particularly relevant with regard to norms and attitudes towards things like the valuation of work and educational level (21); stigmatisation and the internal and external perception of places as deviant places connected with crime, disorder, physical and social decay, which may have effects on the labour market access opportunities; and social networks where social ties and inter-relationships provide role models and contacts that help to access the wider society (7,8). Tests of elements of these theoretical ideas did not result in unanimous support (9,10). Self-selection processes in neighbourhood change may hide that individual and not neighbourhood characteristics play a major role. There is only limited empirical support for the stigmatisation idea; however, this does not imply that stigmatization is irrelevant. Finally, research has shown that spatial proximity does not necessarily lead to more contacts and exchanges between social categories (1). On the contrary, highly mixed neighbourhoods may even reproduce or reinforce social distance. On the other hand, large concentrations might result in more social interactions between people from the own category and in less social interactions with others, as was in relation to immigrant

and ethnic groups demonstrated for the Dutch case by Dagevos (4) and van der Laan Bouma-Dof & van der Laan Bouma (13). Based on such findings many people fear that social integration might influence economic integration and integration in other spheres of life. In the process of integration, economic success is then not seen as the independent factor, but as the dependent factor instead. But in a certain way concentration might result in a city that does not function as a whole, but much more as an archipelago of different social worlds. Therefore such a situation is often criticized and combated via urban policies. However, the impact of concentration on social interaction is only limited. The Dutch authors just mentioned, for instance, could not show that a diminished interaction with others did result in less economic success. In other words, more research is needed in order to understand better the relations between the different domains of integration.

Segregation and Concentration in a Few European Cities

In a recent overview of levels of 'ethnic' and socio-economic segregation, Musterd (14) has shown a wide variety of segregation levels in European cities. Some examples are presented here. Segregation of immigrants and 'ethnic' groups clearly differs between states, cities and categories. Levels of 'ethnic' segregation (Table 1) appear to be low in German and French cities, but also in Norwegian and Austrian cities such as Oslo and Vienna, and are higher in UK cities and Brussels. Dutch cities reach average segregation levels. The comparison also shows clear differences between cities within a country. Higher segregation levels can be found in Oldham than in London and Manchester; in the Netherlands, higher levels can be found in The Hague compared to Amsterdam. In addition there are important differences between population categories. In UK cities,

Table 1
Scores on the Index of Segregation; Various Population Categories in Various European Cities (1990s), Wards, Neighbourhoods, Small Urban Districts

Frankfurt Turks	19
Milan non-Italian	20
Milan non-Italian	23
Paris Algerians Dept. 75	23
Rotterdam Surinamese	26
Oslo 3rd world immigrants	29
Vienna Immigrants	30
Düsseldorf Turks	30
Amsterdam Surinamese	34
The Hague Surinamese	39
Oldham Black Caribbean	39
Amsterdam Moroccans	41
Rotterdam Moroccans	44
London Black Caribbean	45
The Hague Moroccans	49
Manchester Black Caribbean	51
Stockholm Iranian 14 municip	58
Brussels Moroccan	59
London Bangladeshi	63
Manchester Bangladeshi	63
Oldham Bangladeshi	75

Source : Musterd (14)

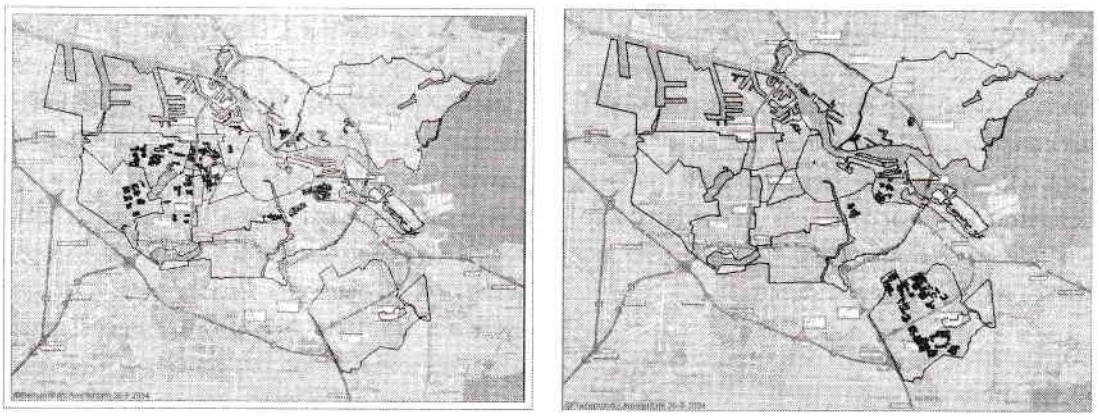

Fig. 1
Concentrations of Moroccans (left) and Surinamese (right) in Amsterdam, 2004; > 2 sd above the mean

Source: City-Monitor. Department of Geography, Planning and International Development Studies, Universiteit van Amsterdam; and Department of Research and Statistics, Municipality of Amsterdam

Bangladeshi appear to be much more segregated than Black Caribbean; In the Netherlands Moroccans show somewhat higher levels of segregation compared with Surinamese.

Concentration levels and dynamics in terms of concentrations can be illustrated with data from the so-called Amsterdam City Monitor. That monitor allows for the construction of concentration areas of a specific population category, starting from very detailed spatial data (six digit postcode data); concentrations are pulled together if they are adjacent. Examples are provided for Moroccans and for Surinamese, in 2004 (Fig. 1) and information on the dynamics in concentrations are presented for the entire period between 1994 and 2004 in Fig. 2. The graphs show us that clear concentrations of Moroccans and Surinamese can be found. However, one should not be misled by these graphs, which may suggest the existence of enormous concentrations of these population categories. Fig. 2 reveals that in 2004 the share of Moroccans in Moroccan concentrations reached a level of 31 per cent; the share of Surinamese in Surinamese concentrations is 34 per cent. In 2004, 56 per cent of all Moroccans who were living in Amsterdam, lived in one of the Moroccan concentration areas, against 35 per cent of all Surinamese living in Surinamese concentrations. The dynamics with regard to these population categories are different as well. The share of Moroccans in the city rose between 1994 and 2004 from 6.4 to 8.5 per cent, a 34 per cent increase; the share of Moroccans in Moroccan concentrations increased from 24 per cent to 31, which is a 27 per cent rise. For Surinamese a slight increase in the city can be shown (3 per cent), but a slight decrease of the share of

Surinamese in Surinamese concentrations (-2 per cent). The percentage of all Moroccans living in Moroccan concentrations rose with 6 per cent; for Surinamese this figure is plus 1 per cent. Overall, the geographical patterns concerning Moroccans are rather unstable, whereas the Surinamese patterns do not appear to change that much.

Comparative research on socio-economic segregation is even more difficult than comparing segregation of 'ethnic' groups. The various definitions that are applied and the differences in data availability just allow for some very crude conclusions. Some data have been put together in Fig. 3. A clear group effect can be shown as far as segregation levels are concerned, with differences between rich and poor. Socio-economic segregation levels tend to be relatively high for the highest social classes. They are best able to separate themselves from the rest of the population. Lower levels of segregation are shown for lower social classes. That also implies, at least for the European cities shown here, that people with a relatively weak social position do not tend to be detached from middle class residents and that there is much social mix in many European cities. The poor and the middle-class are still within the same system. However, the generally low levels of segregation of the poor do not imply that there are no differences at all. Levels are very low in Copenhagen, Bern and Berlin but rather high in Antwerp. Apart from that it is interesting that there are clear differences between cities

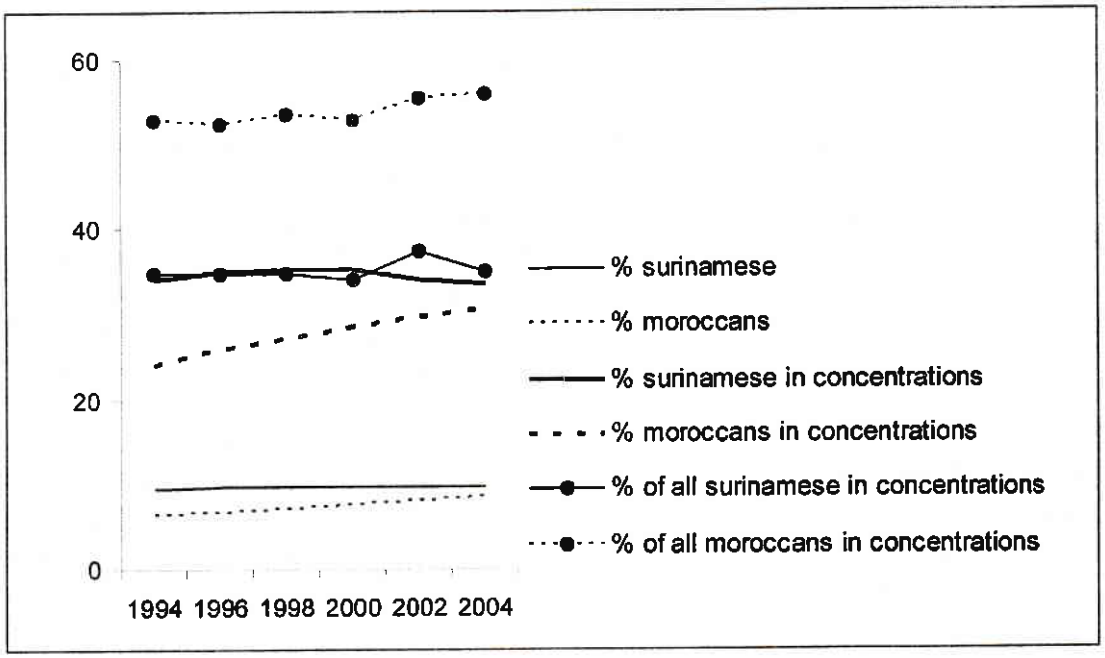

Fig. 2 Surinamese and Moroccans in Amsterdam: Shares, Percentage in Concentrations, Percentage of the Category in Concentrations

Source: City-Monitor. Department of Geography, Planning and International Development Studies, Universiteit van Amsterdam; and Department of Research and Statistics, Municipality of Amsterdam.

within one state as well: unemployed people are less spatially segregated in Manchester compared to Leeds and Birmingham.

How can these differences be interpreted? Urban dynamics and geographical inequalities in European cities are first of all related to ongoing globalisation processes and related economic restructuring. However, these processes obviously do not affect each city in the same way. Some cities appear to be able to adapt to new circumstances very rapidly, whereas others seem to be hindered by their past. The historical paths cities have followed seem to explain, at least to some extent, the different levels of economic success in the current era. This has had implications for segregation as well. Apart from these city level-related urban histories, there are state level differences too. Some states have developed a strong filter, through which inequalities that were triggered by the economic restructuring were reduced; some states did not.

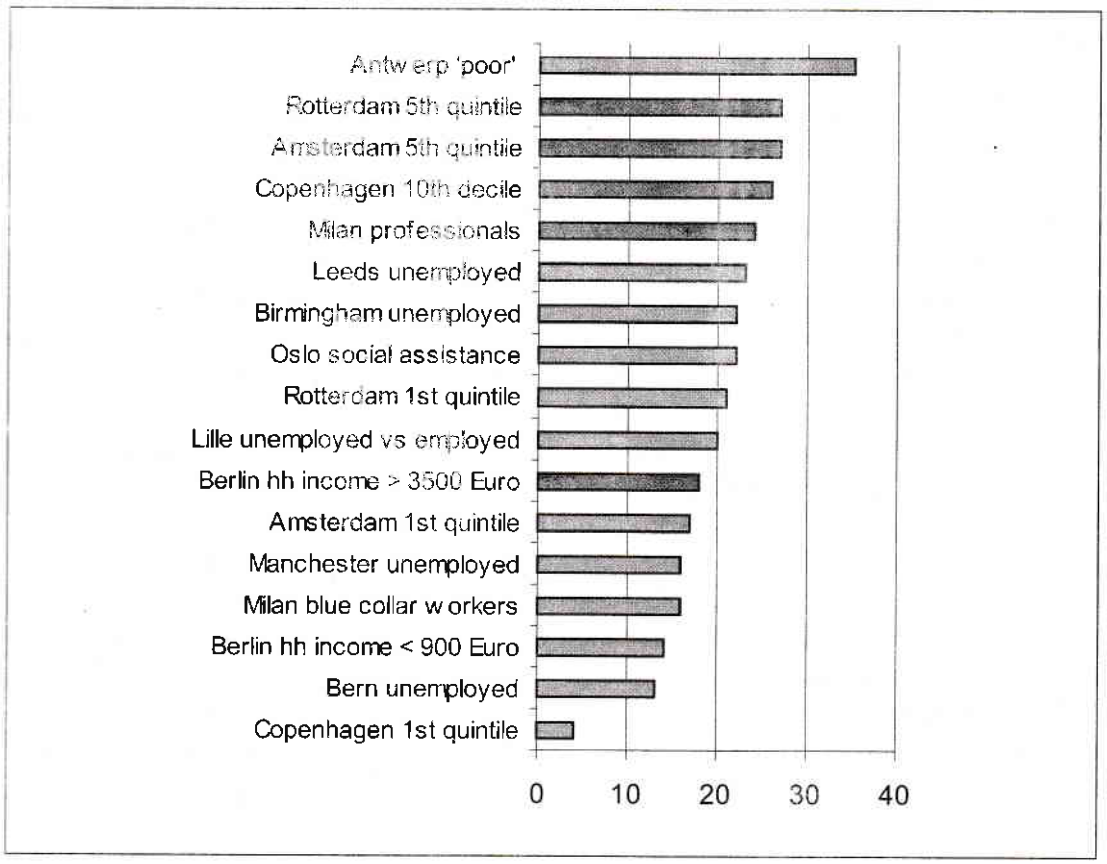

Fig. 3
Socio-economic Segregation; Various Population Categories in Various European Cities (1990s), Wards, Neighbourhoods, Small Urban Districts

Sources: Musterd (14)
Grey is low status; Black is high status

In addition to these explanations in which was referred to macro-level processes of globalisation and economic restructuring, to state-level impacts of the welfare state, including policy attitudes towards certain 'models' of integration (multicultural, assimilationist), and to city-level impacts of urban histories (path dependency) there should also be some attention to group-level impacts of cultural differences. Different segregation levels for different population categories may be ascribed to different attitudes and to different identities these categories have. Ceri Peach (1999), for example, interpreted the different levels of segregation between Blacks and Bangladeshi in terms of different attitudes towards the rest of society. Bangladeshi turned out to search for relations with people from their own origin much more and more persistently than Blacks did. Another example refers to the Surinamese in Dutch cities. Due to the colonial past they spoke Dutch already and they were heavily influenced by Dutch culture way before they settled in The Netherlands. Consequently, their segregation and concentration patterns show more moderate levels compared to those of Moroccans, who brought with them more cultural differences. However, in this debate it is extremely important to consider the differences between generations as well. Differences between younger generations tend to be smaller than between older generations; therefore uncontrolled comparisons blur the understanding.

In short, 'ethnic' segregation levels are lower where cultural distances between the categories are smaller. Social spatial segregation levels are lower where social distances (social inequality) are smaller. Welfare state models that are characterised by strong redistribution regimes may play a big role to lower social segregation.

Segregation and Integration and Neighbourhood Effects

As was already noticed in the introduction of this paper, there is a firm belief that segregation and concentration in terms of ethnicity and/or social position are tightly related to integration and participation opportunities in society. Socialisation processes, role models, stigmatisation practices and the quality of social networks would all help to support that belief. The basic assumption seems to be that urban social realities in which there is a high level of segregation, where strong spatial concentrations of specific population categories can be found, where it is difficult to escape from, would all result in blocking the interaction between population categories and would prevent social mobility of those who are living there. But this would – at least – require serious levels of segregation and concentration. That is not what was presented with regard to European cities. Generally, levels of segregation, both in the 'ethnic' and in the social spheres, are moderate and most 'ethnic' concentrations appear to be far from absolute. The scale on which 'ethnic' and social enclaves manifest themselves does not support the assumptions either. There may be some persistent concentrations of poverty and of specific 'ethnic' categories in some cities and occasionally that may cause serious problems with participation and integration (past and recent riots and tensions in cities such as Bradford, Antwerp and some French 'banlieues' are cases in point), but overall there are at most 'pockets of poverty' and just small and not absolute 'ethnic'

concentrations. It was, therefore, not a big surprise to find out in recent research, carried out in Amsterdam, that indicators of participation, such as unemployment levels and the level of education that could be obtained were clearly different for different 'ethnic' population categories, which show almost similar levels of segregation. Conversely, younger-generation immigrants who are showing different levels of concentration appear to have rather similar levels of participation in the sphere of education (13). Moreover, it is interesting to notice that children of immigrants, who are living in relatively similarly concentrated environments, are performing clearly better in terms of education and other participation indicators compared with their parents (4). In short, the logic of the neighbourhood effect does not appear to be very strong.

However, the analyses so far were just referring to the 'ethnic' dimension and were not designed to discover neighbourhood effects. Therefore, it makes sense to pay attention to research projects in which this objective has been put central. These projects regard studies in cities and contexts that have only moderately segregated cities in the first place: Sweden and The Netherlands, and which are known for their relatively strong welfare states and moderate social and socio-spatial inequality. Yet, the policy focus is based on the assumption that neighbourhood effects exist there too. We were able to use large-scale longitudinal datasets covering several millions of individuals who could be followed over time. In Sweden, analyses covered the entire population. Results are published in Musterd *et. al.* (16,17). The main objective of these analyses was to investigate whether the share of so-called socially weak households, living in the direct environment of an individual has impact on the social mobility opportunities of the individual. In other words: have neighbourhoods with a larger share of poor people, i.e. neighbourhoods with a larger concentration of poor people, more negative impact on opportunities for participating in the labour market, compared to neighbourhoods with a smaller share of poor people? We were able to construct these social environments for each individual and to 'follow' the individuals over a period of time (5 years in the Netherlands and 9 years in Sweden). The analyses could be carried out while controlling for relevant individual variables. The conclusion for the analyses with Dutch data was that there seemed to be virtually no neighbourhood effects on the social mobility for those who were in a relatively weak social position. This conclusion holds for analyses for the entire country, for the three large cities and for Amsterdam. In Sweden, however, a relatively clear effect could be found, even after controlling for the theoretically relevant variables, such as level of education, age, country of birth, urbanisation level, change in household situation and change in the urbanisation level as well as the change in strength or weakness of the environment they were living in themselves.

Several interpretations for the different outcomes in the Netherlands and Sweden can be provided, but these still have to be tested in future research. We believe that the most plausible hypothesis is that neighbourhood effects do exist in both contexts, even though levels of segregation, concentration and inequality are relatively moderate. The idea is that relative differences may be more

important than absolute differences. It is not an easy task to explain the neighbourhood effects, but a negative stigma of neighbourhoods with a high share of poor inhabitants may play a significant role. Moreover, the neighbourhoods with relatively high shares of poverty are also relatively mixed neighbourhoods (there are virtually no homogenous poor neighbourhoods). Social interaction in these mixed neighbourhoods tends to be problematic, though, because of social and cultural distances between inhabitants. Most likely, these inhabitants will not be inclined to support each other in finding a way out. This is a contradictory view relative to socialisation theory, which tells us that mixed neighbourhoods would have positive effects because they provide a large number of good role models. There does not appear to be empirical support for these ideas. Besides, the concentrations of poverty are usually rather small, which implies that good role models can also be found just around the corner. An explanation for the differences we found between the two countries may be that the Dutch have been relatively more successful in targeting problem categories in stigmatised areas and bringing people back into education and to the labour market, thus reducing the negative impacts of stigmatisation. This type of policy is as yet less well-developed in Sweden, due to the fact that several cities have been confronted with rapid influx of (lower income) immigrants with a relatively weak position much later than in The Netherlands.

Findings confronted with Dominant Policy Interventions and Dominant Perceptions: Some Conclusions

The still rather open question then is, what kinds of policy interventions are effective to reduce the negative effects of living in certain neighbourhoods and to enhance further integration in society? The current dominant response in Europe clearly is based on the philosophy that mixing the population is most adequate and preferable. Housing and social mix, usually through tenure diversification, frequently combined with demolition programmes, is regarded to be the best answer. Offering positive role models, using networks of the 'good examples' and reduction of negative stigmatisation through mixing, all of that would explain the preference for socially mixed neighbourhoods. Neighbourhood diversification has thus become the keyword par excellence across Europe, so it seems. In the Netherlands, France, Germany, Finland and Sweden mixture ideas are predominant. In the UK the debate is more moderate, but also there, politicians aim for mixed communities. In the DETR report on 'The State of English Cities' (20) it was argued that tenure mixing and social mixing are regarded as appropriate policy strategies in order to overcome the risk of neighbourhood effects.

However, our findings suggest that more mixing is not the appropriate strategy. In fact, neighbourhoods with the highest percentage of poor people are already the most mixed neighbourhoods! In Sweden, for example, less than 1 per cent of all inhabitants who were unemployed in 1991 were living in neighbourhoods with over 20 per cent unemployed, and actually the average percentage of long-term unemployed (unemployed in 1991, 1995 and 1999) in these neighbourhoods was less than 30 per cent. These few neighbourhoods, the 'worst' in Sweden, are thus highly mixed already, with a

lot of 'good role models' nearby. A similar situation can be found in the Netherlands. Yet, the presence of a 'good role model' does not appear to help. A good role model of a middle class family might not influence a working class family nearby just because of the fact that the social distance between these two families is too big; despite the spatial proximity the two families might be living in two different worlds. We already referred to research done by Blokland-Potters (1), who illustrates that interactions between people of different social categories in mixed environments are hardly developed. Policies aimed at more social mix therefore do not seem to be effective. Perhaps these policies are actually counterproductive. The most mixed neighbourhoods, when developed at a micro scale, tend to be rather weak and fluid social environments, not seldom very dynamic and hard to sustain, unless they are in a market position moving upward to more homogeneous gentrified areas. If that gentrification perspective is not available, few people will be living there on the basis of choice. In these situations, spatial sorting processes will always be prevalent. Those who are able to improve their social position will usually also be searching for another – 'better' – residential environment that fits the newly attained social position. Policies aimed at creating more mix are therefore doomed to fail. It is not a viable option. Probably a better strategy is to fight against stigmatisation through direct interventions in these areas aimed at improving the level of education of individual residents and assisting unemployed residents in getting a job. These policies can be developed in an area-based framework, but might also be helpful as non-spatial sector strategies.

References

1. Blokland-Potters T (1998). *Wat Stadsbewoners Bindt; sociale relaties in een achterstandswijk.* Kampen: Kok Agora.
2. Boal F.W(1976). 'Ethnic Residential Segregation', in D.T. Herbert and R.J. Johnston (eds.) *Social Areas in Cities.* London: John Wiley, pp. 111-158
3. Burgers J & S.Musterd(2002). 'Understanding Urban Inequality: A Model based on Existing Theories and An Empirical Illustration', *International Journal of Urban and Regional Research*, 26, pp. 403-413.
4. Dagevos J, M.Gijsberts & C.Van Praag(eds.) (2003). *Rapportage minderheden* 2003. Onderwijs, arbeid en sociaal-culturele integratie.
5. Dagevos J, m.m.v.J.Iedma & R.Schellingerhout (2004). *Gescheiden werelden? De etnische signatuur van vrijetijdscontacten van minderheden.* Paper voor de sociaal -wetenschappelijke studiedagen, 22/23 april 2004. Den Haag: Sociaal en Cultureel Planbureau (SCP).
6. Duncan O.D & B.Duncan(1955). 'Residential Distribution and Occupational Stratification', *American Journal of Sociology,* 60, pp. 493-503.
7. AAlen I.G & M.A.Turner (1997). 'Does Neighborhood Matter? Assessing Recent Evidence' *Housing Policy Debate,* 8, pp. 833-866.
8. Friedichs J, G.Galster & S.Musterd (eds.).(2005). *Life in Poverty Neighbourhoods; European and American Perspectives.* London, New York: Routledge.
9. Galster G(2002). 'Trans-Atlantic Perspectives on Opportunity, Deprivation and the Housing Nexus', *Housing Studies,* 17, pp. 5-12.
10. Galster G & A.Zobel(1998). 'Will Dispersed Housing Programmes Reduce Social Problems in the US?', *Housing Studies* 13 (5) pp. 605-622.

11. Hamnett C(1994). 'Social Polarization in Global Cities: Theory and evidence', *Urban Studies, 31, pp. 401-424.*

12. Laan Bouma-Doff, W.Van Der & Van Der Laan Bouma(2005). 'Concentratie versus Integratie. Vormt ruimtelijke concentratie van allochtonen een rem op de integratie in de Nederlandse samenleving?', in P. Brassé & H. Krijnen (eds.). *Gescheiden oif gemengd. Een verkenning van etnische concentratie op school en in de wijk.* Utrecht: Forum.

13. Musterd S (2003). 'Segregation and Integration: A Contested Relationship', *Journal of Ethnic and Migration Studies*, 29, pp. 623-641.

14. Musterd S (2005). 'Social and Ethnic Segregation in Europe; Levels, Causes and Effects', *Journal of Urban Affairs*, 27, 3, pp. 331-348.

15. Musterd S, W.Osterdorf (1998). *Urban Seggregation and the Welfare State : Inequality and Exclusion in Western States.* London : Routledge.

16. Musterd S, W.Osterdorf & S.de Vos (2003). 'Environmental Effects and Social Mobility', *Housing Studies* ,8, pp. 877-892.

17. Musterd S & R. Andersson (2006). 'Employment, Social Mobility and Neighbourhood Effects', *International Journal of Urban and Regional Research,* 30 (1) pp. 120-140.

18. Peach C(1999). 'London and New York: Contrasts in British and American Models of Segregation (with comment by Nathan Glazer)', *International Journal of Population Geography,* 5. pp 319-351

19. Sassen S(1991). *The Global City: New York., London, Tokyo.* Princeton, NJ: Princeton University Press.

20. `State of English Cities' (2000). DETR. Brian Robson, Michael Parkinson, Martin Boddy, Duncan Maclennan.

21. Wilson W.J(1987). *The Truly Disadvantaged, the Inner City, the Underclass and Public Policy.* Chicago: University of Chicago Press.

Inventory of Water Resources along the Tamil Nadu Coast, India

M.Devarajan and S. Mohan
GIS Division, Tamil Nadu Water Supply and Drainage Board, Chennai

and

V.Madha Suresh
Department of Geography, University of Madras, Chennai

Landforms influence the incidence of water resources in any region, along with other parameters like climate, vegetation and soil. This paper looks into the linkage between the landforms and water resources along the coast of Tamil Nadu. Coastal waters have been facing the seawater intrusions in the recent decades. Tamil Nadu coast runs for 998 km in 14 districts. It is defined by alluvial plain, deltaic plain, wetlands, sand dune tracts, and sand dune development is quite significant both in the northern and southern parts of the coast. Dunes provide local sanctuaries for ground water potentials that are tapped for drinking water. Those water-rich sand dunes are identified along the Tamil Nadu coast, using remotely-sensed imageries. There have been reports of sea water intrusions in some of these aquifers. The present study in the final analysis outlines briefly on the management strategies of these aquifers.

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Landscapes are surfaces composed of an assemblage of subjectively defined components. Each element of the landscape that may be observed in its entirety and has consistence of form or regular change of form is defined as a landform. Landforms are the result of constructive and destructive processes acting on landscapes (3,12). Air and water react with rocks to cause the familiar results of weathering. Organisms absorb mineral nutrients from the rocks on which they live. Gravity tends to pull down structures that rise above the general ground level. The intensity of these processes depends on climate, vegetation and altitude above or depth beneath the ocean. Water that is a dominant geomorphic process is, as well known, a basic element for human life (16,17,18). Climatic realms and realities and their impact on landforms and water resources in any region lead to a formation of hydrological and geo-chemical heterogeneity that has profound impact on socio-economic landscapes of the region (1,5,19). This paper looks into the linkages between the landforms and water resources along the coastal environment of Tamil Nadu, India. The immediate concern of the people in the entire coastal belt is the shortage of and poor quality of available water.

Seawater Intrusion

Seawater intrusion, unique to coastal aquifers, occurs whenever the coastal aquifers outcrop

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along the continental shelf. It may also develop or be accentuated whenever a direct surface access exists between ground water and seawater. The sedimentary aquifers in the coastal zone are in hydraulic connection with the sea, and a delicate dynamic equilibrium exists between fresh water and saline water in them. Rapid urbanization and industrial growth in the last a few decades combined with intensive agricultural practices have put a severe stress on the limited fresh water resources in the coastal zone aquifers (8,22). This has upset the balance between the recharge and deeper aquifers. The drying up of shallow wells increased the capital costs for lifting water from wells and quality deterioration in coastal aquifers appears to be the manifestations of this phenomenon. The over-exploitation of ground water from these aquifers has also disturbed the hydrodynamic equilibrium between fresh and saline waters, leading to the development of landward hydraulic gradient at places along the coast and ultimately, to sea water intrusion (7,9).

Quality of Groundwater

Quality of ground water in the coastal zone shows a wide variation from potable to brine. The *in situ* salinity of ground water in many areas like parts of Sivagangai and Ramanathapuram districts owes its origin to the prevailing marine depositional facies and to the transgressions and regressions of the oceans. Seasonal variations in ground water quality are noticed in many areas, and they may be due to the influence of tidal effects in streams and estuaries. Lithology, amount of rains, and topography are also seen influencing the chemical quality of the groundwater. The excessive incidence of TDS (total dissolved solids), fluoride, nitrate, etc., in certain pockets of the State like Ariyalur, Dharmapuri and Erode gives a great concern for tapping the available resource. The change in water quality of these sources may also be partly caused by the depletion of water level due to exploitation of the ground water

Geomorphology of Tamil Nadu Coast

Tamil Nadu state may be divided in to four physiographic units such as the coastal plains, the Eastern Ghats, the central plateau, and the Western Ghats. The coastal plains stretch over a distance of 998 km from Pazhaverkadu Lake to Kanyakumari in the south with an elevation of 2 to 30 m above MSL. The plains consist of Chozhamandalam coast in the north, alluvial plains of the Kaveri delta in the middle and southern plains from Pudukkottai to Kanyakumari. There are 54 development blocks, falling in 14 coastal districts of the State.

Reports published by ONGC, NGRI, GSI and CGWB provide useful information on the subsurface configuration of the basement of sedimentary basins and the thickness of various geological formations encountered. The sedimentary formations, which are disturbed by tectonic activities, have resulted in wide variations in their thickness. Different granular zones have been identified and the depth of occurrence and thickness of granular zones vary laterally. The monsoon by and large is erratic and fails frequently, causing acute water scarcity. Alluvial plains, deltaic plains and flood plains characterize this coastal belt and the coastal and climatic processes have developed definite geomorphic units in these plains.

The coastal plains are generally underlain by a sequential pile of unconsolidated sediments of

Quaternary origin, showing wide variation in thickness and texture. Sediments comprise sands, clays and silts of fluvial, fluvio-marine, marine and aeolian origin, mixed with gravel. They are underlain by formations ranging in age from Tertiary to Archaean. Exposures of crystalline rocks are not uncommon on the coastal area. Periodic upheavals and subsidence in the geologic past have played a major role in shaping the present geomorphology of the coastal zone.

Landform Development and Distribution

Tamil Nadu coastal stretch extends landward from the shoreline to an elevation of 2 m to 8 m above the mean sea level, and it is marked by beach ridges and broad inter-terrace depressions. It is largely characterized by a variety of complex features like deltas, bays, creeks, estuaries, tidal flats, marshes, dunes, mangrove swamps and beaches. They got evolved through a variety of processes including depositional activities of major rivers; eustatic changes, tidal effects, and neo-tectonic activities have their own characteristic geomorphological, tectonic and hydrogeological features. A number of sand dunes of varying heights dot the coastal zone. It displays a fairly low level or gently rolling topography. The straight coastline, especially in the northern part, may be the result of the development of vast alluvial expanse by the streams flowing eastward to the sea.

Following are some of the major landforms of the coastal area of the state:

Alluvial Plain

Alluvial plain is formed by extensive deposition of alluvium consisting of gravels, sand, silt, and clay being brought down by multitude of streams. It is generally flat with minor undulations and usually gets developed on both sides of the river that periodically overflows its banks. When this plain formed due to earlier cycle of deposition and occupies higher elevation then it refers as older and upper alluvium. Similarly, when it forms during late cycle of deposition and occupies lower elevation, then it refers to younger and lower alluvial plain

Flood Plain

It is a quite flat plain lying adjacent to streams. It is the surface of unconsolidated fluvial sediments (gravels, sand, silt, clay) derived from sediments transported by the streams. Hydrologically, it is a landform normally subjected to periodic flooding by parent streams. It is among the most dynamic topographic surface, and may have one or more terraces representing abandoned flood plain.

Deltaic Plain

It is a flat to gently sloping plain of large aerial extent in a fan shape of thick river- borne sediments mostly of alluvium, formed in the region extending landward from the mouth of the streams; and it may be the end of the river cycle also. It is an alluvial plain characterized by repeated channel bifurcation and divergence, multiple distributary channels and inter-distributary flood basins. It is the product of rapid deposition of stream-borne sediments into shallow standing bodies of water.

Wetlands

The coastal zone includes the near shore marine waters, islands, beaches, inter tidal areas, wetlands and inland area to the limits of

coastal watersheds and flood-prone areas. Coastal watersheds are those lands that drain directly into coastal waters of usually 0.5 ppt water salinity (4). Wetland is a dynamic ecosystem having complex interrelationship of hydrology, soil and vegetation. The U.S. Fish and Wildlife service defines wetlands as follows (2):

"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface of land and it is covered by shallow water." Wetlands have a tendency to support predominantly the hydrophytes; the substrata is predominantly with undrained hydric soils; and the substrata is non-soil and is saturated with water or covered by shallow water for some time every year. Sandy part of the coastal zone is classified into various landforms like beach, coastal dunes, spits and bars.

Vegetated wetlands are dominated by vegetation. They include mangroves, swamps, and marsh. They may be detected and mapped by seasonal (winter / summer) imageries. Mangroves are trees of various species of several families, which grow only where they can come into permanent contact with seawater or brackish water. They occur at the edges of the tropical or subtropical seas, and in bays, lagoons and estuarine region (4).

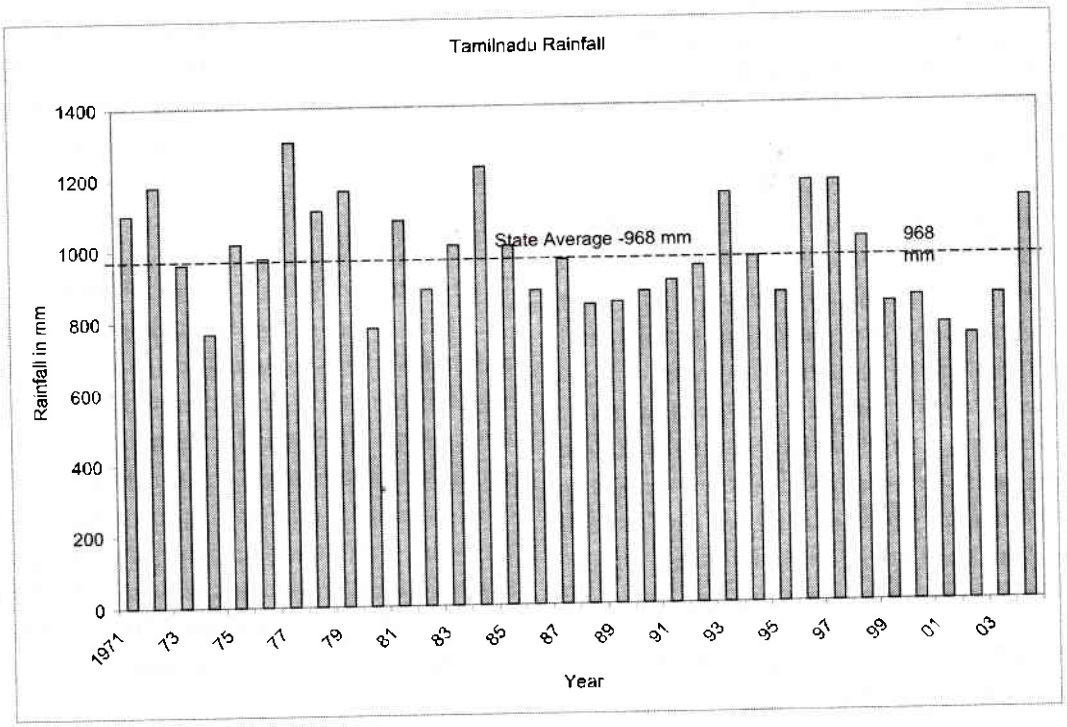

Fig. 1
Annual Rainfall - Tamil Nadu

Marshes are greasy wet areas with standing or slow moving water. Vegetation comprises of grass and sedge sods, frequently interspersed with channels or pools of open water (11).

Rainfall

Tamil Nadu coast, especially in the north, is endowed with good distribution of rainfalls. Coastal zone receives precipitation from both southwest and northeast monsoons. Especially during northeast monsoons, the coastal zone receives rainfall frequently from cyclones, causing widespread flooding in the zone.

It gets rainfall on an average of about 1400 to 1600 mm. Still, there is a water shortage largely because of poor management of available resources. Chennai, Pondichery, Chidambaram are places where the rainfall is more during the monsoon seasons well above the state average of 977 mm. From 1971-2006 in 17 years the state's average crossed 1000 mm mark and in another 16 years the normal rainfall of the state stood above 780 mm mark which is considered as normal rainfall (+ or – 20 % of average rainfall) Only 3 to 4 years experienced less than the normal. The higher state average has been the result of substantial contribution of rainfall occurred in the coastal tract.

Aquifers of Tamil Nadu Coast

In the coastal zone, the fresh water is seen occurring in the following sequences:

Fresh water in pheratic condition underlain by saline water in a homogeneous and isotopic medium; Fresh water separated from underlying saline water by a semi-previous or impervious layer; Fresh water separated from overlying saline water by a semi-previous or impervious layer; Fresh water grading laterally into saline water occurring under pheratic to confined conditions; and Fresh water zones alternating with saline water zones.

Though the available potential in the granular formations of this zone is high, the quality of the water poses the problem for exploitation. The quality variations is partly due to the over extraction in the coastal aquifer and the consequent seawater intrusion into the fresh water system. Further in some parts, like Ramanathapuram district, the marine nature of the sediments deteriorates the quality of water.

Depending on the water table and aquifer conditions, different types of abstraction structures like open well, shallow bore wells and deep bore wells are used for extraction. Increased water demand due to population explosion and changing life style has resulted in over extraction of the aquifer causing depletion of water sources. Ground water resources in the extensive coastal zone aquifers face constraints of seawater intrusion and salinity hazards.

Coastal alluvial sediments form important repositories of ground water. The eastern coast uniformly comprises aquifers with primary inter granular porosity; ground water generally occurs in these aquifers under pheratic conditions in the shallow zone and under semi -confined to confined conditions in the deeper zones. Artesian conditions have also been encountered at places along the eastern coast (Parpanachery near Nagoor and Kilvelur near Nagapattinam ,Nambivayal and Enanivayal near Pattukkottai). The disposition of fresh and saline waters in coastal aquifers varies widely depending on the prevailing

hydrological and hydro geological conditions. Some of the well-known aquifers located along the Tamil Nadu coastal zone are: Minjur -Panchetty aquifer, Thiruvanmiur aquifer around Chennai city, Marakkanam –Kilpettai sand dune aquifer near Pondichery, Rajapettai-Thiagavalli sand dune near Cuddalore and Cuddalore sandstone series, shallow coastal aquifer (dunes) around Vilunthamavadi –Vedaranyam tract parallel to the coast, freshwater islands of Rameswaram and Theris in Thuthukudi and Thirunelveli districts. Apart from the shallow ones, deeper aquifers like Orathandu aquifer of Thanjavur district , Manamelkudi aquifer in Pudukkottai, Thiruvadanai aquifer in Sivaganagai-Ramanathapuram districts are some of the best known aquifer systems located along the costal tract of Tamil Nadu. The water-yielding capabilities of these aquifers depend on the geomorphic set-up and the texture of the sediments constituting the aquifers (20).

Dune Development and Ground Water Resources

Coastal dunes cover small areas and are defined as topographical feature of eolian origin composed of sand grains deposited downwind from a natural source of sand (10). They develop in any environment in which loose rock particles of sand size are exposed to wind action and area free to migrate and accumulate as unconsolidated masses. The size and shape of the dunes varies with the climatic conditions and depositional capabilities. The thickness and the age are conducive for infiltration and saturation whenever there is rain over them (14,15).

Dunes provide local sanctuaries for ground water potentials that are tapped for drinking water in many parts in the coastal zone where the groundwater is saline or the subsurface is of fluviomarine or marine. Tapping of ground water in these potential areas of sand dunes for drinking is effected through shallow wells, shallow filter point, medium depth tube wells, ring wells, infiltration galleries, skimmed wells and radial ones depending up on thickness and depth of sand dunes and the water demand. Shallow wells and skimmed wells are very well promoted for local irrigation needs. In the shallow zones, large diameter wells, collector wells and filter points are normally constructed for tapping the ground water.

Minjur-Panjetty Aquifer System

It is a coastal freshwater aquifer system north of Chennai tapped to augment the supply of drinking water to the growing city of Chennai here, in the height of exploitation, there happened saline water ingression. The Chennai metro water authority developed an artificial system to arrest the saline ingression with the help of batteries of bore wells through which floodwater is diverted in to the aquifer. Some of the bore wells have been used as source wells in times of drought or there is surface water shortage. Thereby, this aquifer system is used both for exploitation and for conservation so as to have a sustainable availability of fresh water.

Thiruvanmiyur Aquifer

As a medium to shallow depth aquifer system mostly parallel to the coast, the sand dune of older age, Thiruvanmiyur aquifer acts as a recharge basin managing to store the seasonal floods of south Chennai city. The swamp that spreads west of the aquifer acts as a buffer to

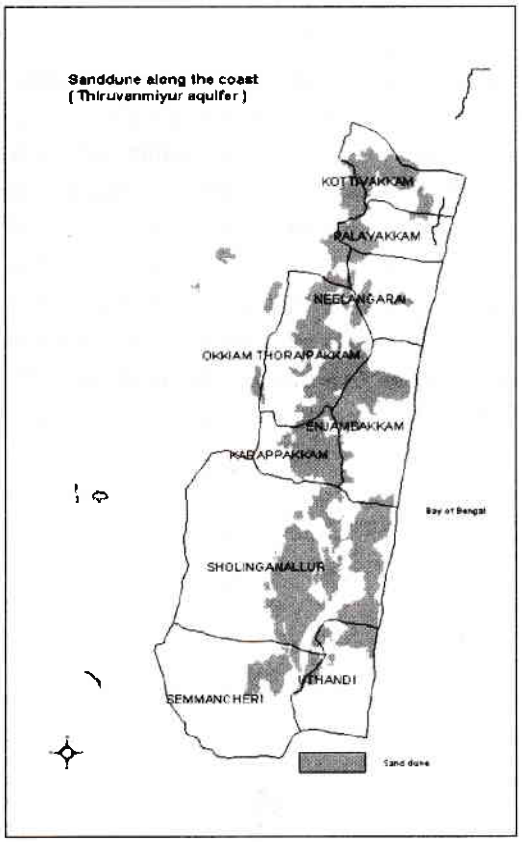

Fig. 2 Thiruvanmiyur Aquifer

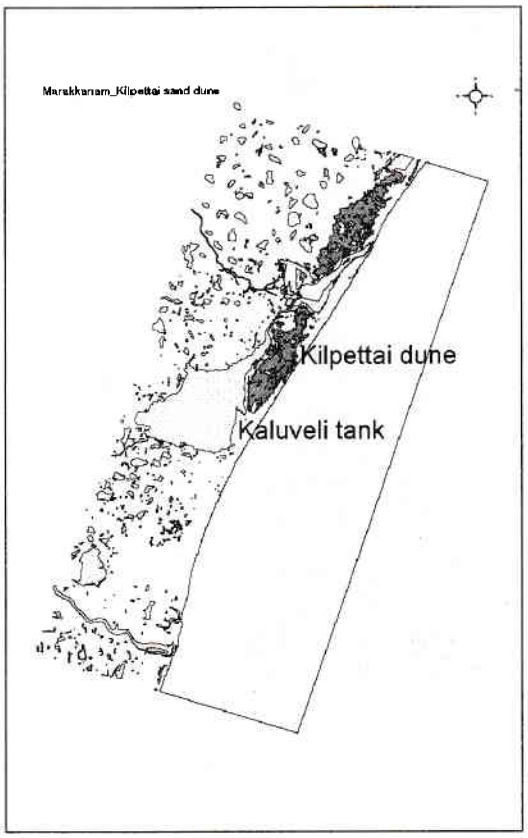

Fig. 3 Marakkanam-Kilpettai Aquifer

prevent a detrimental effect to the freshwater aquifer system. Economic viability-led urbanization seems to be detrimental to natural infiltration of this aquifer. Exploitation through bore wells by commercial and recreational establishments developed in the outskirts of Chennai city brings out threat to the potential of the aquifer system despite the enactment of stringent water laws.

Marakkanam –Kilpettai Sand Dune Aquifer

An extensive sand dune in between river Palar and River Sankarabharani often disconnected by natural and man-made activities along the eastern coast holds a rich freshwater aquifer. The saturated layer extends up to 8 to 15 m, providing a definite potential that is currently exploited for irrigation and drinking water needs. Very slow developmental activities around these places still secure the potential and quality of the aquifer.

Cuddalore Sandstone Series

Cuddalore Sandstone series occupies most part adjacent to the eastern coast of Tamil Nadu is of tertiary formation having rich ground water resources. Neyveli mining seems depleting the water table in the east of the mining area drastically, leaving the

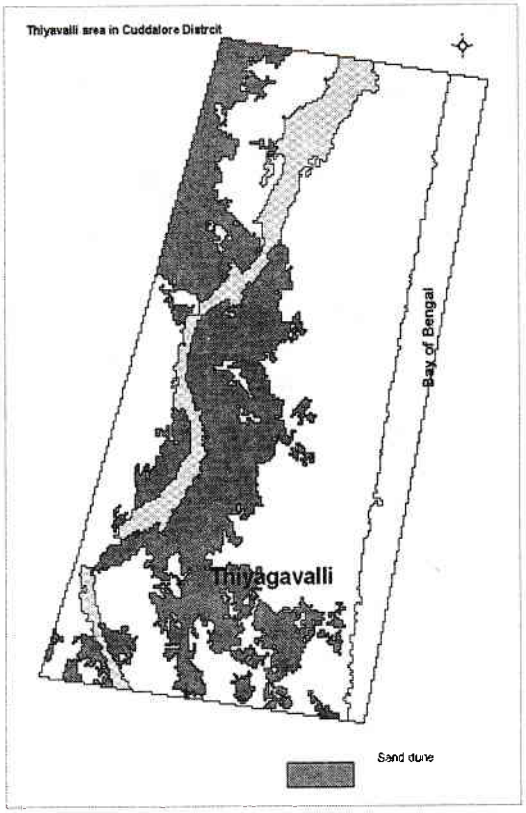

Fig. 4
Cuddalore Aquifer

villagers around in peril. Water level in many villages has gone down leaving the fertile lands into fallow lands

However, saline water intrusion is possibly obstructed by the sand dunes extending along the coast (Rajapettai - Thiagavalli - Parangipettai) frequently replenished by heavy seasonal monsoon. Industrialization and the effluents discharges in the Cuddalore stretch make the precious fresh water source polluted. In the southern part, the Theris help to prevent the saline ingression in to the tertiary formation in Tirunelveli and Toothukudi districts.

Orathanadu Aquifer

It is a deep-seated aquifer extending in larger part of the undivided Thanjavur district. Up to 1980s, exploitation of the aquifer was very limited to where schemes related to government funding was implemented. A large number of flowing wells were identified in this zone and with in a span of 20 years the natural flows gets retarded or mostly arrested due to over exploitation by indiscriminate drilling for agricultural activities.

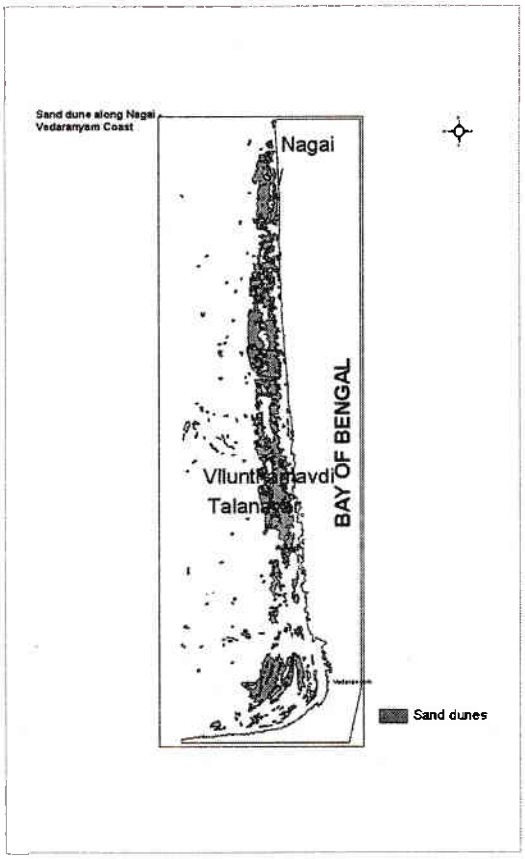

Fig. 5
Vilunthamavadi-Vedarnyam Aquifer

Vilunthamavadi –Vedaranyam Coastal Aquifer

A wide range of dunes separates the coast and the inland in the said stretch, and it is of recent alluvium spread along the shore from Poigainallur to Vedaranyam. The broader stretch at places acts as recharge zones where the normal rainfall itself is higher compared with the other part of the state. (1100-1500 mm rainfall). Skimmed wells and radial arms type of structures are developed in places like Prathabaharamapuram and Vilunthamavadi stretches. Rich potential is seen in the shallow sand dunes around Thalanayar, Pushpavanam, Thethakudi and Vadamalai areas where the quality is also good for drinking purpose.

Thiruvadanai Aquifer

It is also a deep-seated aquifer system abutting the seafloor, having its catchments around Karaikkudi. The unexploited aquifer, after free flow of funds made available for farmers' is put to threat by agricultural activities from late 90s onwards. Many rural villages get their drinking water supply from the aquifer, and of late measures have been initiated to enrich the deep-seated aquifer by providing recharge bore wells

Sand Dunes along Ramanathapuram Coast

A vast stretch of sand dunes is seen along the coastal areas of Ramanathapuram district especially in Kadaladi, Thirupullani and Ramanthapuram blocks where the depth is not so considerable. However potable water is being tapped in the shallow zones.This is one of the priority zones for developing traditional water harvesting structures.

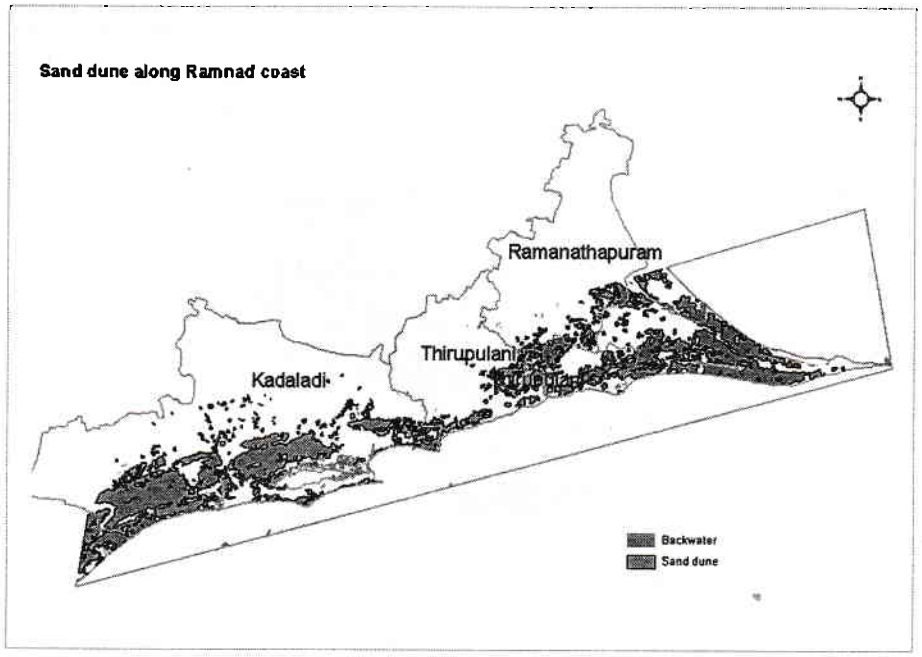

Fig. 6 Thiruvadanai Aquifer

Theris of Southern Districts

Huge mounds of sand by aeolian origin spots adjacent to the sea coast from Thuthukudi to Kanyakumari called locally as *Theris* (Ethamozhi *theri,* Kudhiramozhi *theri.*) The theris are the places where the rainfall and the floods during rainy seasons extinct in them, thereby making the slope side rich for water resources. Source for many water supply schemes in the costal area uses the *theris* for its sustenance(21).

Revival of Traditional Sources

Village ponds and *ooranis* have been considered for hundreds of years as a source of water supply and recharges to the ground water. The swales and the ridges are the two important geomorphic units developed in the coastal tracts. Swales are the linear depressions void of sand columns, made of clay beds. Monsoon runoff fills the depressions and infiltration is negligible because of the underlined clay bed. Depending on the intensity and duration of rainfall the storage exist for number of days. This has been a good source for the water needs of human beings and livestock. In these ponds, evaporation loss at times leads to enrichment of total dissolved solids (TDS), and turns the storage saline (13).

Oorani in a Coastal Village

Poor maintenance of village ponds often spread water-borne deceases both during winter and summer seasons. Health awareness and programme of potable protected water supply slowly put these village ponds in disuse. Erratic monsoon and increase in population results in encroachment of these ponds, thereby reducing the water storage spread. Still these are the locations considered to be the most dependable for storage of freshwater in the areas where the subsurface water is invariably saline in the coastal area. These ponds could be converted into a sealed

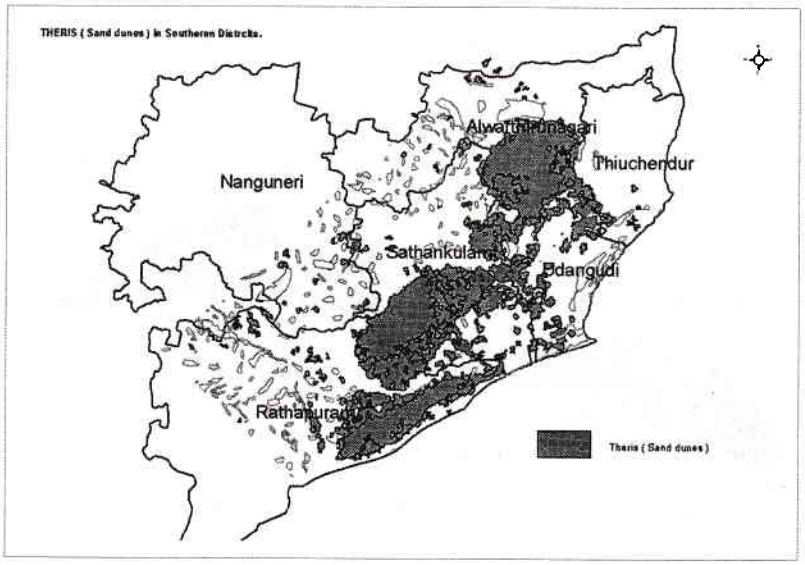

Fig. 7 Theris in Udankudi& Sathankulam Blocks

tank for sustainable drinking water supply.

Still there are locations on the coastal belts where small settlements on the estuaries and lagoons where there is no freshwater source and the people trek a long way for a pot of fresh water. It is all the more difficult for them during rainy season. Roof water collection during the rainy season may be the possible way for making storage of fresh water in those areas. One can see a successful attempt of this way-out in Vedaranyam block in Nagapatnam district. The rooftops of schools, temples and other public buildings in addition to the rooftop of residential houses have been utilized for harvesting rainwater. The area ideal for this kind of practices is the taluks of Chidambaram, Vedaranyam, Pattukkottai, Ramanathapuram, and parts of Kanyakumari.

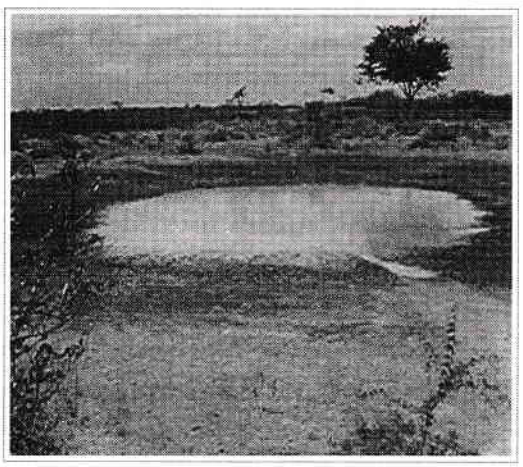

Fig. 8 Oorani in a Coastal Village

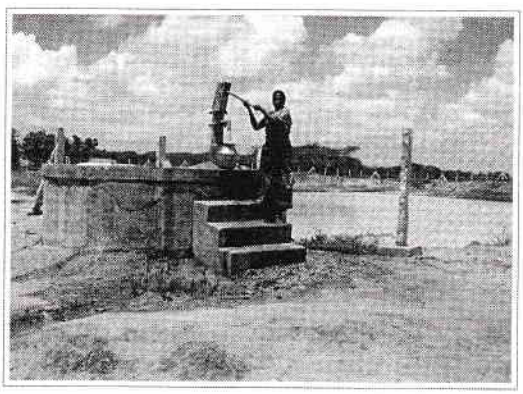

Fig. 9 Oorani after Improvement

Managing the Coastal Aquifers

Efforts to combat the threats of overexploitation of ground water and seawater intrusion are being taken up in the country with an urgency they deserve (6). They include regular monitoring of ground water levels and water quality of various aquifers in the coastal zones, design and implementation of artificial recharge schemes for recharging the overexploited aquifers, and implementation of regulatory measures for restricting ground water exploitation in critical areas. Rainfall studies are required to quantify the surface flow and level of water storage and recharge, thereby monitoring the sustainability of groundwater sources. Traditional ways of water use may have to be revived. Mass awareness campaigns may be organized at grass-root level to inculcate the habits of water conservation and judicious use of available resources among the rural population.

Seasonal rainfall pattern is to be studied so as to quantify the periodical surface flow. The available water storage structures need to be enumerated and its efficiency has to be worked out for rejuvenation activities. Surface water bodies like ponds (*ooranis)* in the coastal area need to be identified and rejuvenated to make it a safe area of storage. Identification of suitable abstraction structures based on the need and availability of source with proper assessment and forecast is to be designed and executed.

The traditional system of in-well sand-filled dug-wells in ponds *(ooranis)*, may be encouraged with proper treatment measures. The existing / defunct traditional water sources need to be augmented with suitable treatment measures. Study need to be encouraged to improve the natural recharge arrangements to control saline ingression and to improve the overall water quality problem. Further, initiatives that help improving public awareness on water storage, water use for better living condition and discouraging encroachment on waterways and storage areas and over pumping need to be developed.

References

1. Alan L. Flint (2003). *The Role of Unsaturated Flow in Artificial Recharge Project.* San Francisco: U.S. Geological Survey.
2. *Bloom L. Arthur (2002). Geomorphology: A Systematic Analysis of Late Genozoic Landforms.* New Delhi : Printice – Hall of India, Pvt Ltd.
3. *Carl R.Goodwin (2004). Feasibility of Regional - Scale Aquifer Storage and Recovery (ASR): Scientific Uncertainties.* Florida: U.S. Geological Survey.
4. Carter R.W.G (1988). *Coastal Environments.* London: Academic Press.
5. David R and G. Pyne (2002). *Aquifer Storage and Recovery Issues and Concepts.* New York: St John River Water Management System, USA.
6. Devarajan M (2007). 'Ensuring Sustainable Drinking Water Sources in Rural Area - Application of Integrated Technology Alternatives', *Proceedings of the National Seminar on Hydrocare,* Annamalai University, Chidambaram, Tamil Nadu.
7. Fletcher G. Driscoll (1989). *Groundwater and Wells.* Minnesota:Jhonson Filtration systems Inc.
8. Grenoble S (1974). 'Study for the Development of Groundwater in the Thessaly Plain'. Hellenic Ministry of Agriculture.
9. John Zbicki (2004). *'Using Chemical and Isotopic Tracers to assess Hydrogeologic Processes and Properties in Aquifers Intended for Injection and Recovery of Imported Water'. San Francisco: U.S.* Geological Survey.
10. Jhornbury D.William (1997). *Principles of Geomorphology.* New Delhi:New Age International (P) Ltd.
11. Lundgren Lawrence (1986). *Environmental Geology.* Eaglewood Clifes, N.J: Printice Hall.
12. Manning C.John (1989). *Applied Principles of Hydrology.* New Delhi:CBS Publications.
13. Ramakrishnan (1998). *Groundwater.* Chennai: Chennai Metro Water Supply and Sewage Board.
14. NEPA (2003). *Impact Assessment of Aquifer Recharge.* Roma. Itallia: Luciana Sinisi National Environmental Protection Agency.
15. Karanth K.R (1987). *Groundwater Assessment Development and Management.* New Delhi: Tata McGraw - Hill Publishing Company Limited.
16. Mariolakos *et. al.* (2001). *'The Artificial Recharge of Groundwater'.* Proceedings of the 10th Biennial Symposium, Argentina.
17. Patra K.C (1997). *Hydrology and Water Resources Engineering.* New Delhi: Narosa publishing House.
18. Reetta Kuronen (ed.) (2002). ' Water Services -An Evaluation Report'. Helsinki: National Technology Agency, Technology Programme.
19. Todd D.K (1980). *Groundwater Hydrology.* New York:John Wiley & Sons.
20. TWAD Board (1997). *Feasibility Study for Locating Artificial Recharge Structures in Agrahara Valavanthi Micro Watershed of Karaipottanar Watershed.* Chennai: R & D cell, Hydrogeology Wing.
21. Weeks E.P (2000). *A Historical Overview of Hydrologic Studies of Artificial Recharge.* Lakewood, Colorado: U.S. Geological Survey.
22. TWAD Board (1996). *Karaipottanar Watershed Study. Chennai:* R&D cell, Hydrogeology Wing.

Child Labour in Lock Factories of Aligarh City, India

(Ms.) Abha Lakshmi Singh
Department of Geography, Aligarh Muslim University, Aligarh

Haroon Sajjad
Department of Geography, Jamia Milia Islamia, New Delhi

and

Sarfaraz Asgher
Department of Geography, Jammu University, Jammu

It has been estimated that more than100 million children in the age group of 5 to 14 years are working in industries and in different trades in India under inhuman conditions. To make a study on children employed in industries, lock factories of Aligarh city, India, which employ some 30,000 children, were selected. It revealed that the poor parents are forced to send their children into hazardous jobs to sustain life; employers prefer them because of low wages and problem- free management to sustain their lock – manufacturing units; and the government is helpless and indifferent to their problems. Remedy lies in limiting the population growth, political will and social awakening.

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A large number of children throughout the globe is forced to take occupations beyond their physical and mental strength despite several United Nations since 1923. Child labour is one of the most pressing moral issue of the time and requires urgent action for its elimination. The reports estimate that at least one quarter of children in developing World is working (16). ILO estimates that the number of the working children between the ages of 5 to 14 years in developing countries is about 250 million, of whom some 120 million work full time (5, 7, 8).

India has the largest number of child labourers in the World, around 20 million in hazardous and 50 million in bonded (16). According to Government of India, the number of working children was estimated at about 17 million in the National Sample Survey, with a projected 20 million working – children by the year 2000. Other studies indicated that these figures are a gross under estimation. A labour ministry report suggests that 44 million children in 5 to 14 years age group are in the labour force. Different definitions of the working – child explain the wide variations in the numbers, since the official figures generally omit children engaged in non- wage domestic work (17).

Child labour has an element of economic compulsion associated with it. It involves a time and energy commitment, which affects children's ability to participate in leisure, play and educational activities (4). It includes

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children prematurely leading adult lives , working long hours for low wages under conditions damaging to their health and to their physical and mental development, sometimes separated from their families, frequently deprived of meaningful education and training opportunities that could open up for them a better future(6). According to the Child Labour Prohibition and Regulation Act, "any work that is not voluntary , that is imposed upon and keeps the child away from the education process, from the joys of childhood or endangers his/ her health falls in the realm of the child labour".

With industrialization in India the employment of children increase and is continuing in certain industries like the glass factories of Firozabad, brass-ware of Moradabad, the carpet industry of Palamau, Mirzapur, Varanasi, Allahabad and Kashmir, diamond industry of Surat, handlooms of Kanchipuram, powerlooms of Bhiwandi, Mumbai, match and firework of Sivkashi, gem cutting of Jaipur, woodcarving of Saharanpur, *zari*(silver and golden threads) embroidery of Lucknow, *bedi* (local cigarette) industry of U.P., Tamil Nadu, Karnataka and Kerala, lock industry of Aligarh etc; and the lists in both organized and unorganized sectors are endless. The present study is concerned with the child labourers working in the lock factories of Aligarh city, India. The research is presented in two sections. The first section is based on secondary data, which gives a brief over view of the lock factories of Aligarh. The second is an analysis of primary data regarding the social, economic and health conditions of the children working in the lock factories of Aligarh.

Data and Methodology

The secondary data were obtained from a variety of sources (1, 2, 9, 10, and 13). Primary data were collected through a survey of lock factories located in the older part of the city with interviews with working children, their parents, employers and Government officials. The survey was conducted by the authors during 2000 – 2002. The sample design adopted consisted of two stages. The first stage consisted of selecting the lock factories in the old part of the city randomly. In this way 50 lock manufacturing units were selected. The second stage consisted of selecting child labourers from these factories. About 500 child labourers were selected randomly. To make the data more reliable, child sample lock manufacturing units were visited frequently.

Study Area

Aligarh has earned a place on the industrial map of India through its traditional product of lock. Aligarh is a small city located in the state of Uttar Pradesh(Fig.1). It is about 130 km away from Delhi. Like most towns in Uttar Pradesh, the railway lines demarcate the city into two parts, the new and old. The new is less congested and appears to be clean. The old city is congested and presents a picture of decadence. It is a realm of ordinary people, striving to survive in the face of daunting odds. Here about 80 per cent of the population lives by making locks and a large scale exploitation of child labour has become a tradition.

The lock factory was established in Aligarh in 1842 when British Government began manufacturing locks in the Government Postal Workshop, which served as a training ground for a large number of mechanics. This attracted

artisans and entrepreneurs. Gradually the skill became hereditary and the manufacturing business became a matter of tradition, and thus the industry got localized in Aligarh. In 1887, locks were manufactured on a small scale in the form of cottage industry but by 1907, there were around 30 lock factories in the city usually created as joint stock companies. By the beginning of 20th century new designs of high quality of locks made from both brass and iron were produced. Later on entrepreneurs started training people in the art of lock smithy. Since then about 2000 skilled artisans were engaged in this industry. This large cadre of skilled local artisans provided great stimulus to the lock industry by establishing small units throughout the length and breadth of the old city (10).

After partition of the country, many traders were forced out of business and are large number of workers got unemployed. But there was no large scale migration of Muslims, who own most of the lock industry. In the post - Independence period new markets for locks emerged and there was mass production of locks. Previously the manufacturing was done manually by die – punching but it was carried out in large factories by using powered machines. Consequently, this gave rise to competitions on the grounds of technology and the big manufacturers started thinking about mechanization (13). Organized units were developed in the industrial estate (established in 1973) and the production of locks was further expanded.

Aligarh city emerged as a city of locks and the lock industries continue to be the main industry. There are over 5,000 units manufacturing locks, which are working as semi-organized and tiny groups respectively in the industrial estate and outer areas of the city. About 100,000 persons are working in these units. Of them 30 to 35 per cent are children. It is a fact that children working as labour in Aligarh have become experts in manufacturing various parts of lock. According to a detailed survey, over 1,500 children are working as specialized labour in plate cutting, 2,000 in body drilling, 2,200 in manufacture of lock machine, 2,900 in casting, 3,000 in fitting process, 1,600 in washing of locks, 2,500 in key manufacturing, 1,900 in designing of locks, 5,700 in electroplating polish, 5,000 in packing and 2,100 children in other processing fields of the lock industry in Aligarh (12).

Results and Discussions

City survey conducted by the authors revealed that in the old city except for a few small-scale units, most of the units were owned by families. Each and every house has a lock-manufacturing unit where the services of children are used.

Profile of the Sample Child Labourers in the Lock Factories

Table 1 reveals that of the total sample child labourers (500), 70 per cent of them were males. A rising incidence of female child workers was observed because employers are often eager to employ young girls, since they are paid less than boys and are often employed at younger ages. Thus the girls work both at home (i.e. filling of water for domestic use, washes clothes and dishes, cook food and look after young siblings etc.) and in the lock manufacturing units. More than half of them are between the age group of 11 to 14, and 38 per cent were between the age group of 7 to 10. This shows that there is exploitation of

children below 14 years of age also in the lock factories. Employers say that the children are quick to acquire special skills on buffing machines, electroplating, spray painting, filling components, making springs, assembling and packing lock.

Table 1

Profile of Sample Child Labourers Working in Lock Factories of Aligarh City (200-01)

1. Sex – wise Distribution

Sex	Number	Percentage
Male	350	70.00
Female	150	30.00
Total	500	100.00

2. Age – wise Distribution

Age Groups	Male	Percentage	Female	Percentage	Total	Percentage
0-6	30	8.57	50	13.33	51	10.00
7-10	141	40.28	50	33.33	191	38.20
11-14	179	51.15	80	53.34	259	51.80
Total	300	100.00	150	100.0	500	100.0

2. Religion – wise Distribution

Age Groups	Male	Percentage	Female	Percentage	Total	Percentage
Muslims	190	54.29	86	57.34	276	55.20
Hindus	160	45.71	64	42.66	224	44.80
Total	350	100.00	150	100.0	500	100.0

3. Caste – wise Distribution

Age Groups	Male	Percentage	Female	Percentage	Total	Percentage
Scheduled caste	150	42.86	50	33.34	200	40
Backward caste	170	42.57	90	60.00	260	52.0
Upper caste	30	8.57	10	6.66	40	8.0
Total	350	100.00	150	100.0	500	100.0

4. Schooling

Schooling	Male	Percentage	Female	Percentage	Total	Percentage
Drop-outs	196	56.0	35	23.33	231	10.00
Never fone to school	154	44.0	115	76.67	269	38.20
Total	300	100.0	150	100.0	100	51.80

Source; Field Survey (2000-01).

In terms of religious affiliation, about 55.2 per cent of the children are muslims and 44.8 per cent, hindus (the total city population 6, 67,732 persons, of which 60 per cent are hindus and 40 per cent are muslims), and most of them belong to the backward community. There is thus a dominance of muslim child labour in the old part of the city because this area is dominated by muslim population. Only 18 per cent belong to the upper caste. The scheduled and backward caste (25 and17 per cent of the total city population) people are the most deprived ones, and the parents of this group want their children to work as even paltry wages given to minors increase in the family's income.

About half of the child labourers never went to school, and out of the remaining, about 46 per cent were drop-outs from schools. Drop-out rates in the classes 1 to 5 were 47 per cent and in classes 1 to 8 were 62 per cent (Department of Education, 2000) in the country. Nearly half of the child labourers who got enrolled in primary schools, does not complete it. In the case of female child labourers, only 7 per cent was drop-outs while rest of them has not attended any school.

Family Background of the Sample Child Labourers working in the Lock Factories

The family background of the 500 respondents assumes more significance because it is the family, which has the greatest influence on the child's life. Nearly three quarters of the children came from nuclear families, and the rest from joint families. Economic necessity of the nuclear families compels them to work from early age. It may not be the case in the joint families. Nearly 63 per cent of the fathers of the sample child labourers were illiterate. Most of the parents (92.4 per cent) work in the lock factories. Dependence on family labour is predominant in the lock-producing units. The tendency to pursue fathers' occupation seems to be the tradition.

More than half of them earned between Rs. 1,000 to 1,200 per month. There exists an inverse relationship between income of the household and child work participation. A large proportion of the sample working children belongs to the households with the household income of about Rs.700 per month. About three quarters of the families were in debt. The low income and heavy loan burdens thereby push the parents to send their children for work.

Children are an economic asset to the poor. Poor families need the labour and income of their children. The income they bring in and the work they do however small it may be, may be a welcome addition to the household income. Family size in poor households is normally large (more than 10 may not be rare in the study area), and the children's earnings may be very helpful to the large size households. It was observed that in the some cases, the child did not have either parent or the father was an alcoholic or disabled or unemployed, and mother was busy with the household chores or she may be an earner. Such families often have too many mouths to feed, and many entrust children to relatives who are owners of lock manufacturing units or to middlemen who barter them to any lock factory-owner who wants cheap labour. Poor parents obtain a loan and surrender their child as security. Since they have no resources to repay the debt, they agree to let their children work. Thus the basic cause of child labour is poverty in the family.

Employment Conditions and Type of Work done by the Sample Child Labourers in the Lock Factories

The working conditions in the household manufacturing units are not healthy. There is no ventilation, no sanitation, no toilet facilities and no proper drinking water facilities; and lights are dim. Children work in cramped, unhygienic and unsafe surrounding. Children were engaged in assembling and packing locks (16 per cent), electroplating (12 per cent), working on hand press (12 per cent),

Table 2

Family Background of the Sample Child Labourers working in the Lock Factories of Aligarh City (2000-01)

1. Type of Family

Families	Number of Families	Percentage
Nuclear	359	71.80
Joint	149	28.20
Total	500	100.00

2. Educational Status of Fathers

Education	Number of Families	Percentage
Illeterate	315	63.00
Literate	185	37.00
Total	500	100.00

3. Parental Occupation

Education	Number of Families	Percentage
Main	462	92.40
Subsidiary	38	7.60
Total	500	100.00

4. Monthly Income of Parents

Income in Rs.	Number of Families	Percentage
800 - 1000	93	18.60
1000 - 1200	274	54.80
1200 - 1400	133	26.60
Total	500	100

5. Indebtedness

Extent of Debt	Number of Families	Percentage
Under debt	133	66.60
Without debt	167	34.40
Total	500	100

Source; Field Survey (2000-01).

polishing (11 per cent), working on buffing machines (9 per cent), making springs (9 per cent), spray painting (8 per cent), and filling component (6 per cent). About 35 per cent worked 12 to 14 hours a day. Children are paid low wages as is evident from Table 3. The monthly income of these children ranges from Rs. 250 to 550 per month i.e. these children get Rs. 8.50 to 18.30 per day. Girls are paid less than the boys and this is one of the reasons as to why employers are eager to employ young girls. Boys are paid better and they also receive permission from their parents to spend a part of their income for extra food, clothes and entertainment (particularly for movies). While in case of girls most of them do not receive their wages directly from the owners but it is their parents who collect their income. They are not permitted to spend any money themselves. Parents are thus allured by the gains from employment of children more than the exploitation of children and denial of education to their children.

Government officials say that child labour helps sustain the small scale lock manufacturing units where locks are produced at lower costs. Officials and employers argue that children serve as apprentices, acquiring needed skills for adult employment and contributing to the income of their families. They further argue that the employment of children sustains India's traditional craft-oriented industries and that child labour makes India's exports more competitive.

Impact on Health of the Sampled Child Labourers working in the Lock Factories

The child labourers are at a constant risk of health hazards due to the area where they live, their living conditions at home and working conditions in the lock factories. The environmental conditions in the old city are deplorable characterized by congestion, overcrowding, lack of fresh air and sun light, lack of drainage, toilet and drinking water facilities, open-clogged drains, and water logging , dirt and filth with garbage (including faecal matter) pilfered everywhere. The conditions in their home are similar (14). The unhygienic conditions in the household lock manufacturing units have serious adverse impacts on child's health. The children suffer from diseases like tuberculosis, bronchitis, asthma, skin diseases, ear and eye problems and deformity of fingers. Children work with potassium cyanide, trisodium phosphate, sodium silicate, hydrochloric acid and sulphuric acid, and they inhale noxious fumes and are exposed to electric shocks. Accidents and injuries are common; many children report headache, leg pain, respiratory problems and problems of eyesight. Some problems like respiratory, tuberculosis, and eyesight increase with age and number of years of work. Due to their peculiar postures for long hours without any rest, many suffer from backache, shoulder pain and leg pain.

Of the total sample workers (500), more than half of them reported of having tuberculosis. About 21 per cent reported of suffering from bronchitis, and 8 per cent from asthma. Pneumoconiosis and bronchitis are also very common. Many children suffer from skin diseases (6 per cent), and have severe ear problem and loss of eye sight (8 per cent). They reported of severe ear problems after working at buffing machines and eye problems due to working in dim lights. They do not take bath regularly and wear the same clothes day after day. They are not aware of that this will cause

skin diseases. Continuous working with their nimble fingers to insert levers in the locks has led to the deformity of fingers. About 3.4 percent of the sample child labourers reported of deformity of fingers.

Most of the child workers come from very poor households, so environment at home is characterized by poor housing conditions in terms of size, structure, ventilation, overcrowding and multipurpose rooms. Lack of toilet facilities at home has led to the use of

Table 3

Employment Conditions and Type of Work done by the Sample Child Labourers working in Lock Factories of Aligarh City

1. Type of Work Done

Type of work	Male	Percentage	Female	Percentage	Total	Percentage
Packing	62	17.71	15	10.00	77	15.40
Electroplating	37	10.57	22	14.67	59	11.80
Hand Press	51	14.57	7	4.67	58	11.60
Polishing	41	11.71	11	7.33	52	12.40
Key Cutting	35	10.00	14	9.33	49	9.80
Lock Fitting	33	9.42	13	8.67	46	9.20
Buffing	27	7.71	19	12.67	46	9.20
Spring MAking	21	6.00	23	15.33	44	8.80
Spray Painting	24	6.86	17	11.33	41	8.20
Filing Component	19	5.43	9	6.00	28	5.60
Total	350	100.00	150	100.00	500	100.00

2. Working Hours

Hours/day	Male	Percentage	Female	Percentage	Total	Percentage
8-10	93	26.57	83	53.33	176	35.20
10-12	120	34.28	47	31.33	167	33.40
12-14	137	39.15	20	12.33	157	31.40
Total	350	100.00	150	100.0	500	100.00

3. Monthly Income

Income in Rs.	Male	Percentage	Female	Percentage	Total	Percentage
250-350	73	20.85	38	25.33	111	22.20
350-450	87	24.86	49	32.67	136	27.20
450-550	190	54.29	63	42.00	253	50.60
Total	350	100.00	150	100.0	500	100.0

Source : Field Survey (2000-01)

public toilets, toilet sharing, and defecation in the open. Lack of clean and potable water in their houses has led to the use of the public water supply, leaving water logging around and inside the house; streets and houses do not have proper drainage facility and heaps of garbage are found lying uncollected. The unhygienic conditions attract vectors of diseases, such as mosquitoes, flies, cockroaches, rats, fleas, bugs, ticks, and mites. Rotten garbage spreads malaria, amoebiasis, dysentery, diarrhoea etc. Contaminated water contains virus, which causes jaundice, typhoid etc. Stagnant sewage is also a breeding ground for mosquitoes. Table 4 reveals that the child labourers also reported of environmentally related disease like dysentery/ diarrhoea (35 per cent), malaria (37 per cent), jaundice (19 per cent), and cholera (9 per cent).

Conclusion

The study reveals that poverty in the family, social structure, inefficiency or inappropriateness of the educational system, attitude of the employers, a lack of awareness among parents about the implications of child labour for health and development, and lack of political will are some of the factors behind the

Table 4

Impact on Health on the Sample Child Labourers working in the Lock Factories of Aligarh City

1. Health Problems due to working in Lock Factories

Health Problems	Male	Percentage	Female	Percentage	Total	Percentage
Tubeculosis	203	58.00	62	41.33	265	53.00
Bronchitis	3759	16.85	46	30.66	105	21.00
Asthma	5127	7.72	15	10.00	42	8.40
Ear and Eye Problem	4131	8.85	9	6.00	40	8.00
Skin Diseases	3520	5.71	11	4.33	31	6.20
Deformity of Fingers	3310	2.85	7	4.66	17	3.40
Total	350	100.00	150	100.00	500	100.00

2. Health Problems due to the Environmental Conditions at Home, Neighbourhood and Working Place in Aligarh City (2000-01)

Health Problems	Male	Percentage	Female	Percentage	Total	Percentage
Dysetry	147	42.00	28	18.66	175	35.00
Malaria	120	35.14	4763	42.00	186	27.20
Jaundice	57	16.28	2039	26.00	96	19.20
Cholera	23	6.57	20	13.33	43	8.60
Total	350	100.00	150	100.0	500	100.00

Source : Field Survey (2000-01)

high incidence of child labour in the manufacturing units in Aligarh city. The parents who are poor, illiterate, and indebted, with a large size of household put their children to work. For parents it is the surest way of enhancing the family income to sustain the life. The employers are eager to hire the children, as they work for long hours in deplorable conditions at cheap rates without any complaints. Thus they can produce locks at lower costs. For the employers it is the surest way of sustaining their small lock-manufacturing units. The government has adopted a callous attitude because child labour on one hand helps to enhance the family income and on the other hand it helps to sustain the small manufacturing units. If all the laws and regulations are strictly followed, these units will stop working and the children will be on the streets where they would take to crime and land as juvenile delinquents. So more concrete measures are needed to the improve working conditions, and to influence the attitudes of employers and families towards child labour. The Government could pay a more active and decisive role at the local level. Voluntary organizations may be encouraged to intervene and interact. Smaller family size has to be popularized. Thus political will and efficient administration are required to remove the child labour. Employees should have more social commitment, and parents have to be educated for children education and environmental hygiene.

References

1. Asger S (1998). 'Child Workers in the Lock factories in Upper Kot Area of Aligarh City', Aligarh:Department of Geography, Aligarh Muslim University. (Master's Project Report).
2. Census of India (1991). *District Census Handbook: Aligarh, Primary Census Abstract, Part XIII, B.* New Delhi: Census of India.
3. Department of Statistics and Economics, Aligarh (1998). *Statistical Bulletins of Aligarh District 1996 to 1998.*
4. Fyfe A (1989). *Child Labour.* Cambridge, U.K: Polity Press.
5. ILO (1996). *Child Labour: Targeting the Intolerable International.* Geneva: ILO Report VI (1).
6. ILO (1986). *Child Labour: Report of the Director General to the International Labour. Conference.* Geneva: ILO.
7. ILO (1997). *Combating the Most Intolerable Forms of Child Labour: A Global Challenge.* The Hague: Ministry of Social Affairs and Employment.
8. ILO (1997). *Statistics on Working Children and Hazardous Child Labour in Brief.* Geneva: ILO.
9. Ministry of Education and Social Welfare (1991). *Education in India.* New Delhi: Statistics and Information Division.
10. Nevill H.R (1926). *Aligarh Gazetteer,* Volume VI of the District Gazetteers of United Provinces of Agra and Oudh.
11. Sajjad H (1997). *Employment of Landless Labourers.* New Delhi: BR Publishers.
12. Saxena P (2000). `Poverty pushes them to be Child Labour', *Hindustan Times,* Jan. 20, 1999.
13. Siddiqui J.M (1981). *Aligarh District: Historical Survey.* Aligarh: A.M.U., Publications.
14. Singh A.L *et. al.* (1995). 'Income, Environment and Health: A Household Level Study of Aligarh City: India', *Habitat International,* Shielfiled, 20 (1).
15. Singh A.L & A. Rehman (1998). Housing and Health in the Low Income Hoseholds of Aligrah City', *Indian Journal of Regional Science,* 30(2)
16. UNICEF Report (1997). *The State of Worlds Children.* New Delhi: Oxford University Press.
17. Weiner M (1996). 'Child Labour in India, Putting Compulsory Primary Education on Political Agenda', *Economic and Political Weekly,* November.

A Study on Surface Temperature Trends over Andhra Pradesh

T.V. Krishna & S. Sachidevi
Department of Geography, Andhra University, Visakhapatnam

Climate is known for variations and changes over time and space. Now there has been feverish talk and discussion all over the world on global warming and climatic changes. The present study exanines the trends in surface temperature over Andhra Pradesh. The monthly temperature data for 25 meteorological stations of Andhra Pradesh for a period of 70 years, 1931 to 2000 have been analysed. Trend analysis of summer maximum and winter minimum temperature was carried out using linear regression technique. Significant positive trend in maximum temperature is observed at Hyderabad and Anantapur. There is an increasing trend in minimum temperature at Hyderabad, and Kakinada and Ramagundam show significant negative trend. Decadal variations in summer maximum and winter minimum temperatures are also analysed.

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Global warming is one of the most serious challenges of today and it has drawn the serious attention of scientists and social activists.. Numerous studies have been made on global, continental and regional scales on this important issue. Observed climate records indicate significant warming in global temperatures by about 0.3° – 0.7°c in the past century. Several studies have been reported in search of trends in rainfall and temperature over the Indian region. Mean annual surface air temperature in India shows a significant warming of 0.5°c/100 years, and recent data indicate a substantial acceleration of this warming, especially after the 1990s (7). Extremes in minimum and maximum temperatures are also expected to increase in the future.

Pramanik and Jagannadhan (8) have studied temperature trends in India. Jagannadhan (5) presented a detailed analysis of the seasonal oscillations of temperature over the Indian region, while Benarji and Sharma (3) discussed the oscillation of daily mean maximum temperatures. Sen Roy and Prasad (10) analysed annual temperature anomalies in India during the period 1901-1982. Rupa Kumar and Hingane (9) studied the long term variations of surface air temperature at major industrial cities in India. In the present study 25 climatological stations (Fig.1) from Andhra Pradesh are chosen to study the variations in annual temperature, the extremes in maximum and minimum temperature, and temperature trends in summer maximum and winter minimum temperature.

Data and Methodology

The monthly maximum and minimum temperature data of 70 years (1931-2000) have been collected for 25 climatological stations from IMD weather reports. Monthly and yearly average temperatures were computed. Data were analysed for two climatic periods that is 1931-60 and 1961-90.

Mean annual temperatures were calculated for all stations for two climatic periods, and results were compared to observe the general trend of temperature. The main objective of

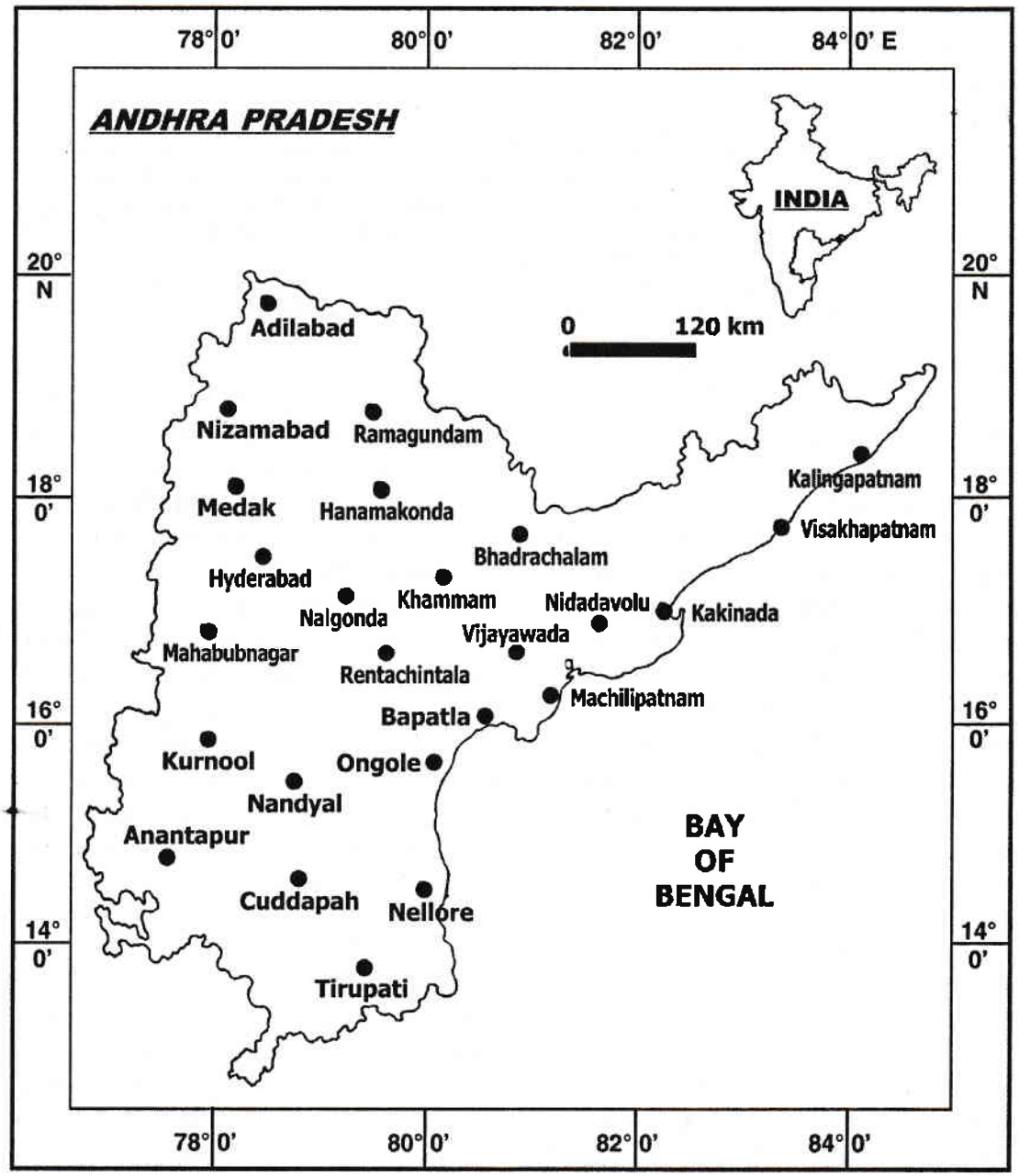

Fig. 1. Location of Climatological Stations

the present study is to identify trends in surface temperatures in Andhra Pradesh. Hence some representative stations have been selected from three regions of Andhra Pradesh, Coastal Andhra, Rayalaseema and Telangana to study the trends in summer maximum and winter minimum temperatures. May is the hottest month and it represents summer season and December is the coldest month that represents winter season. Hence maximum temperature of May and minimum temperature of December have been analysed. Trends of the maximum and minimum temperatures have been evaluated by fitting linear regressions, and the coefficients were tested for validity.- Decadal Fluctuations in maximum and minimum temperatures were also analysed.

Results and Discussion

The mean annual temperatures for two climatic periods i.e. 1931-1960 and 1961-1990 have been computed to compare the results and to identify the trends. The temperature variability for two climatic

Table 1

Mean Annual Temperature (°C)

Station	Period		
	1931-60	1961-90	Difference
Anantapur	27.6	28.0	0.4
Cuddapah	29.3	29.5	0.2
Hanumakonda	27.7	27.9	0.2
Hyderabad	25.9	26.7	0.8
Kakinada	27.8	28.4	0.6
Kalingapatnam	27.2	27.3	0.1
Kurnool	28.1	28.3	0.2
Machilipatnam	27.9	28.0	0.1
Mahabubbagar	26.7	26.8	0.1
Nellore	29.2	29.4	0.2
Nidadavole	27.8	28.2	0.4
Nizamabad	27.0	27.5	0.5
Ongole	28.6	29.4	0.8
Ramagundam	28.6	28.7	0.1
Rentachintala	29.0	29.5	0.5
Visakhapatnam	27.3	27.9	0.6

periods have been analysed and presented for the 16 stations as shown in Table 1.

The difference in temperature between two time periods is positive in all stations. The larger difference is noted for Hyderabad and Ongole, and the least in many of the stations.

It is globally observed that the temperatures are on the rise, and extremes in maximum and minimum temperatures also appear to be

Table 2
Mean Maximum and Minimum Temperatures

Station	Mean Max. temp. (°c) of hottest month	Max Temp (°c). ever recorded	Mean Min.Temp (°c) of Coldest month	Min.Temp (°c) ever recorded
Anantapur	38.1	43.0	17.2	11.5
Bhadrachalam	41.0	51.0	16.1	8.40
Cuddapah	40.3	46.1	19.1	10.6
Hanumakonda	40.8	46.7	16.1	9.80
Hyderabad	41.5	46.4	13.4	7.20
Kakinada	36.9	46.7	19.1	12.0
Kalingapatnam	34.0	45.0	17.6	12.2
Khammam	41.3	47.2	16.7	9.40
Kothagudem	41.0	51.0	16.9	9.60
Kurnool	40.0	45.6	16.6	9.30
Machilipatnam	36.5	47.0	19.4	13.2
Nandyal	40.0	46.0	18.0	10.4
Nellore	39.6	46.7	20.0	14.4
Nizamabad	41.5	47.2	13.8	6.10
Ongole	38.2	47.0	19.7	14.0
Rajahmundry	42.0	49.0	18.0	12.9
Ramagundam	42.8	47.2	15.0	8.50
Rentachintala	41.5	47.2	16.8	10.6
Visakhapatnam	34.0	45.0	17.5	10.5
Vijayawada	39.7	49.0	19.1	14.2

increasing. It is the case in India too. In Andhra Pradesh, some parts of Telangana region are frequently subjected to extreme maximum temperatures of 45°c to 50°c during summer

Table 3(a)
Decadal Mean Minimum Temperature (^{o}C)

Station	Decade			
	1961-70	1971-80	1981-90	1991-2000
Visakhapatnam	18.4	18.8	19.8	17.9
Kakinada	17.5	19.7	18.5	20.0
Nellore	20.7	21.0	21.6	21.3
Anantapur	17.9	17.5	19.3	17.6
Kurnool	17.2	16.3	18.2	17.3
Mehabubnagar	16.6	16.6	17.2	16.4
Hyderabad	13.9	14.6	15.9	14.4
Ramagundam	15.3	14.8	15.3	13.7

Table 3(b)
Decadal Mean Maximim Temperature (^{o}C)

Station	Decade			
	1961-70	1971-80	1981-90	1991-2000
Visakhapatnam	36.3	36.5	35.9	36.2
Kakinada	37.7	38.4	37.5	37.5
Nellore	39.0	40.0	39.6	39.8
Anantapur	38.5	42.4	39.5	43.4
Kurnool	39.8	39.8	40.8	40.5
Mehabubnagar	38.7	39.5	39.7	39.5
Hyderabad	38.7	38.8	39.8	39.3
Ramagundam	42.1	42.5	42.0	42.4

and extreme minimum temperature of <10°c during winter. This study observed such extreme events over Andhra Pradesh. Table 2 gives the mean maximum and minimum temperatures for the selected stations.

The mean maximum temperature of the hottest month varies from 34.0°c at coastal stations, Visakhapatnam and Kalingapatnam to 42.8°c at interior Telangana stations, Ramagundam. The maximum temperature ever recorded show that Kothagudem and Bhadrachalem recorded higher value of 51°c followed by Rajahmundry and Vijayawada with 50°c. Heat waves are frequently noticed during summer in these areas. Mean minimum temperature of the coldest month for the same stations as well as the minimum temperature ever recorded during 1961-2000 are also shown. The lowest mean minimum temperatures of 13.4°c and 13.8°c are recorded at Hyderabad and Nizamabad and higher values of minimum temperature are recorded at coastal stations, Kakinada, Machilipatnam and Nellore. The minimum temperature ever recorded also shows the same trend as mentioned above. Telangana which includes Hyderabad, Bhdrachalem, Nizamabad and Ramagundam shows extremely lower values of minimum temperature of <9°c and coastal stations exhibit higher values of minimum temperature.

The temperature fluctuations in minimum as well as maximum temperatures for every decade have been analysed and shown in Table 3. Decadal mean minimum temperature for the selected stations was calculated for the period 1961-2000. Increase in mean minimum temperature is found in some stations and some stations reported decrease. For the two decades 1961-70 and 1971-80 only three stations that is Visakhapatnam, Kakinada and Nellore recorded increase in temperature whereas the rest of the stations registered a decrease in the minimum temperatures. But in the following decade i.e., 1981-1990 all stations except Kakinada registered a marked increase in the mean minimum temperatures over the previous decade (1971-80). However this phenomenon showed a reversal when it comes to the last decade i.e., 1991-2000, wherein almost all the stations except Kakinada showed a decrease in minimum temperature over the previous decade (1981-90). Ramagundam (13.7) and Mehbubnagar (16.4) registered very low minimum temperature values in the decade 1991-2000.

There is a general rise of mean maximum temperatures in the decade 1971-80 over the decade 1961-70 for all the station given in Table 3(b). But in the succeeding decade i.e., 1981-90 only three stations namely Kurnool (40.8), Mehbubnagar (39.7) and Ramagundam (42.0) registered increase in mean maximum temperatures. This decreasing trend seems to continue into the decade 1991-2000 also where all the stations except Anantapur and Ramagundam registered decrease in the maximum temperatures. Stations like Visakhapatnam and Nellore showed insignificant increase in maximum temperatures over the previous decade (1981-90). However these values are lower than those when compared to the values recorded in the decades 1961-70 and 1971-80. So it may be concluded that the trend is towards decrease. Rest of the stations show a clear decreasing trend in the maximum

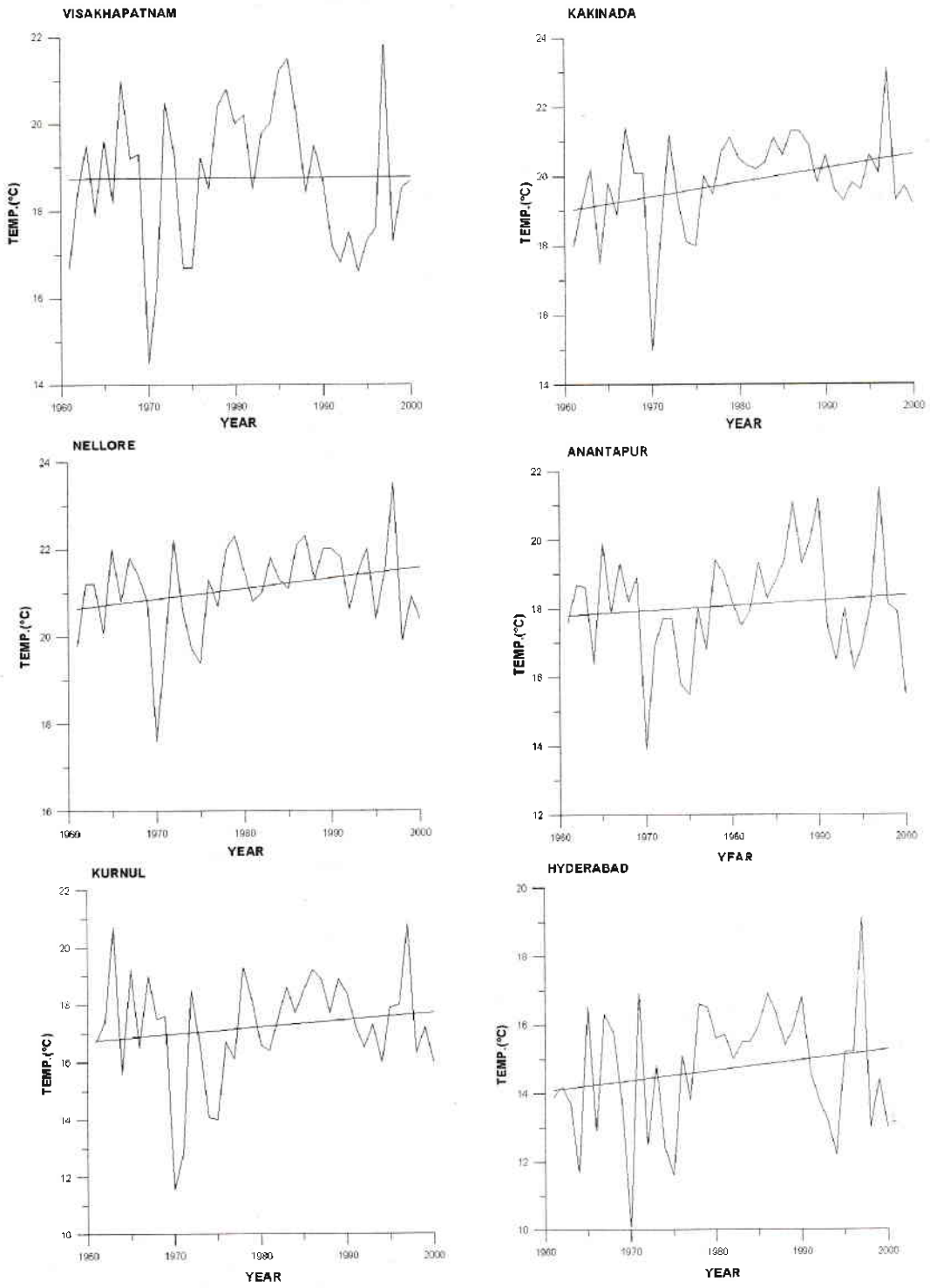

Fig. 2. Minimum Temperature Trends

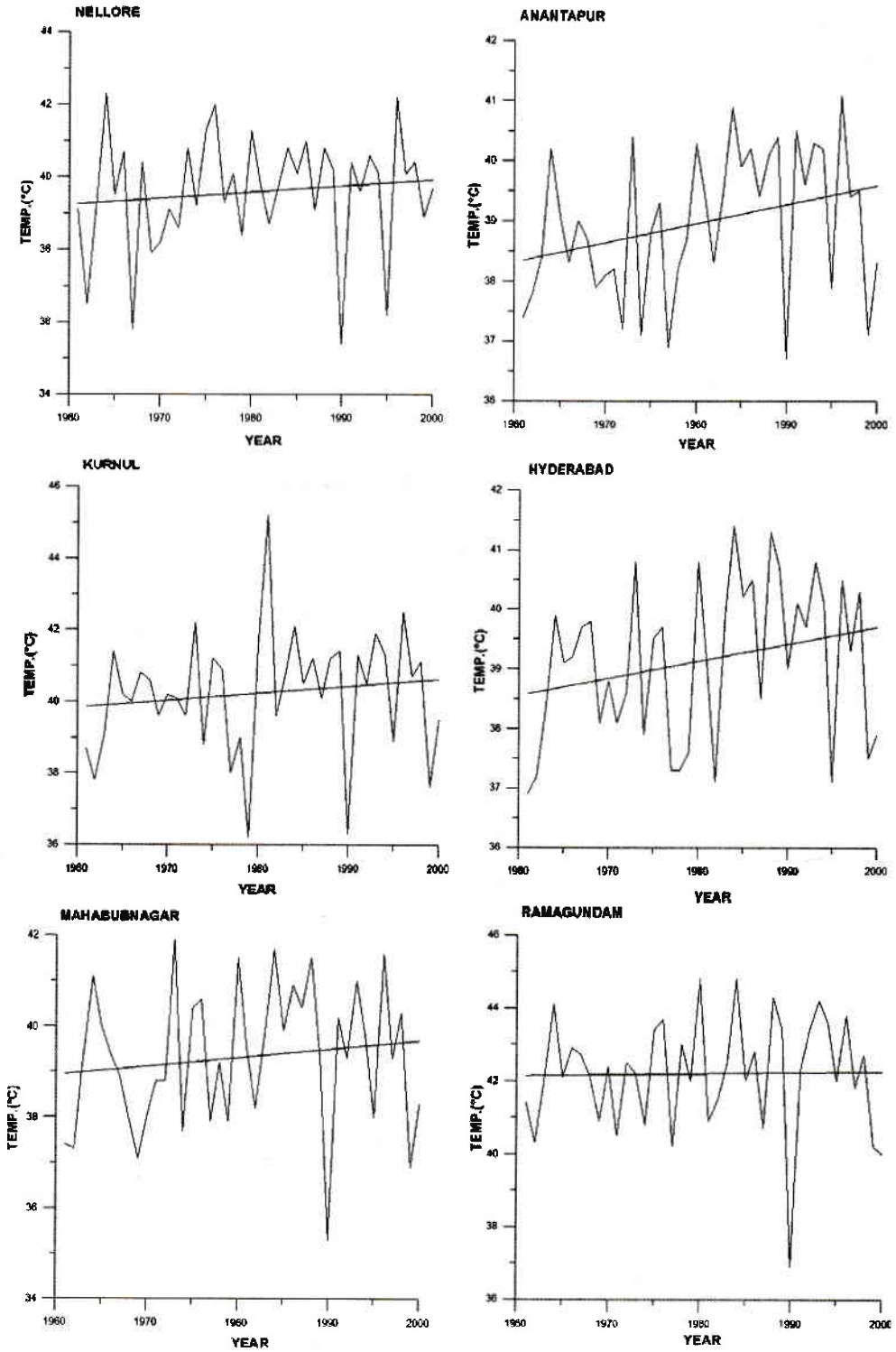

Fig.3. Maximum Temperature Trends

temperatures during the decade 1991-2000. According to the above analysis the overall trend shows a clear decreasing trend of temperature in the decade 1991-2000 for all the stations.

Trend Analysis

Trends of the maximum and minimum temperature have been evaluated by means of linear regression with time as independent variable. The linear trends are given as temperature changes in °C per decade/year. The regression analysis gives an indication of the overall tendency of the temperature.

It is observed that coastal stations such as Kakinada and Nellore recorded an increasing trend of minimum temperature and trend is significant. Kakinada shows an increasing trend of minimum temperature of 0.4°C/100 years and Nellore shows 0.2°C/100 years. Other stations like Visakhapatnam, Anantapur, Kurnool, Hyderabad and Mehabubnagar are also showing positive trends which are insignificant with least trend values.

But Ramagundam shows significant negative trend with decreasing trend of temperature i.e., 0.4°C/100 years. With regard to maximum temperature, Anantapur and Hyderabad showed positive trend (significant). The increasing trend of maximum temperature at Anantapur is 0.3°C/100 years and for Hyderabad it is 0.2°C/100 years. The remaining stations that are Nellore, Kurnool, Mehabubnagar and Ramagundam show positive trend but the trend is insignificant. Coastal stations like Visakhapatnam and Kakinada are showing decreasing trend of temperature.

Conclusions

The analysis of mean annual temperature reveals that there is a general increasing trend in the temperature during the period 1961-90. Urban centres like Hyderabad, Visakhapatnam, Kakinada and Ongole have shown an increase in the mean annual temperature. Analysis of maximum temperatures ever recorded shows that Andhra Pradesh especially Telangana region is prone to heat wave conditions with extreme maximum temperatures during summer. With regard to decadal variability of minimum temperatures the decade 1981-90 recorded higher values of minimum temperature. There is a clear decreasing of maximum temperature in the decade 1991-2000. It may be due to pre-monsoon cyclones. Trend analysis of mean minimum temperature shows significant positive trend at Kakinada and Nellore and rate of increase in temperature is high . The trend in maximum temperature indicates that Hyderabad and Anantapur exhibit significant positive trends.

References

1. Ashrit R.G and Rupa Kumar K (1999). 'Surface Temperature and Precipitation Trends at Major Urban Centres over India', *Voyu Mandal, 29 (1-4), pp. 349-354.*
2. Babu C.A and K.Mohan Kumar (1994). A Study on theTrends in Temperature over Indian Region'. Pune: IMD: Proceedings of National symposium on 'Climate Variability' in Feb.1984.
3. Banerji A.K and K.K.Sharma K.K (1966). 'Seasonal Oscillation of Daily Maximum Temperature', *Indian Journal of Meteorology*, 17.
4. Hingane L.S, K.Rupoa Kumar and B.V.R.Murthy (1985). 'Long Term Trends of Surface Air Temperature', *Indian Journal of Climate* , 1(5), pp. 521-528.

5. Jagannadhan P (1957). 'Seasonal Oscillation of Temperature', *Indian Journal of Meteorology and Geophysics*, 8.

6. Kothawale (2005). 'On the Recent Changes in Surface TemperatureTtrends over India,' *Journal of Climate, Geophysical research Letters*, 32.

7. Pant G.B and K.Rupa Kumar (2006). 'Global Warming: The Indian Context', *Vayumanadal*, 32(1-2).

8. Pramanik S.K and P.Jagannadhan (1954). 'Climate Change in India. Pat II Temperature,' *Indian Journal of Meteorology& Geophysics*, 5(1), pp. 29-47.

9. Rupa Kumar K and L.S. Hingane (1998). 'Long Term Variations of Surface Air Temperatures at Major Industrial Cities of India', *Climate Change*, 13, pp.287-307.

10. Sen Roy N and K.Prasad (1991). 'Climate Change and Global Scientific Response', *Vayumandal*, July-Dec. 1991, pp. 69-82.

Exploring the Indian Coast

Prof. B. Arunachalam
Professor of Geography (Retd.), University of Mumbai, Mumbai

Nautical Perspectives of the Tamil Ship Bell in The Willington Museum, New Zealand*

A bronze ship bell, 166 mm high and 153 mm; in diameter is in the possession of the Dominion Museum, at Wellington in New Zealand in its Maori section. The bell gifted to the museum by William Colenso is in the hold of the Museum since 1890 A.D. William Colenso who discovered the bell found it with the Maoris, who were using it as a cooking pot in a village, not visited by Europeans before. The village is near Whangerei in the interior of the North Island. The Maoris told Colenso that the bell was found in the roots of a large tree, and that it must have blown over in a storm, years before and remained there unnoticed. The use of the bell as a cooking pot seems to have cracked the lower part of the bell lip or skirt on an unknown date. This cracking may have decreased 'the height of the bell by about 40 to 60 mm.

The bell carries an inscription running almost around the circumference at the bottom, on the outer side, but it does not run the full length of the circumference. Some early workers who scrutinized the script said that it is in odd characters like shorthand. while still others opined it was Javanese. However the inscription was sent to Britain for translation and verification. In South India, the Tamil people immediately recognized the script as Tamil in obsolete style, of a bygone era. Further they testified that the upper part of the ship's bell was of a kind commonly in use in the old timber vessels. The bell was inspected by the Bishop of Dornakal in the Museum itself in 1926, by J.M. Barron of the Straits (Malaya) in 1941, and later still by Prof. Viswanathan, the Jaffna Tamil scholar, Thaninayagam, all of whom confirmed that the inscription is in Tamil character and that the bell must have belonged to a Tamil ship, wrecked

Artistic Features of the Tamil Bell

The Tamil bell is made of bronze. an alloy that is 60% copper and 40% tin. The bronze

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casting reveals that it is the worK of a skilled craftsman, as irdicated by the file marks on some of the lettering. The original bell may have been about 6 inches (160mm) high. The square structure on top was for holding the bell aloft by means of a rod. The bell on the top is worn out in the inner side. The bell is cast to be used, as a ship bell.

At the base of the square attachment on top in the centre, are two holes running through the bell, that must have been used for suspending a striker-ball (the tongue). The ball could have been attached to a cord for ringing the bell with a deep ringing tone.

In the lower part of the bell, between flanges or bands is the inscription in Tamil characters. There are 22 letters. Though some experts feel that the letters are 'welded on', in all probability they are embossed and are in good 'mint' condition.

Rear Adm. K. Sridharan of the Indian Navy read the Tamil inscription as Shikkaya Tanava Udaya Kappal and Dr. R. Nagaswamy of Tamil Archaeology Department also read it as the same, but pointed out that palaeographically, the Tamil characters are in error as to Sangam rules; the characters possibly could be

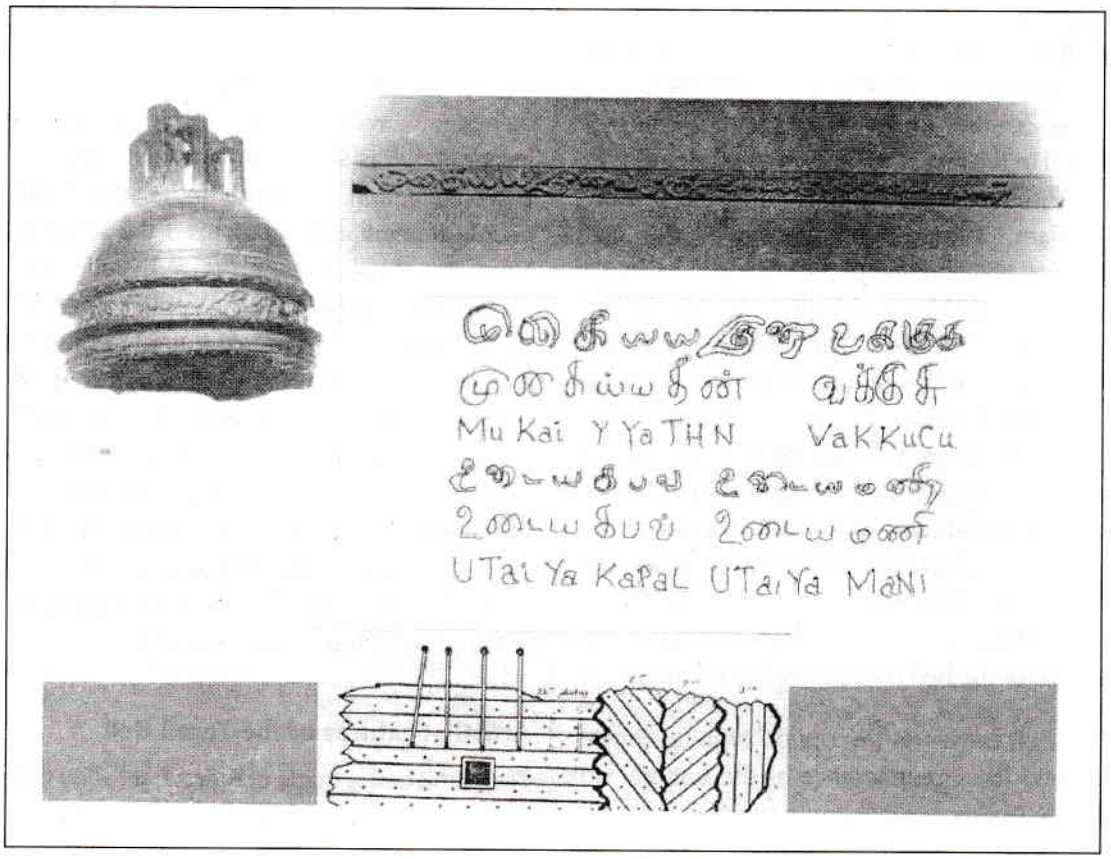


Fig. 1
The Tamil Bell and the written script around the bell at its base;
the script translated, with the Tamil text; Piece of Deck Timber washed Ashore

modern, post 15th century, notwithstanding the fact that dots (*pulli*) over some letters are missing. However, later reading by epigraphists indicate this translation is in error, and the correct rendering would read as 'Mukayathin Vaksu Udaya Kappal Mani', i.e. The ship bell of Mohideen Baksh. This rendering gives rise to two different interpretations: the bell of the ship owned by Mohideen Baksh or the bell of the ship named Mohideen Baksh. Which is correct? - difficult to answer.

If the bell belonged to a Tamil timber vessel, as it seems likely, how and when did it reach the shores of the North Island of New Zealand? While it is true that the Tamil Shipping Community had sailed in their own vessels, since Pallava and Chola times and had reached as far as Java, Timor, Philippines and South China. there is still no evidence to indicate that the Medieval Tamils ventured further into the Pacific. as far as New Zealand.

The inscription suggests that the owner was a Muslim Tamil, probably from one of the well-known ship-owner families hailing from the Coromandel coast or further South. the Ramanathapuram - Tirunelveli coast. The owner appears to be of Arabic descent. Many Arab-Tamil Muslim families have settled on this coast since at least the tenth century A D. and have been associated with maritime mercantile activities. forming trade guilds.

Epigraahists who have studied the Tamil inscription differ considerably in dating the script. Mr- Yesudas of the Scot Christian college. Nagercoil and Mr. R. Paneerselvam of the Scandinavian Institute of Asian Studies at Copenhagen have dated the script on the bell between 1400 and 1500 A.D. Prof. Viswanathan dated it as between 1440 and 1540 A.D. A Tamil monthly named Aaraichi (i.e.Research) dated July, 1971 quoting from a Soviet journal has stated that from C14 dating, the date of the bell is estimated to be around 15th century. The date of the bronze metal cast is also dated around 1450 AD. Rear Adm. Sridharan affirms that the bell is of Pandyan origin, though he cites no evidence to substantiate his view-point. Dr. Rasanathan, President of the International Movement for Tamil Culture. at Auckland, in New Zealand is of the view that" without any shadow of doubt, it was the Cholas and only the Cholas who brought the Tamil bell to New Zealand."

More recent analysis seems to suggest otherwise. The bell could have been of a later date, 17th or 18th century, since the script appears more akin to post-seventeenth century Tamil. The inscriptional Tamil, without the use of dots (pulli) could have been very well on account of embossing on metal, thus introducing grammatical incorrectness. The question of how the Tamil bell got to New Zealand has never been satisfactorily answered. Before 1400 A.D., the maritime trade with Java was in the hands of the Tamils, and the Tamil shipping reached as far as Bali, Lombok and Timor, but not beyond in the Pacific. Robert Langdon propounds a theory that the bell was taken as a souvenir from East Indies to Spain and later brought to the Pacific in a 'lost caravel' that was wrecked in the Tuamotu islands; and somehow found its way to New Zealand. This theory appears far-fetched, though the date could have been around 1550 A.D. Brett Hilder, who did much study of the bell suggests that the bell belonged to an Indian Ocean ship, and that the ship had become derelict, probably abandoned,

dismasted and waterlogged. The abandoned vessel could have drifted about 8000 km to the West Coast of New Zealand over a duration of time. He further states that the bell belonged to the ship of Mohideen Baksh. The 'derelict theory' is sustained by the fact that derelicts are carried by the permanent currents circulation, such as the Southern Oceans Drift. In support, Hilder gives two examples of an unmanned life-boat and a water-bottle from South African Coasts having reached the Bass Strait. He also quotes the example of the wreck of a Mahogany ship from Victoria in 1890 towards New Zealand. However, no example of a massive long distance movement of a wreck is known.

John Tasker talks of a mystery wreck of Ruapuke beach. The Raglan County Chronicle of January, 1903 details an old wreck in a nearby beach, identified by the Maoris as lying there for over 80 years, even long before the arrival of Capt. Cook. Mr. T. B Hill procured in 1875 a timber piece of the wreck and found it to be teak. It is surmised that the bell with Tamil inscription came from this ship. From the wreck. a few old timber planks and an assortment of copper and brass bolts have also been identified. Local historians found portion of the deck and sides of a large teak-built vessel. The side timber was built in three layers on the diagonal principle, and the planks were fastened together with tree-nails or wooden screws and strengthened with brass bolts. No iron nails were used in the construction. When the wreckage was sighted in 1892, an estimated 50 square feet of the deck was examined and found to be made up of "five thicknesses of two inch timber at 45 degree angle, with the top and bottom planks parallel." Copper bolts and lignum-vitae screws had been used. Individual planks were 6 to 9 inches wide. The heavy beams and timbers were secured with large brass bolts of unusually good quality measuring 87.7 cm. long and each weighing nearly 6.35 kg. The ship's bell had been stripped from its position. and just below where it should have been was a bronze plate inscribed in Tamil characters. Here is a tangible piece of evidence with the potential to prove a pre-Cook Tamil vessel wreck. The bronze plate was removed from the deck by Mr. Hill, placed in a box and sent to Auckland museum for deciphering the script, but unfortunately this priceless plate has totally vanished without a trace and has never been seen again. Mr. Hamilton who had examined the plank joinery, talks of the use of caulking and from his observation makes a pertinent remark that the ship can be dated post-1800.

The remains of the wreckage of the vessel lay nearly covered with sand at the mouth of the Toreparu river. The vessel was some distance from the high tide level of the shore. The wreckage has been repeatedly sighted in 1890. 1893. 1902. 1912 and 1944. Each time it got exposed, it has been studied. and brass bolts and tree nails removed.

A million dollar question is whether this Ruapuke beach wreck is the same as the Mohideen Baksh carrying the Tamil bell. It is yet not certain, since much has been lost from the wreckage, due to the treasure hunters' plunders. Since the wreck site in the Ruapuke beach is on the west side, and the site of the bell, Whangerei is near east coast of the North Island, it is not clear how the bell reached the east coast from the west-side. Possibly a curious Maori treasure hunter took it from the wreck and threw it away at the site where it

was found; it is also possible that the current circulation could have carried it over along the coast.

Before answering the question how the wreckage and bell reached the New Zealand coast. it is necessary to consider the ownership of the vessel and its date. All along the east coast of Tamil Nadu there are a number of Muslim Marakayar (corrupted from Marakala rayar. i.e. ship owners) settlements. in which there were many rich merchant families engaged in overseas trade. peari diving and fishing enterprises. They used tc trade on a number of commodities with East African and Arab ports on one hand. Sri Lanka, Malaya, East Indies and beyond on the other. Since 1658 A.D the Dutch Colonial traders had established a prosperous spice trade with East Indies. and were operating from the Tamil coast, often with the aid of Marakayar merchants and their shipping vessels. A Dutch trader by name Jane de Muttu Aquaris operating from the port of Pazhaverkadu (Pulicat) in partnership with a marakayar Meer Mohamad Shaft in early eighteenth century had spice trade with Java through a ship named Mohideen Baksh.

This ship was on a regular trade charter with Pazhaverkadu and Nakapattinam on the Indian side with East Indies on the other. Could the bell have come from this ship ?

K Rajan of the Tamil University, Thanjavur gives an interesting account that a descendant of the Marakayar family, hailing from Marakayar Pattinam near Vedalai on the Ramanathapuram coast, by name O.M.S.K. Marakayar (now deceased) had filed a litigation against the New Zealand museum claiming ownership of the bell. No further details are available regarding the case details.

Idris Marakayar of Kilakarai talks of a number of shipping magnates in the Marakayar families between 15th and 19th centuries. One of them, Habib Marakayar who lived in the end of the 18^{h} and beginning of 19th centuries, had a prosperous sea-trade with Sri Lanka, Arabia, Aden, Malaya and the East Indies. He was the owner of 40 ships, most of which were engaged in Indo-Sri Lankan trade. But two of his vessels, Mohideen Baksh and Kadir Baksh were on charter to transport cargo between the Tamil coast and Java and further Indies. He further adds that the vessel Mohideen Baksh was caught in a severe storm off Java and was lost. No further details are known. It is also known that the ship Kadir Baksh was built in Nakapattinam. Possibly the Mohideen Baksh was also built there, but the main lacuna is absence of official records. Family records may give some clues

The Jaffna Tamil scholar, Late Mr. Thaninayagam who had visited the New Zealand Museum in mid-twentieth century makes a significant observation that the Tamil inscription embossed on the bell carries one more word below the main line. He reads the word as 'Marakayar'. How this word was missed by earlier observers is not clear. However this word adds substance to the view that the bell belonged to a Marakayar Ship.

From the above analysis. it is nearly certain that the vessel carrying the bell was of a later rather than an earlier date. in all probability late eighteenth century The ship carrying the bell belonged to a Tamil Marakayar family.

The last issue to be settled is to know how the ship reached the New Zealand coast If the

belief that the ship was lost off Java in a storm is correct. The derelict or abandoned vessel could have very well drifted. Caught in the South Pacific-Australian current circulation running South, the wreck could have been carried as far as the West Coast of New Zealand. Since the seas here are a 'trap' the drifting wreck could have been washed ashore on the Ruapuke beach_The distance from Java is considerable and the drift may have taken many decades.

There is yet another possibility. The Dutch and the British were in the eighteenth century, procuring mast timber of huge size for their 'tall ships' from Norfolk Island, just north of New Zealand. The `Mohideen Baksh' may have been on a Dutch contract. and sailed further east beyond Java and could have wrecked near Norfolk Island. If so. the drift distance is short, and quite likely.

In conclusion, it may be noted that the Tamil Bell of Willington Museum and the wreck of the ship that carried it are still unresolved mysteries. Many views have been expressed but doubts linger. Perhaps future may provide a positive answer.

Acknowledgement

Grateful thanks to late Vice Admiral V.E.C. Barbosa (Indian Navy) for inputs of immense value in the preparation of this paper.

References

1. Aaraichi (1971). `The New Zealand Bell', (*July Issue)*
2. Aarasaratnam (1986). *Merchants, Companies and Commerce of the Coromandel coast, 1650-1740.*
3. Hilder, Brett (1975). `The Story of the Tamil Bell', *Journal of Polynesian Society*, 84.
4. Idris Marakayar (in Tamil) (1986). *Glorious Kilakarai.*
5. Langdon R (1973 -74). `The Lost Caravel' *Nautical Magazine.*
6. Tasker J (1998). The Mystery Wreck of Rupuke Beach' in Tuhfat-ul-Mujahidin : *Myth and Mystery*

Environment and Ecology of Coral Reefs of the North Coast of Saurashtra

Ever since the voyage of Charles Darwin in the H.M.S. Beagle (1832-36) and his observation on the coral islands of the Pacific and the Cocos Keeling atoll in the Indian Ocean, the distribution and characteristics of the coral reefs and islands of the tropical Indian seas have received much attention. Moresby and Powell conducted a survey of the Maldives and Lakshadweep archipelagoes (1835), and Foote (1889) called attention to the existence of a raised reef in the Rameshwaram island that lies in between India and Sri Lanka as the surviving remnants of an old fringing reef. Seymour Sewell (11) wrote on the coral coasts of India, and mentions ``throughout the tropical region, coral growth is abundant, and in Indian waters we have numerous examples of coral reefs of all kinds. Around peninsular India itself, there is except for a small length of coast at the extreme south end, an absence of

such reefs owing to the effects of fresh water and mud brought sown by the rivers". None of the workers like Krishnaswamy (8), Ahmad (1), Hari Narain *et. al.* who have investigated the Indian coast mention the occurrence of coral reefs elsewhere on the mainland coast of Peninsular India. Chatterjee, Chapghpar (2), and Stoddart (14) make passing reference to the corals of the Okha, while Srivatsava and Gupta have attempted dating of dead coral reefs on Saurasthra coast. This study analyses the distribution and the morphology of the coral coast of Saurashtra in its environment and ecological setting.

The north coast of Saurashtra overlooking the Gulf of Kutch to its North extends over a west to east coast of 150 km from Okha headland on the Arabian Sea front to the Jodiya Bandar at the entrance to the Little Rann. The coral reefs and islands lie between 22° 20′ N and 22°47′N and between 68°55′E and 70°15E on a low marshy coast.

Coral reefs and islands associated with them are built by hermatypic corals living in polyps under ecological conditions that permit the growth of the corals and algae. The coral reefs that skirt the shores of the north coast of Saurashtra are essentially of two types (i) *Fringing reefs* that rim the northern littoral of the mainland coast facing the Gulf of Kutch and a limited stretch of the Okha headland, facing the open Arabian Sea, and (ii) *the Insular platform reefs* of varying sizes that lie off the shores in shallow waters.

Local traditions identify these types of island on the shores: the *beyt* or *bet* is an offshore island, a detached outlier of the mainland, often a rock platform, well above high tide level; the *tapu* is a low sand shoal or mangrove, almost at sea-level, partially or fully flooded during flood tide; this often forms the nucleus around which the coral island is built; and the *kudda* or *kadao* invariably a coral reef awash during the high tides.

The Fringing Reefs

The coast of Okha headland facing the Arabian Sea and running south towards Dwaraka is cliffy, and is developed over miliolite limestones and the older Gaj beds. Around Dwaraka, the sea-cliffs are fronted by a rocky wave-cut platform, a kilometer wide but with no corals. From Kachchigadh about 8 km,north of Dwaraka till the Humani Point of Okha, a fringing reef—*The Armada Reef*-skirts the coast and runs SW-NE at a mean distance of a kilometer from the shores. Where they are the widest off Armada, they extend upto 3 km from the shore. The inshores between the reef and shore dunes is a low platform strewn with coral mud and dead corals and blown off algae. It forms a back water ½ a metre deep at half tide. Over the reef, the flood stream runs north with a speed of 2 km and the ebb runs south – south – east at about the same rate. Towards the north, the tidal stream becomes stronger and the heavy tide rips caused around Okha headland - the sea breaks even in calm weather– result in the reefs fading out, possibly because living corals cannot remain attached to the floor under the intense tide rips.

To the immediate east of the Okha headland, the sheltered shallow Positra and Pindara bays and the Okha Rann in between have no corals, living or dead. Along the eastern rim of the Pindara bay, patches of the dead coral reefs occur, partially sunken in the mudflats fronting the bay. From here upto Bedi Bandar, extending over a stretch of over 30 km, the

mainland shore has a front of a continuous reef, backed by a muddy reef flat : a few bets such as the Roji bet, the Narara bet, Didi ka bet, and Pirotan lie in this reef flat section. Known in parts as the *Gandhiya Kadao* off Dhani bet, the *Narara reef* off Narara, *Munde reef* off Bedi Bandar, these fringing reefs have waters of variable depths in their foreground, but never exceeding 10m. Most of this reef is dead except in sections having a relatively deeper front and a more open exposure to tidal currents. The dead coral reefs not only fringe the coast, but are also found extending inland upto high tide level near Salaya, Bedi, Chudeshwar and Mungani. The Sinclair reef consisting of dead corals that dry lie on mudbanks at the entrance of Salaya creek. A kilometer west of Rozi is a detached reef dry even at low water. Nowhere the dead reefs occur beyond 2 km form the low water limits.

Each of Bedi Bandar, the shore recurves northwards towards Jodia Bandar and beyond. Here too, coral banks have a continuous front off the shore at a distance of about 4 km to 6 km from the shores. The reef that is behind the reef edge is muddy, but is being steadily invaded by the tidal marshes and mangroves from the land end. The waters in the foreground of the reef are shallow, not more than 4m deep with projecting rock masses dotting the floor.

The Platform Reefs

Off the Okha island, at the entrance to the Positra Bay lies the conch shaped Beyt or Sankhodar, a rocky limestone tableland in the south, with a sand spit protruding on its leeside towards north-east in the direction of the running tide. It had no skirting reefs. At the open end of the spit, under its protection from strong tides and heavy monsoon breaking is a foul ground, *the Hanuman danda Reef* in shallow waters, not exceeding 5 m at any time. It is an active growing area of present day coral polyps. Three km north of the Beyt, and 5 kilometre NE of Okha is the *Chandri Reef* with a sand cay in its core, covered at high springs on its southern side. The part of the reef that dries stretches more than a kilmetre. To the south of the reef, the slope is steep descending the navigable channel 10 m deep. The 16 km long Gururdan shoal with a depth of water 7 m to 20 m on it lies due west of this reef. Heavy breaking occurs during the monsoon on the shoal that lies at the entrance to the Gulf, but the Chandri reef on its lee gets sheltered. The *Paga* or *Turtle Reef* oval shaped and 6 km long NE-SW, is due east of Beyt about 6 km south-east of Chandri. It also has a sand cay on its western side, covered only at high water springs. The reef gets exposed during ebb and half tides; however the northern lip of the reef never shows above water. To the south of the Paga reef and midway between it and the Positra headland on the mainland is the *Boria reef*, sunken in the muds and is also insular, covered only during high tides. A smaller island reef in shallow waters lies a kilometre north of it.

Four kilometres to the east of Paga reef, and separated from it by a navigable channel, 12 m to 18 m deep is the largest insular reef the *Bural* or *Chanka reef*. The north face of the triangular reef is 16 km long the west face about 14 km and the third, NE-SW face about 20 km. The reef is built surrounding four *tapus* : Nora and Chanka in the north, Bhaidar in the middle and Chusna in the south. After the first quarter ebb, the fringing reef begins to show : the whole reef and reef flat, excluding the islands are covered

at high water. The north face of the reef is steep, descending to the Gulf at the bottom at depths 20 m to 30 m. Along this north face, the tide runs east (flood) and west (ebb) at a rate of 4 to 7 knots, causing heavy tide rips at the north- east end of the reef.

Six km south of the Bural reef,is the small rocky bluff, Ajad 2 km high surrounded by a coral reef except on the south-east where a narrow strip of drying mudbank extends from a high watermark of sands. The *Vudda Kudda* reef of 4 km south-east of Bural reef and 7 km northeast of Ajad consists of three etatched drying reefs ; a navigable channel. 10m deep separates this reefs from the Bural. The *Gunjao Kudda* around the Panero tapu lies southwest of Vudda Kudda close to the mainland shore, and separated from it by a narrow inlet barely 2 km deep. It overlooks the fringing reef near Roji bet.

Further east, beyond Dhani bet, and just outside the harbour channel of Salaya port lies the *Karumbhar reef* skirting the shores of Karumbhar Tapu a low sand ridge covered with scrub jungle. The reef consists of hard dead coral and a reef flat of the soft muds. The flat is covered with water 1 to 2 m deep at half tide. The reef is continuous to the north and west of the Tapu, the directions facing the running tide, and has steep flanks on both the sides descending to a depth of 15m to 20 m. To the east and south, the sides facing the mainland shores there are no reefs.

Off the harbour of Sikka port, about 15 km east of Salaya, and to the east of the Sikka channel is the Goos reef 5 km by 3 km on a prominent sand cay flat that dries before the reef itself. About 2 km, west of the *Goos reef*, lying right abreast of the Sikka channel is the tiny *Siri reef*.

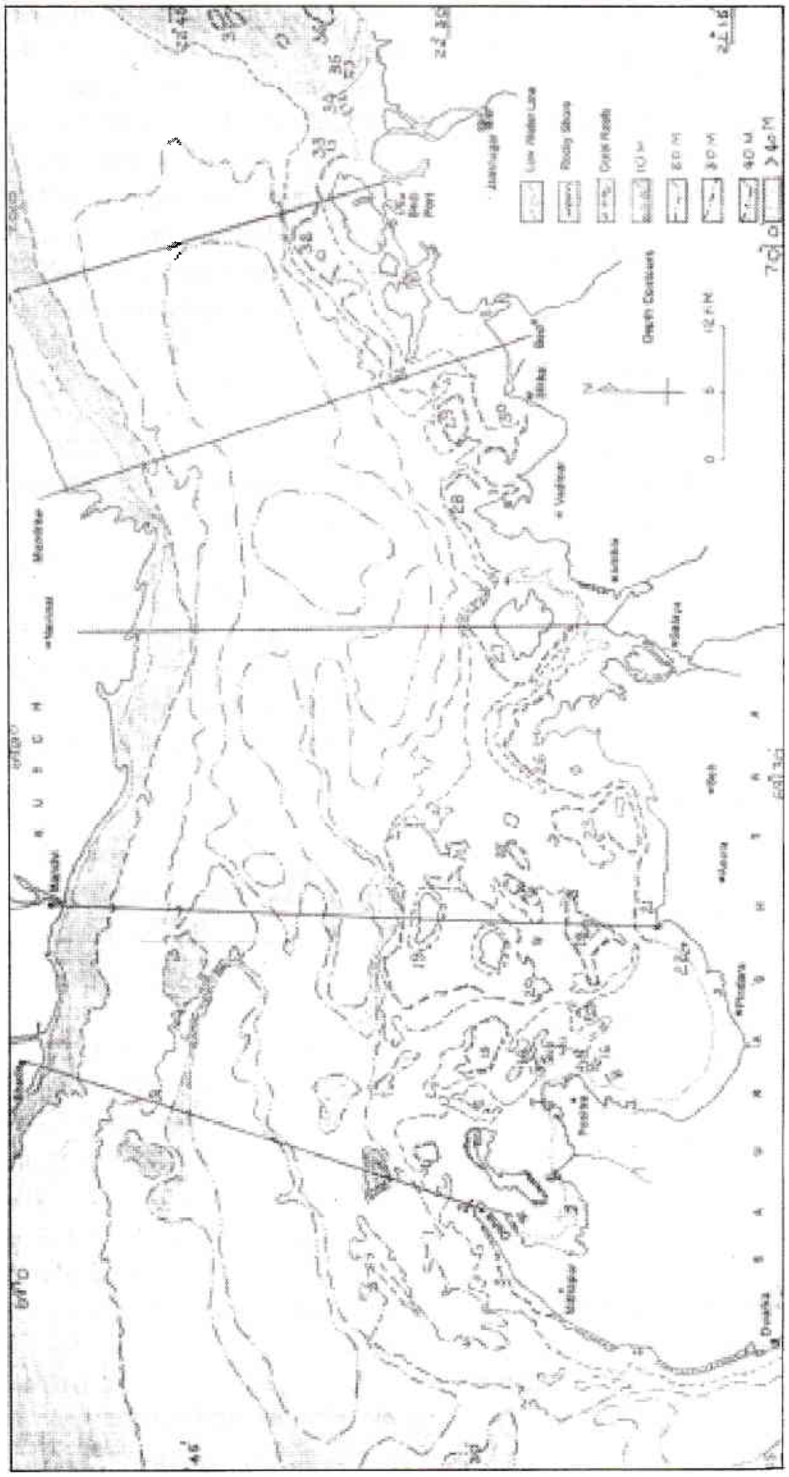
East of the Goos reef, not many island reefs occur. Off the prominent knoll, Aku Pir, occur three small island reefs known as Balachadi rocks, about 5 to 7 km off the shore and just outside the edge of the rocky platform and the fringing reefs. *The Mungra reef* 10 km, further north and adjoining the shoal waters leading to the Little Rann is the eastern most of the coral reef. It forms a westward projecting spur of a sand and mud flat at the south end of the Rann entrance. The western reef face dries first in ebb tide.

A careful scrutiny of the distribution of both the fringing and insular platform reefs in the Gulf of Kutch shows that coral reefs characterise only the southern part of the Gulf adjoining Saurasthra and that no coral formations occur along the northern side of the Kutch shores, through the distance separating the two shores does not exceed 40 km. All the coral reefs are bound by the 10 m depth limits. As soundings in the Gulf reveal, the floor of the Gulf at depths of over 10m (but never exceeding 50 m) is sandy and muddy and is remarkably free of any coral, barring the coral debris collecting at the foot of the reef face.

The corals of the region are massive, hard Madreporarian type belonging to Astracidae and Fungaide families. Corals of the staghorn (Merulina Laxa) and leaf branching type are rare, the brain coral (Gonaistrea retiformis) is more common. The generic diversity of corals of the Gulf of Kutch is low, barely 18 as against 29 in Lakshadweep, 32 in the Palk Bay and 66 in Maldives.

Environment and Ecology

The ecological conditions that permit the growth of the coral polyps and that too of the



Note: Numbers 1 to 37 are Coral Islands

Fig. 1. Gulf of Kutch showing Depth Contours, Coral Reefs, Rocky Shores and Locations of Cross Profiles

hardier, massive types only on the southern but not on the northern side of the Gulf calls for and explanation. The prevalent sea temperatures of 21°C in January and 27.5 °C in May- June in the Gulf, a shallow sea bottom, not exceeding 50 m in depth in any part of the Gulf, absence of fresh water river discharge and consequential low turbidity of water. Sky conditions that are clear for most part of the year except a few cloudy days during the monsoon, a salinity varying between 32 (Feb.) and 38 (Dec) a calcium carbonate content of less than 10 per thousand in the sea salts, and a low sub-colloidal matter content in bottom sediments are all features conducive to active coral growth shared by the whole Gulf area. But, other physical conditions vary between the two coasts. The Kutch lowlands adjoining the Gulf are covered by Quaternary alluvium and Aeolian dune deposits of recent origin, and the sea adjoining has the presence of a large number of shifting sand shoals, that shift in position with the seasons. On the other hand, the north coast of Saurashtra in the West is underlain by limestones and marls belonging to the Gaj and Dwaraka beds, capped by a littoral concrete that is calcareous grit. In the east, a basaltic rock plain overlain by quaternary marine, estuarine and fresh water deposits occur. While muds, sands and sandstones are possibly too friable to permit permanent successful colonisation by organisms like corals, calcareous substrata are the most ideal for such organisms that bore by means of acidic secretions (15).

Sea-conditions too are more conducive to coral growth in the southern parts of the Gulf. A scrutiny of the meteorological conditions of the coastal stations reveal. Variable light and north west to east winds blowing in the Gulf between late October and February. The dominant destructive waves and swells thus progress from the southwest, with considerable consistency, and break heavily on the northern shores and the sand shoals that lie close by stirring from the bottom. At the head of the Gulf, the maximum spring tide ranges are about 6.5 m and the mean spring ranges between 3 and 4.5m higher on the Kutch shores more directly exposed on the northern shores, than on the southern sections. Also, the main tidal stream running east with the flood and west with the ebb with a speed of 4 to 7 knots runs closer to the north coast. At the north-east end, tidal bores develop. The flood current here is stronger than the ebb. Heavy tide rips and overfalls thus are more common in the north of the Gulf., while the tidal streams running in between the islands in narrow channels in the southern parts is very much arrested in velocity, 2 to 3 knots. It is the dominant wind and wave coupled with the sand shoals explain the absence of corals in the North of the Gulf.

Within the southern section of the Gulf, adjoining the Saurasthra coast, active present day growth of the coral polyps is associated with the insular platform reefs, rather than the fringing reefs along the shores. The islands on the western parts, and that on the north and west faces are more alive than those on the east. The island reefs closer to the mainland shores have reef faces on the western and northern sides, but on the southern and eastern faces have only mud banks, with remnants of desolving dead corals. The availability of nutrient and algae supply, and oxygen circulation explain these variations. Also, it is noted that the reef face of the fringing reefs are relatively at a higher level in the east, i.e the

Munga and Balachadi reefs with a mangrove vegetation rapidly colonising them. On the other hand, the reef flats backing the fringing reefs around Salaya, Sikka and Bedi are invaded by tidal waters, 1 to 2 m deep after the half tides. On the other hand, remnants of the older , dead reefs are seen at or about the high tide level. Thus it is clear that the active growth is steadily progressing westwards, as dead reefs gather in the eastern, more sheltered areas. Also three levels of reefs, though not very much varying in elevations, are identifiable from the mainland shore outwards into the Gulf.

Morphology of the Coral reefs

In a system of taxonomical classification of reefs put forth by Maxwell (1970), the fringing reefs of north shores of Saurashtra belong to the `wall reef' type and the off-shore islands to the elongate platform reef' type. The morphology of both tyoes of reefs of the Gulf can be studied form profiles across the Gulf and imagery analysis of individual reef areas.

The intra-tidal section extending from the dry main land to the outer edge of the wall-reef reveals distinct ecological zonation and morphological distinction according to the location in relation to the tide. The littoral fringe on the immediate land edge in the upper sections of the inter tidal zone, reached only by the higher tides, and of a variable depth of about half to one km is invariably a mangrove characterized by species such as *cher* (Avicennia officinalis) *karod* (Rhizophora Senegal), *kunri* (Coriops Candollecena), pilu (Salvodara Persica), *garod* (Acacia Salvadora Oleoides), *desi baval* (Acacia Arabica) *Saladi* (Boswellia Serrata) and *jar* (salvadora Oloeides), The invasion by the colonizing vegetation is in a more advanced state in the eastern parts around Jodiya Bandar. Beyond this mangrove belt is a much wider reef flat in the eulittoral zone, of width ranging between 3 and 6 km covered with muds and silts of a uniformly fine texture, littered with dead corals and patches of remnants of dead coral reefs about a meter above the low tide level in the neighbourhood of Pindara, Bet and Salaya. This zone has a characterisitic association of Penicillus, Hacimeda, the calcareous red algae Lithothamnion, foraminifera, barnacles and limpets. Attached to the dead reefs in places occur oyster beds, that have been commercially worked for pearls in the past. The back reef and the reef flat zone covered with smoothly creeping in sea-water.after half tide is a belt of weak wave action. However photosynthesis increases towards the seaward margin of the reef flat. The whole reef flat presents the appearance of a wave abraded surface with a veneer of coral muds.

Beyond this eulittoral zone, at its edge the fringing reef proper develops, presenting a steep face seaward, as the floor falls to depths over 5 m. The reef has an algal ridge on the top, resistant, calcitrant corals *in situ* below and coral rubble and debris at the foot of the slope.

While the back reef zone has a restricted coral growth of Favia favus, favotes melicerum and Montipora informis, the mid-reef zone has a richer growth of Porites. Favis favus Pavona varians, siderastran radians and others; the seaward reef zone is the most active with a far greater abundance and genetic diversity. The insular platform reefs are slightly different in morphology. They have a far more profuse growth of all genera found in the Gulf. Most of

them are elongate in the direction of tide flow, with growing protrusions on more open western and northern faces. In case of larger reefs like the Bural, Karumbhar, Gunjao Kadao and Ajad, the reefs are built around pre-existent island nuclei, well above tide level. Other smaller ones have sand cays in the core, at times partially above tide level, and hence higher than the reef. Mostly, the sand banks are washed during flood tides; they are invariably on the western or northern side of the reef. The oval platform reefs also possess flats behind them covered with mud and decaying corals. The sheltered back reefs have a higher content of hard corals. (Goniapora planulata). The reef front with active living corals falls to deeper levels through steep slopes especially so on the northern and western faces. The inner platform reefs on the east of the Gulf have no reefs on the eastern and southern faces and have wider mud flats on the back reef.

The coral environment of the north coast of Saurasthra is under siege and is being fast degraded. The damage and destruction of the mangroves unheeded, for a variety of reasons is exposing the coast to intense tidal activity that leads to the disturbance of the coral coimmunity. Dredging activities in and around the coral reefs and islands not only increase the turbidity of water but also undermines coral colonies. Industries especially cement around Sikka and Jamnagar and oil terminal at Vadinar with potentials of oil-spill present for ever are other contributing factors. A concerted effort is warranted to conserve the coral environment of the Gulf of Kutch.

References

1. E. Ahmad (1972). *Coastal Geomorphology of India.* New Delhi : Longmans.
2. B.F. Chapghar (1972). `The Wonderful World of Corals` *Science Today*, June 1976.
3. R.W Fairbridge *et. al.* (1966). *Reinholdt's Encyclopaedia of Oceanography.*
4. R.B. Foote (1890). `The Coral Reefs of Rameshwaram Island' (Scot. Geo. Maz. 6)
5. S.K. Gupte (1972). `Chronology of the Raised Beaches and Inland Coral Reefs of Saurashtra', *Journal of Geology*, 80.
6. Hydrographer of the Navy (1975). *West Coast of India Pilot* (11th) edition).
7. M.S. Krsihna (1968). `The Evolution of Coasts of India', *Bulletin of National Institute , India*, 38
8. S. Krishnaswamy (1954). `The Coasts of India', *Indian Geographical Journal*, 76.
9. P.H. Kuenen (1950). *Marine Zoology in India.* New York: Wiley.
10. G. Mathai (1928). `Report on Madreporanian Corals in the Collection of the Indian Museum', *Memoirs of the Indian Museuam 8 pp. 1924 - 1928.*
11. R.B. Seymor Sewell (1932). `The Coral Coasts of India', *Geographical Journal*, 76.
12. B. K. Srivastavs (1968). `A Note on Quartenary Geology of Saurashtra Peninsula', *Quarterly Journal of Geology, 40.*
13. D.R. Stoddart (1978). ` Descriptive Reef Terminology' in D.R. Stoddart and R.E. Johannes (ed.) *Coral Reefs : Resesarch Methods.* UNESCO.
14. D.R. Stoddart (1969). `Sea Level Change and Origin of Sand Cays : Radiometric Evidence', *Jounal of Marine Biology*,11.
15. J.D. Taylor (1978). `Zonation of Rocky Intertidal Surfaces in Stoddart and Johnannes'. *Coral Reefs : Research Methods.* UNESCO.

The Enigma of the Lost Pahruli – A Nautical Enquiry

The Post-Tamil *Sangam* epic `*Cilapadhikaram*' dated to a period 2nd to 5th century A.D. talks of the loss of *Pahruli* river together with *Kumari-Kodu* due to engulfing by a cruel sea. An earlier *Sangam* period work `*Kalithogai*' also refers to the loss of Pandyan territory to the sea. Though some scholars have interpreted Kumari-Kodu as the Kulwari Hill peak, adjoining a `cluster of hills', the more logical meaning of `Kodu' as sea frontier (as for example Kozhikodu) seems to apply here. The loss of land around Kanyakumari at the land's end of the Peninsula, and the submergence of the lower Pahruli river mouth seem to be indicated.

An early commentator of `*Cilapadhikaram*' (PeraSrayar) mentions that a single district of `Pannadu' alone went under the sea, together with the Kumari fringe and he locates the Pahruli river close to Kanyakumari. A much later commentator Adiyarkunallar, of about 13th century, however talks of the loss of 49 *nadus* stretching over 700 *kadams* (1400 miles) south of Kanyakumari, without any substantiating facts. This latter geophysically untenable assertion can be ignored as poetic symmetry and legend rather than truth.

Tennet in his `History of Ceylon' makes references to the local Chronicle, Rajavali that mentions three tidal inundations in south and south-west Ceylon, the last of them being 306 BC. The other chronicle Mahavamsa however places the last tidal flooding around BC 200. The epic `*Manimekhalai*' written about the same time as `*Cilapadhikaram*' mentions the destruction of the premier Chola port, Puhar (Kaveripattinam) on the Coramandal (Chozhamandalam) Coast. Tidal surges, accompanying severe cyclones and tsunamis are a regular feature of the east coast of India and it is perhaps one such tidal devastation that brought about the washing away of the lowlands around Kanyakumari, during a period of human memory, preceeding the two Tamil epics.

Both the Periplus and the Ptolemy make reference to the loss of land in the Pandyan territory, Paralia, beyond the Chera country of Quilon and Kottayam. Obviously *Paralia* is the corruption of Pahruliar.

While the historical literary references provide evidences of the loss of land around the southern tip of the Indian peninsula, they need to be substantiated by physical evidences above and below the seal-level in Kanyakuamri neighborhood. The present paper seeks to probe such physical geomorphological evidences, especially below the present sea-level. This will incidentally demonstrate the value of nautical data in coastal probes.

Ground Evidences above Sea-Level

A short stream 40 km long by name *Palayar* (meaning `old 'river) enters into the sea 8 km west of Kanyakumari. This river rises in a saddle between the Mahendragiri in the north, Tadakamalai in the east and Kunnallimalai in the west. It flows south past the townships of Nagercoil and Suchindram to enter the sea through a wide tidal lagoon of Manakudi. Though a seasonal stream, its estuarine mouth is characterised by tidal waters, almost 5 km upstream and at present has extensive salt pans

on both banks. The area including the salt pans and lands beyond, is known as Tamaraikulam (i.e Lotus Pond) probably indicative of the fresh water stagnation in the historic past. The river course in this stretch is aggraded. Also the landscape beyond the immediate river bank is dotted with linear tank depressions. These are quite suggestive of past valley subemergence, followed by an aggradational sequence. The immediate sea-front is a belt of sand dunes stabilized on the land side by palm vegetation. This belt is breached by the tidal lagoon of the river with shitting sand bars on either side, dry during the ebb tide. However, there is no evidence of rejuvenation entrenchment in the lower course of the river to indicate a fall in the base level of erosion i.e. the sea-level. Thus, the loss of coastal land to the sea appears to be a consequence of short-lived catastrophical tidal deluge, rather than a long enduring tectonic or euctatic change during the historical past.

The tank depressions on either side of the river form the boundary limits of a wide river valley of the past, within which the present stream channel winds its way south. This wide valley zone extends upstream to Nagercoil and beyond. It could not have been carved out by the present small stream. In short the river is under-fit and the wide valley, a mis-fit. The Palayar thus could very will be the Pahruli of the classical literature.

The shoreline from Kanyakumari in the east to Muttanturai of Kadaiapattanam on the west over a distance of 25 km is low, straight and

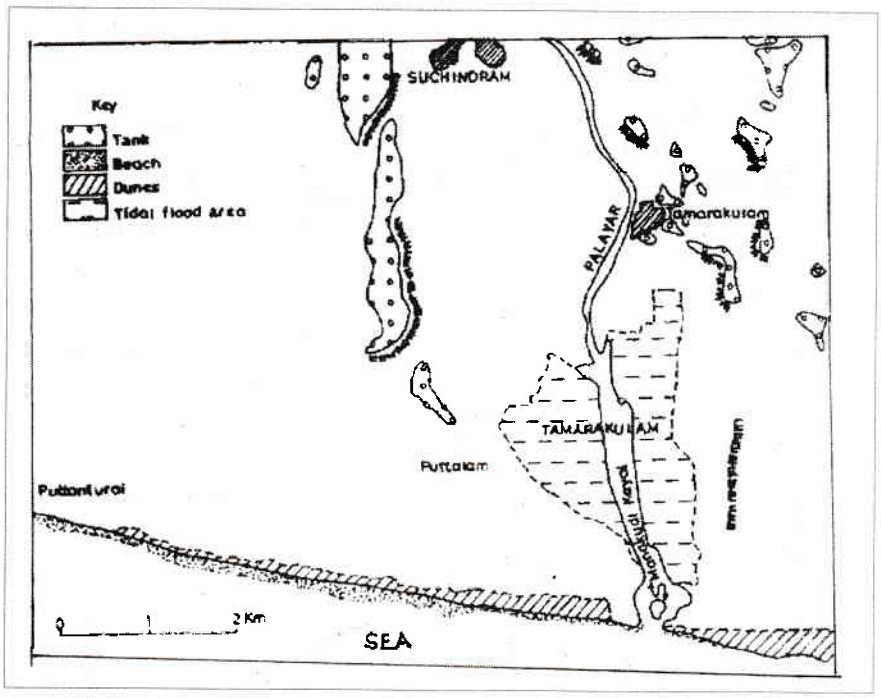


Fig. 1
Paraliar Area -- West of Kanyakumari

sandy, backed by a stretch of dune deposits of the recent past. However, around Kanyakumari and Muttanthurai headlands, the shores become rocky with poor accretion of cove sands. The Crocodile rocks lie off Muttam at a distance of 5 km and is barely awash. Other rocks abound as stacks on both these locations. Very heavy surf breaks all along this sandy coastal stretch especially during the peak of monsoons, when the wind is directly on shore (Fig.1). However there is no significant wave energy in this stretch nor any noticeable sediment transport and sand movement.

It is however the sea-side and sea-floor topography that offer some interesting facts of relevance.

Sea-floor Topography

According to Hari Narain *et al*, the continental shelf that is barely 60 km wide off Cochin and Trivandrum in the Arabian Sea broadens to about 100 km beyond Kolachel upto Kanyakumari, then bends north-eastward to once again narrow down to a mere 25 km around Manappadu in the Gulf of Mannar.

In the study area, the sea-floor from the shores

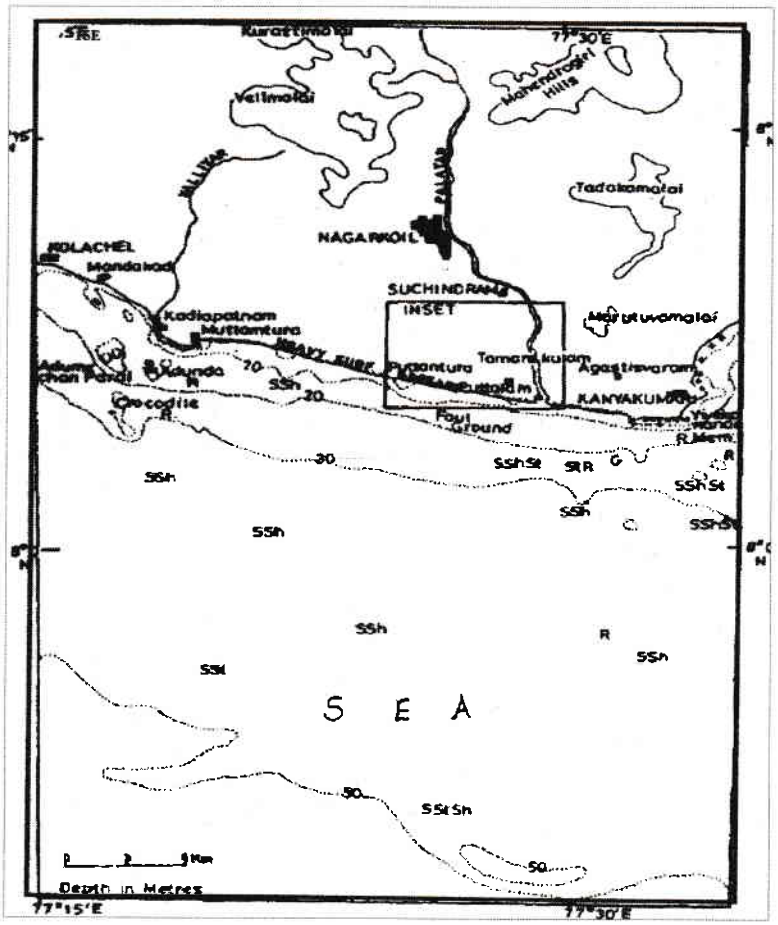


Fig. 2
The Seal Floor South of Kanyakumari

plunges to a depth of 10 m within the first half to 1 km distance and to a depth of 30 m at a distance of about 5 km (Fig. 2). Thereafter at a depth of 30 to 60 m is an extensive gently sloping platform 60 km wide known as the Wedge Bank. The shelf break occurs at about 90 m depth, thereafter the floor plunges to the level of the abysal plains of over 1000 m through very steep gradients of a continental slope area.

The presence of 30 km wide submarine platform at a depth of 30 m to 55 m is suggestive possibly of a lower strand line in

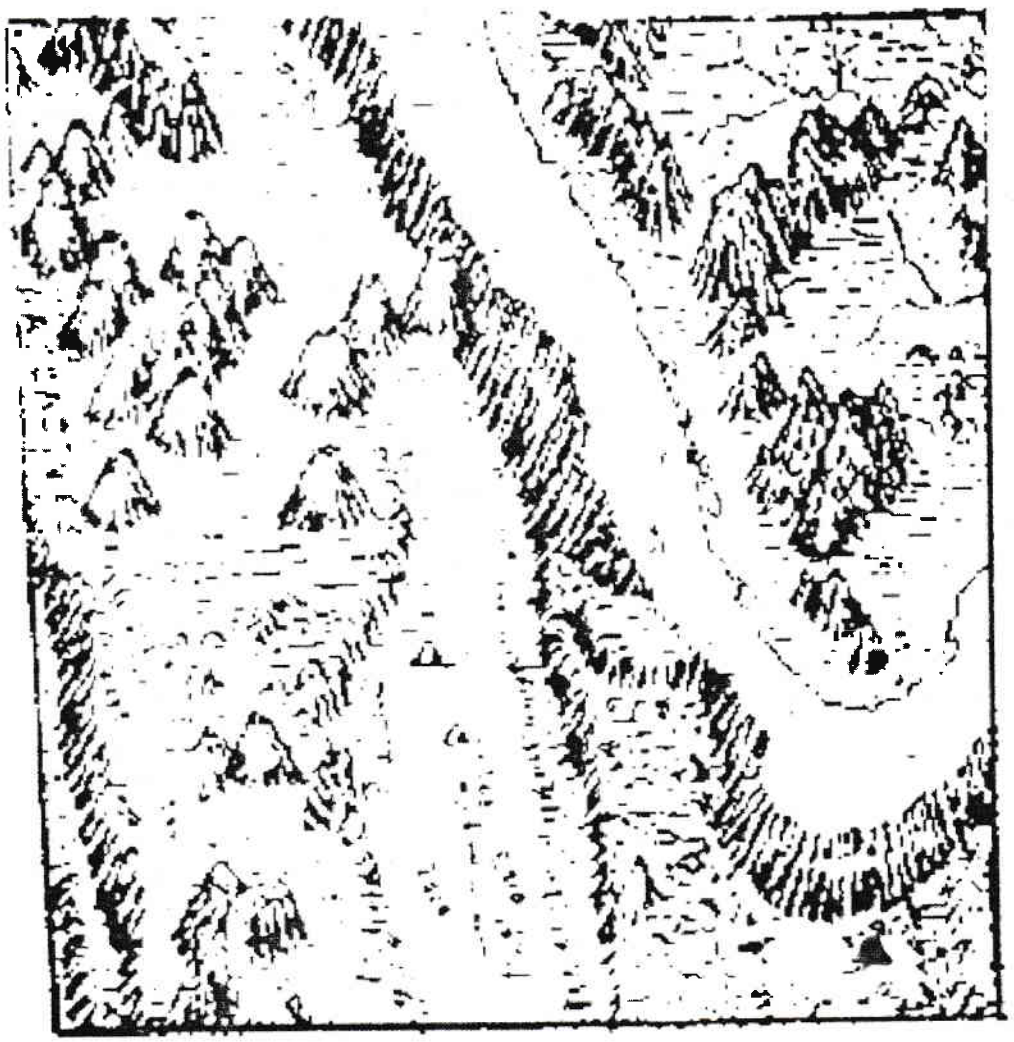


Fig. 3
Block Diagram of Sea South of Kanyakuamri
Note the platform below 30 m.

Holocene or before, but is of no importance in the present historical context. The sharp plunge in depth close to the shore in the near shore water (10 m in a km distance) is more striking and significant in that it may indicate the washing away of the loose soil and sands of the *teri* tract in a vast tidal flood, leaving behind residual stranded rockstacks. Some of which rise to the surface level around Muttam and Kanyakumari. Around these two headlands, wave-abraded rock platforms also abound. The presence of a foul ground (from navigation point of view) just south west of the Palayar estuary in waters 15 m to 20 m depth may also be indicative in this respect.

This sea-floor up to a depth of 30 m is covered by terrigenous sands, broken shells, stones and gravels and occasional rocks. Coral sands occur at depths beyond 30 m, the absence of any uniform sediment cover is probably a result of the continuing silting of ground material, once land, by waves in shallow depths. It would be worth testing the extent of the floor cover below loose sediments.

Using the IRS ID Band 1 digital data of Feb.'99 and IDRISI imaging module the shore and near-shore floor features up to a depth of about 30 m was generated after a enhancement to bring about in sharp focus the under-water micro-relief variations. The intuitive expectations discussed in the para above are well established from the imagery scene that show a a distinct rock pavement beyond the beach sands and off-shore sands and muds in the surf zone, The rock pavement protrudes out into the sea and it is very limited.

In conclusion it may be said that the present ground evidences above and below sea-level up to a depth of 50 m do not indicate any sea level change in the recent historic past. Nor any indication of a vast submerged platform. No valley form extending beyond the present mouth of *Palayar* into the sea-floor is noticeable. On the other hand, the presence of extensive wave erosion all along the coast from Idinthakarai and Kanyakumari to beyond Kolachel in Kerala are noteworthy.

References

1. Chandramohan *et. al.* (1990). *Wave Atlas for the Indian Coast. Panaji : NIO*
2. Closs H, Hannerarian & S.C. Garde. `*Continental margins of India in Continental Margins'*, pp. 629-638.
3. Krishnan M.S (1968). `The Evolution of the Coasts of India', *Bulletin of National Institute of Sciences, India*, 38, pp. 398 - 404

Book Review

Community Action Planning: Addressing Ecological Restoration and Sustainable Livelihoods by T.Vasantha Kumaran, Bala Hyma and David Wood (Chennai: T.R.Publications, 2004).

It is important to begin this review of *Community Action Planning: Addressing Ecological Restoration and Sustainable Livelihoods* by remarking on its most distinctive and positive characteristic. Throughout, we feel the attachment of the authors to the people of the five villages in the Thevaram Basin with whom they worked intensively. We sense that the nature of the connection with the villagers that has been generated through the application of Community Action Planning (the participatory model described in the book) goes beyond a conventional field work association. Members of the Department of Geography at the University of Madras have been working in the Thevaram Basin (located in southwestern Tamil Nadu in the foothills of the Western Ghats, close to the Kerala border) for fifteen years. As readers, we feel that depth of that experience from the outset. The book's Preface takes us on the journey that the project team made so often from Chennai (previously Madras) to the villages which suffer from the impact of high winds and sand dune encroachment which have severely affected agricultural production. The description of the journey and the conditions in the villages takes the form of a personally involved and sensitive reflection on the lives of a people in crisis. This intense commitment represents an underlying quality of the process throughout the book. It concludes with "The Narratives" a personal journal by T. Vasantha Kumaran. This is filled with insight, caring, and the kind of wisdom that comes from his association with the poor of the five villages among whom "there is a yearning for doing better, making a better life, and providing a future for their children" (p. 203). The book is filled with quotations from the project's co-researchers–the people of the Thevaram Basin.

It is clear that this attachment to process and people derives directly from the participatory methodology that was applied in "Making Deserts Bloom", the collaborative research project on which the book is based, that was funded by the Shastri Indo-Canadian Institute and CIDA and carried out by a team from the Universities of Madras, Waterloo, and Guelph.

Interestingly, it is perhaps this very quality of explicit personal commitment that leads to the frequent questioning of the legitimacy of defining such work as research. For decades the jury has been out regarding the academic validity of research methodologies that are based on the participation of local populations in their own interest, the facilitating roles of external "researchers", the combining of

learning and action, the establishing of sustainable outcomes (organizational, economic, ecological, and social), and the establishment of adaptive process designs that can be applied in a wide range of settings. Underlying these attributes has also been the orientation of the most common style of action research to progressive social change. *Participatory Action Research* has been largely the product of work focused at the margins of society and among the poor and disempowered. Despite the enormous amount of this kind of work that has been carried out over the past fifty years, especially in developing countries, we still lack any widely accepted integration and assessment of participatory research. The field remains a widely scattered and disconnected array of activity without even an agreed-upon lexicon of terms that are used consistently by practitioners.

While, at one level, this volume adds to the already vast collection of published and unpublished reviews of participatory research practice, it also assists in the wider methodological project of framing the field. For those interested, not just in another example of the case study implementation of the methodology, but also its epistemological and ontological underpinning, this text is interesting and helpful. The achievement of a recognized general statement on the overlapping theory and practice of praxis methodology is long overdue, and Community Action Planning has much to say that moves us forward in this primary task.

It is to be welcomed that the authors of this volume recognize and reinforce the fact that participatory work of this kind is not neatly structured within a set of standardized stages. They make it clear that they view CAP as "interactive, iterative, and adaptive" and that, as such, its "primary components ... are carried out simultaneously" (p. 40). An important implication of this holistic and nonlinear view of participatory process is "the ability of the process to deliver when problems are identified rather than postponing any action until the 'implementation phase' " (p. 38). However, having made these important characteristics clear, the authors have to confront a universal problem associated with discussing participatory processes describing and analyzing such interdependencies by separating the process into its component parts and giving the impression of sequential steps. Perhaps the key point here is the need to characterize the whole process as a complex relationship building among and between community insiders and outsiders. In this book, as is so often the case, the classification and description of the elements of the participatory process – building trust, involving NGOs, social animation, land use mapping, or applying the various workshops, appraisals, surveys, transect walks, and capacity building techniques, still ends up by giving the appearance of "a step-by-step process" (p. 51) implemented by the external research team.

Because the accounts of the Community Action Planning activity that took place within the project are presented as a combined story/narrative, detailed record of events, and an analysis and assessment, the book provides an excellent opportunity for students of participatory methodology to gain valuable practice insights. There are detailed descriptions of particular events and strategies that examine the process from both the perspectives of the project team and the local

participants. In particular, the key chapters on the design and implementation of Community Action Plan approach to the environmental restoration of degraded land in the Thevaram Basin contain useful comparisons of the five villages and direct and open assessment of the processes. Issues such as a lack of confidence of poor rural people in their own capacities, the continuing impact of the caste system, and the tendency for new community organizations to slide from participatory mode of management into more formal and hierarchical operations are discussed. At the same time, many successes are recorded, particularly in relation to the role of women in the process.

Not surprisingly to any who have been engaged in participatory projects, the book concludes with the recognition that all aspects of the project need continued support. Specifically, the sustainability of the outcomes will be uncertain unless local leadership is encouraged and continuing access to seed money occurs. This is a book for seasoned practitioners, students, and for those with doubts as to the capacity of such a community-based planning to play the future critical role that its subscribers have been asserting for years. Community Action Planning has the sharp taste of reality as it emerges so directly from work in the field. More than anything, it demonstrates that only when the ownership of such processes is firmly in the hands of the participants can there be any hope for the achievement of a a participatory project's goals.

David Morle
Professor Emeritus,
Faculty of Environmental Studies
York University, Toronto, Canada

GPS Principles and Applications by A.Ganesh and R.Narayanakumar; (Delhi: Satish Serial Publishing House. 176 pages; 28 figures; 5 tables; ; Hard-bound; ISBN: 81-89304-24-0. Price: Indian Rs. 795)

The book 'GPS Principles and Applications' by Dr. A. Ganesh and R. Narayanakumar is one such book that was long overdue. At a time when Geographers are making their presence felt in the technological arena by highlighting the role of the geoinformatic technology, this book which deals with one of the components of Geoinformatics, that is Global Positioning System, comes in very handy. It is devoid of jargon and very succinctly describes this seemingly complicated technology to the readers. The eight chapters of the book are very well organized. The authors give an introduction to the technology and trace its history in the first two chapters, and an overview of GPS and its basic principles are dealt with in the next two chapters. Chapter Five which deals with Surveying with GPS illustrates in a very simple language the elements of GPS survey, survey design, the various measuring and positioning techniques and their comparisons. Chapter Six, which deals with GPS and GIS seems more close to the geographers' heart as it specifies a geographical context for the GPS procedures. Chapter Seven, which deals with GPS applications gives an extremely exhaustive list of the potential areas of use of this technology

apart from the misuse that it can be put to. Chapter Eight gives us an update on the competitors to GPS. The three appendices at the end are also quite informative and provide information on a miscellany of facts, which did not find a proper context in the text. The list of acronyms and a very detailed glossary at the end of the book round it off quite well.

It may however be pointed out that while there is a good balance between the chapters in general, the chapter on 'Basic Principles of GPS' is a bit too large and could perhaps have been split. Also the chapter on Competitors to GPS is a bit too short and could have been merged with another chapter at the end.

The book is very user-friendly and a good reference material for students pursuing courses in Geoinformatics, Geography and Civil Engineering apart from others. In fact, it can be used as a text book for some of these courses. Apart from that, it can also be used by officials in various governmental agencies who are trying to grapple with this technology and also the general inquisitive readers with an eye for detail.

Prof.Kalpana Markandey
Department of Geography
Osmania University
Hyderabad

Water Resources Evaluation Methods and Techniques by Prof.A.Ganesh. (Delhi: Satish Publishing House; pages 187; illustrations 60; tables 25; Price: Indian Rs.895)

The book on *Water Resources Evaluation Methods and Techniques* addresses a wide range of procedures for water resources analysis-geomorphic, hydrologic and climatic-through a comprehensive appraisal of a study of Upper Vaigai basin that lies in the rain-shadow region of Theni and Dindigul districts of Tamil Nadu. The entire study is organized into five chapters. The Chapter 1 recounts the main theme of the book, and importance of water resources and basin level study. It includes a detailed review of studies on this subject, though the selection of the study area for this book is not clearly reasoned out. It is appreciable that the author makes use of the data from a wide variety of sources, including remote sensing products. Chapter 2 gives a panoramic view of the study area, describing the geology, geomorphology, climate, soil, and drainage of the basin with appropriate quantitative tools. Chapter 3 evaluates surface and ground water through climatic and mapping analyses. Water balance studies carried out here explain the methodology more clearly and it must be very useful to the students. Similarly the techniques of ground water analysis as explained here may be of good training module for the practicing water resources experts. On the basis of ground water evaluation made by the author in Chapter 4, the planning for water utilization is discussed. With the semi-arid character of the region, the irrigation development through tank irrigation is rightly emphasized. The interesting exercise in this chapter may be the working sheet analyzing the need and the percentage used of water for all the hamlets, villages and towns in the study area for drinking purposes; however, it is to be

pointed out that the exercise could have been more dependable, had the author considered the demand and supply of per capita use for drinking purposes. Chapter 5 summarizes the study and draws conclusions, and it is a needlessly lengthy one. Interrelationship between geomorphic, hydrologic and climatic parameters could have been clearly spelled out here so that methods could have been understood in right perspective. Questions of water management including conservation methods could have been outlined here. Thus the book is not able to contribute much towards helping to develop proper policies for semi-arid region like Vaigai basin. On the whole, the book is a scholarly text discussing the methodologies for water resources of a drainage basin, and the author deserves appreciation for collating available methods on water resources analysis. The book is a good addition for academic scholars for learning the techniques of water resources analyses. However, one disturbing point to be noted here is that the book is over-priced, and only institutions and not the interested scholars, can acquire.

Prof. Daksha C.Barai
Professor of Geography (Retd.)
Bangalore University, Bangalore

Human Settlements: A Planning Guide To Beginners by K.R.Thooyavan (Chennai: M.A.Publication; 453 pages; 34 tables; 14 appendices and annexures; Price Indian Rs.350)

With 31 per cent of population living in cities in India, the book on Human Settlements by Dr.K.R.Thooyavan, a professional city planner who had a long innings in the Chennai Metropolitan Development Authority, Government of Tamil Nadu, Chennai, is timely one. It looks into urban and rural settlements simultaneously and also views into regional planning and the growth of new settlements. Planning measures have focused on socio-economic and political approaches and legal tools that move towards a sustainable environment.

The first chapter traces the historical evolution of human settlements from early civilizations through medieval to industrial revolution along with slums,and blights with suggestions on land use zoning. Settlement patterns are well illustrated in this chapter. The second chapter has brought out trends in planning through utopian concepts. With examples largely from Europe, garden cities, satellite towns and neighborhood blocks are emphasized. Abercome laid emphasis on survey and administration, while Doxidas on dynamic city. The third chapter highlights the concept and use of planning through master plans, zoning etc., where examples are drawn from all over the world. The fourth chapter stresses on plans for development of human settlement policies mainly for the welfare of the people. A detailed study of economic plans is drawn for Chennai Metropolitan Area. The fifth chapter accentuates engineering techniques in physical and economic planning mainly through surveys, mapping and models.

The sixth chapter highlights the relationship between the town and the metropolitan region in relation to land use, circulation and provision of services. The seventh chapter emphasizes on housing in settlements especially in relation to shortages. Experiments on low cost housing vs. government policy in the five year plans and national housing policy are mainly highlighted. Here spotlight has been placed on design and low cost housing experiment in Madurvayal for low, medium and high income housing.

The eighth chapter refers to increasing blight, squatters and slums and the need for urban renewal with development. Emphasis is laid on conservation, rehabilitation and development of central areas and slum improvement in Thailand, Sri Lanka and India especially cities like Kolkota and Ahmedabad. The ninth chapter, while emphasizing with principles of village land-use , workforce distribution, infrastructure and services, concentrates on land and building surveys, village land use layout and plans, housing and provision of amenities. The tenth chapter refers to land as a physical unit where regional plans like that of DVC, Dandakaranya, Nyveli and Chennai are explained. Planning for industrial estates is informative to planners, administrators and entrepreneurs who emphasize on industrial development.

The eleventh chapter deals with "New settlements" wherein the author narrates the design of new towns with emphasis to physical location of land and climate, aesthetic and architectural control. Planning programmes of new towns of greater London's green belt, those of India like Chandigarh and those of other countries all provide examples of new towns to academicians and other readers. Chennai's satellite towns are also described. The twelfth chapter looks into Remote Sensing Applications to identify human settlements, archaeological sites, parking areas, industrial zones etc., for urban and regional development analysis. The thirteenth chapter describes the legal aspects of settlement studies by outlining all acts, rules and regulations. To name a few, the Town and Country Planning Acts, Land acquisition Act, Slum Clearance Act, Environment Protection Act, Industrial Safety Measures, Acts and Rules of Coastal Zone along with a recommended Model for Tamil Nadu are elaborately noted. The last chapter talks of sustainable human settlements and the methods related to it. Methods such as EIA and Carrying Capacity are discussed for Chennai. Participative Urban Governance for a couple of cities is also discussed. Finally two case studies of Arakonam and Tirunelveli Municipalities are discussed.

The book under reference is a good text and serves as a useful guide for students of Engineering and Planning. It is also a good source of reading material for the layman. The text is elaborately illustrated with diagrams, tables and maps and it is to be pointed out that maps could have been better designed and drawn. The book suffers from spelling and editorial errors. Linkages between chapters are found largely missing. The bibliography is fairly elaborate and the Appendices are brought out in detail. On the whole the book is a good attempt to bring all aspects of planning for human settlements though a sequence in flow of continuity from one chapter to the next is lacking. It is a good and appreciable attempt.

Prof. Daksha C.Barai
Professor of Geography (Retd.)
Bangalore University, Bangalore

Obituary

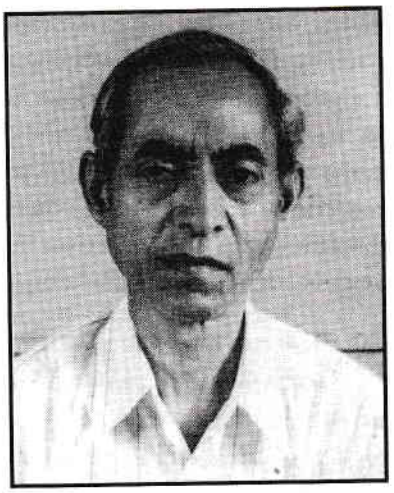
Prof. Aijazuddin Ahmad

The cruel hands of death snatched away a very brilliant geographer from amongst us on 8th June 2006. Prof. Aijazuddin Ahmad, known simply as Aijaz to his friends, was a man of sharp intellect. He had social commitment of an activist and sensibilities of a poet. Death is inevitable to all those who are born. Life will always be followed by death because that, which has a beginning also, has an end. All that which inhales and exhales will one day have to taste the death. Kabir Das, one of the rebel saints of North India, has successfully described the birth and death in the following words :

``The day I was born, I wept and the whole world around laughed. The day I died after a purposeful life, I laughed and the whole world around wept".

Death is painful for those who are left behind but death of Aijaz away from home is more painful.

Aijazuddin Ahmad opened his eyes in this world on 12th January 1932 in Firozabad, an industrial town in Uttar Pradesh, earlier a taluk headquarter of Agra district but now itself a full-fledged district. His home town is famous for glass industry, particularly known for glass bangles. His initial schooling was accomplished in his home town and for higher



education he moved to Aligarh. He graduated from Aligarh Muslim University and obtained a M.A. degree in Geography. Department of Geography of Aligarh Muslim University is the first PG deparment of Geoagraphy in the country which was started in 1930. He was a brilliant student and obtained a first division in both B.A. and M.A. classes.

He had the good fortune of being trained by great teachers like Prof. S.M. Ali, Prof. Moonis Raza, Prof. Mohd. Anas and Prof Mohd. Shafi at Aligarh. He completed his Ph.D thesis under the supervision of Prof. S.M. Ali in 1962. His area of research was arid region of Rajasthan and during the course of his work, he could develop deep understanding of nature-human

interaction. He had imbibed the originality of thought from Prof. S.M. Ali, his supervisor, and capacity to question from his long-term colleague and teacher, Prof. Moonis Raza. Prof. Moonis Raza having worked as the Professor of Humanities and later as a Principal of Regional College of Engineering, Srinagar, had developed fancy for Kashmir. He loved the region. He planned three volumes on this region viz., The Land, The People and The Economy. Prof. Aijazuddin Ahmad was entrusted with the responsibility of co-ordinating the task. The volume on The Land appeared in co-authorship of Prof. Moonis Raza, Prof A. Ahmad and Dr. Ali Mohammad who was working in this project at that time. The other two volumes could not see the light of the day as both were over-burdened with other academic responsibilities.

I had the chance of interacting with Prof. S.M. Ali for a short while but I worked with Prof. Moonis Raza and Prof. Ahmad almost for a quarter of a century. I realized the influence of both the professors i.e. Prof Ali and Prof. Raza on the way of thiniking and analysis of Prof. Ahmad. He was meticulous in bringing out the details and his presentation was always in very effective style and poetic language. Once in seventies, Prof. Kusum Chopra, Prof. S.K. Pal, Prof. Ahmad and myself took our M.A. students to Kashmir valley to complete a course on Field Survey Methods (Physical). The assignment was to trek and study West Lidder, East Lidder and Sind Nala valleys. We started to trek from Pahalgam to Aru to cover the West Lidder valley first. We had engaged a few ponnies to carry the camping material. Prof. Ahmad's eldest son was insisting to ride a horse thinking that ponnies were horses. By the time we reached Aru, Aijaz *sahib* had composed a full poem which he shared with us in the evening. I still remember a few couplets from that poem:

Aru mujhe laaya hai pahalgam se ghoda,
ummeed hai milwaye ga gulfam se ghoda
kya janiye kis marg mein dil uska phansa hai
rehta hai kuchch udas sara sham se ghoda
kahena hi sooye Dilli se aaye hain Qureshi
sab kuchch hi samajh jaaye ga is nam se ghoda

The purpose of the description of this episode is to show his sensitive nature and poetic heart. If rendered in English, it may read as under :

"*The horse has brought me to Aru from Phalgam. I am hopeful that the horse will enable me to meet my beloved. One does not know which is that pasture about which the horse always remember and that is why he remains sad right form the evening".*

The last couplet was to tease me ``Tell him that a person known as Qureshi has come from Delhi, and he will understand everything.''

This also amply reflects the lighter side of his personality. After walking for about 11 km in a hilly terrain he was able to make others laugh. It was poet Aijaz. Very few people know that the collection of his Urdu poems has already been published. The fact that he directed a 22 minute documentary on `Linguisitc Diversity in India' for UGC is also not extensively known.

His scholarship was profound and dedication to academics was complete. His commitment was witnessed by his students and colleagues at the time of the preparation of `The Atlas of Indian Tribes'. He was a social geographer par excellence but he also had deep understanding of Agro-climatology, Regional

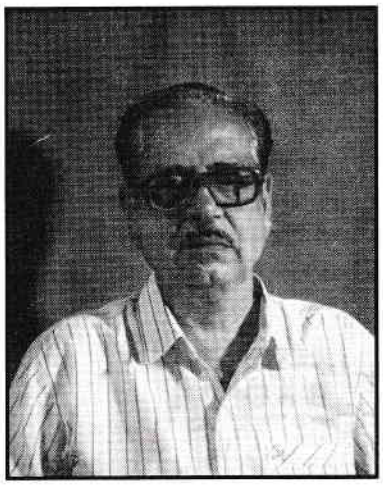
Geography and Agricultural Geography.

Prof. Ahmad has significantly contributed to the teaching of geography at the school level. His book ` General Geography of India' co-authored with Prof. Moonis Raza was published by NCERT as a text book for Plus Two students. This text book is still treasured by those who take civil services examination. His books on social geography and his papers on social issues amply reflect his capacity of deep analysis. His work on the problems of education of Muslims is a pioneer work in this field. Prof. Ahmad was physically frail but intellectually a heavy-weight. He was a private person. He shared his joys but never revealed his tribulations and sorrows. Those who inflicted pain on him were also forgiven

My last meeting with him was in November – December 2005 when he came to attend the meeting of National Monitoring Committee of text-books developed by NCERT. He was invited as an expert member in Geography. During these 2-3 days, he used to sit with me and talk about many things. He often used to travel down the memory lane across the corridors of time. I, then, never realized that it was our last meeting. He departed from us under such circumstances that we could not see him on his last journey. May his soul rest in peace. He is survived by his wife, two sons and a daughter. He has also left behind hundreds of his students, colleagues, friends and relatives who fondly remember him and miss him. May the family members have the strength to bear the loss. His colleagues and students have the moral responsibility to carry forward his intellectual traditions and academic goals. This may be one of the ways to perpetuate his memory and it will be our greatest tribute to Prof. Aijazuddin Ahmad.

M.H. Qureshi
CSRD, School of Social Sciences
Jawaharlal Nehru University, New Delhi

Prof. P.D. Mahadev



Prof. PADMANABHA DOODBATHE MAHADEV, who retired as professor of Geography at Mysore University, Karnataka in 1993, after an eventful profession of teaching and research for about 35 years, passed away at Chennai, Tamil Nadu on November 27, 2005. It is a great loss to Geography and Geographic community. I knew him since my postgraduate studies at the Department of Postgraduate Studies and Research in Geography, Mysore University. Prof. Mahadev was an erudite scholar in the new age geography and he was a spontaneous,

informative and friendly person. He possessed the qualities of a natural thinker and encouraged such traits in his students while teaching urban geography. With a double doctorate to his credit, Prof. Mahadev always adapted a down to earth style in his teaching so as to reach every one of his students. With patience and simple demonstrations, he used to explain intricate concepts. I was fortunate to play host to him when he came to Melbourne a few years ago to visit his youngest daughter.

Born on August 16, 1933 in Coimbatore, he had his schooling in Chittoor, Andhra Pradesh, and got graduated in Geography from the Presidency College, University of Madras in 1958. His teaching of Geography got started in colleges in Andhra and Karnataka, and he joined the University of Mysore in 1964 as lecturer in Geography. In 1969, he obtained his Ph.D from the University of Mysore. On his visit to USA in early 1970s, he worked for another Ph.D at the University of Pittsburgh where he got his second Ph.D in 1973. Both the Ph.Ds had a focus on urban geography of Mysore. During 1979-1985, he worked as professor of Urban and Regional Planning at the Institute of Development Studies of Mysore University and during this tenure, he got rich opportunities to interact with a number of international faculties. He was a visiting professor at Western Washington University, USA, University of Bordeaux, France, and Kyoto and Hiroshima universities, Japan. He organized a number of regional, national and international conferences, and he was very successful in organizing the Tenth Indian Geography Congress of the National Association of Geographers, India and the Eighth Indian National Cartographic Conference at Mysore in 1988. He was the president of the Indian National Cartographic Association in 1988, and of the National Association of Geography, India in 1992-93. He had about 40 research papers published in professional journals, and urban studies were the main theme in many of them.

Prof.Mahadev is a simple, pleasant and soft-spoken person. His deep academic interests helped him to have many friends and close associates all over the country. Towards the end, he had been suffering with mild paralytic stoke and yet, he continued to have shown interest on his friends and development of geography. He is left behind by his wife and three daughters. As a senior geographer participating in a number of policy-making bodies of geographic education at state and national levels, he played a key role in defining the directions of the development of geography in India. Indian Geography cherishes him in memory for ever.

Robert Inbakaran
School of Management
Portfolio of Business
RMIT University
Melbourne,
Australia

Information to Authors

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References should be listed in alphabetical order at the end of the paper and cited in the text as a bracketed number. Footnotes should appear at the bottom of the respective page, typed in single space: and the footnote number, placed a little above the line, should run consecutively throughout the text. Reference details and placement of the citation numbers etc. should follow the style adopted in the present issue.

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