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HyWaMIS (*Hy*derabad *Wa*ter *M*anagement *I*nformation *S*ystem) – A Participatory Approach

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Abstract: A participatory approach was used to develop the framework for an integrated Water Management Information System as a tool for sustainable water management in Hyderabad city, India. Focussing on pollution prevention in the industrial development areas of Patancheru and Bolaram, India, the project activities concentrated on the development and implementation of an initial "industrial module" of the information system providing harmonised data on industrial effluents and their effects on ground and surface water bodies. As a result, recommendations for pollution prevention and control were formulated jointly with local authorities and other stakeholders. The information system concept defines a tool for the integration of existing data and includes instruments for advanced data analysis and presentation to support decision making and public information. This approach was designed to contribute to providing manifold objective functions for different stakeholders and user groups aiming at sustainable regional water management.

Key words: Industrial pollution, water information system, stakeholder platform, participatory process, water quality.

Introduction

The city of Hyderabad with its more than six million inhabitants and a population growth of about 10% per year has suffered from uncontrolled industrial growth in the past, especially in the peri-urban areas, which has already led to significant groundwater and surface water contamination.

The HyWaMIS information system was developed for the Patancheru and Bolaram Industrial Development Areas (IDA). In these case study areas, there are more than 400 big and small pharmaceutical and chemical industries that produce a variety of substances including bulk drugs, pesticides, and paints. The effluents generated in various industrial processes in the past were discharged mostly untreated into unlined channels, streams and ponds. In more recent years, effluents have been treated at a common effluent treatment plant before being discharged into the water system. However, past practices and the continuation of untreated discharge by some rogue industries have led to the severe contamination of surface and groundwater resources which poses a serious hazard for the local water supply and the health of the people living in these peri-urban areas (Kishan Rao, 2001).

In order to design and develop the information system in a way that meets the needs of the people concerned with water management in Hyderabad, the project activities involved representatives from seven different stakeholder groups. By engaging these participants in

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considering the challenges of water management in the case study of Patancheru and Bolaram, the foundations have been laid for a continuing process through which the actors may negotiate conflicts of interest which currently make collaborative efforts extremely difficult.

The application of a Water Management Information System in the Hyderabad area aims to increase the quality of municipal planning and thus contribute to improvements in: the efficiency of industrial and agricultural activities; the supply of water for domestic use; the information available to governmental and non-governmental organisations; and the citizens' quality of life.

Methods

Effective participation in information management is not always easy to organise, especially in relation to environmental issues, which are often characterised by conflicting social perspectives. Managing the constructive involvement of stakeholders is a skill that requires as much emphasis as does developing abilities in technical problem solving and the design of information technology (Allen and Kilvington, 1999).

The case study activities aimed at contributing to socio-political development through an information and dissemination strategy that actively involved the stakeholders in the Hyderabad region. By engaging people in a common objective–the design and creation of a shared information system for the management of water—we aimed to improve the social and political climate between citizens, industry, agriculture, NGOs and government and to favour a more integrated approach to water management. The methods used over the two years of project work were in general loosely structured and flexible to local imperatives. A series of three stakeholder workshops hosted by the Hyderabad Metro Water Supply and Sewerage Board and the Birla Science Centre were unique occasions for a broad range of stakeholders to interact in debate about water management. The communication that was initiated in these workshops was supported by regular project newsletters and the establishment of a stakeholder e-mailing list. A smaller group of about twenty individuals, representing the range of stakeholder groups, formed an Advisory Panel which met on a more regular basis to focus closely on planning specific actions for the remediation of the case study areas.

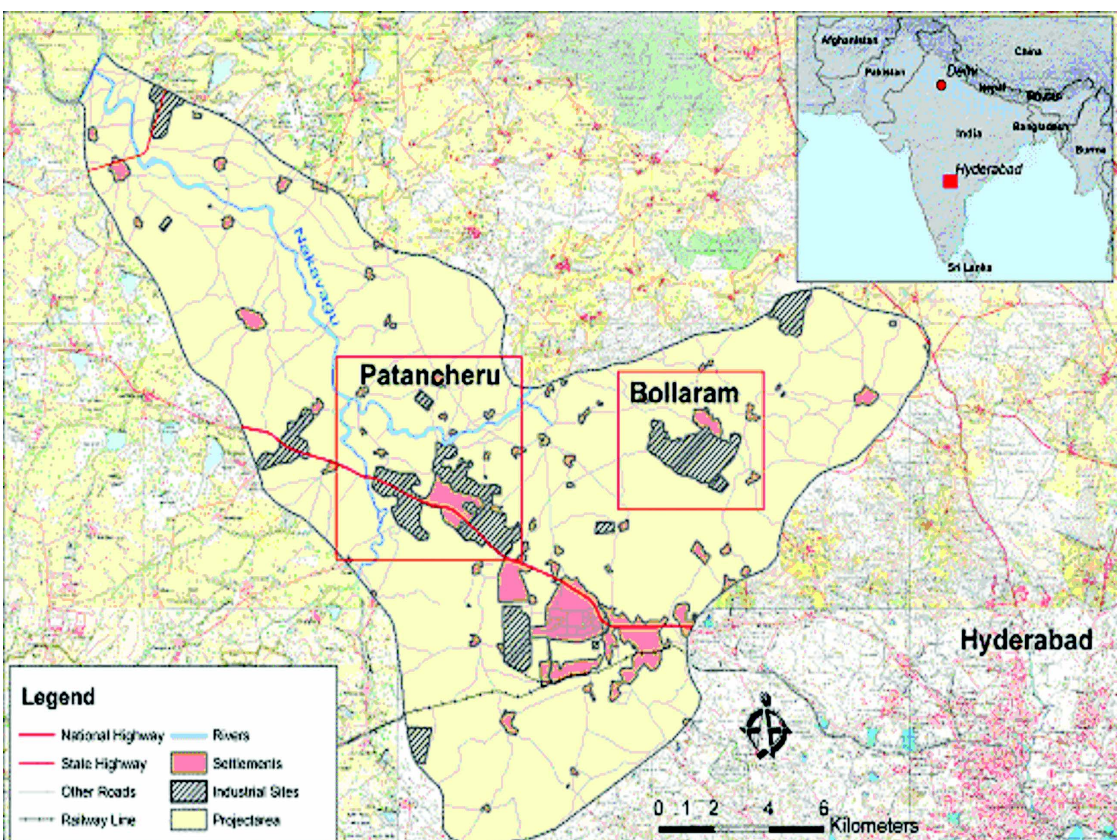

Figure 1: Overview of the project area–Hyderabad and the case study areas Patancheru and Bolaram.

The integration of GIS technology not only enables efficient data management but can also provide informative maps as decision support in water management. The generation of thematic maps together with the required pre-processing and management of geographic data is a task, for which Geographic Information Systems provide the optimal platform and were utilized for the project tasks. Further, the potential of GIS as a planning and public participation tool was explored for information and planning applications in response to the needs and requirements of different stakeholders. The GIS tool enables the integration of different steps of the decision-making process: (i) on a technical level, by defining categories and levels to be analysed, identifying causes and consequences of environmental problems and relations between environment and factors of development, by selecting a set of indicators related to the target sectors and by identifying reference thresholds; and (ii) on a political level, by harmonising framework and methodologies, by identifying problems and target sectors that must be analysed and by identifying development goals as reference values for decision-making (Valentini, 2001).

Results

Stakeholder Process

The HyWaMIS initiative sought to open participatory ways of information gathering, and conflict resolution through stakeholder platforms for building civil-society capacities for integrated water management.

A questionnaire was developed and distributed to local stakeholders in Hyderabad in order to gain insight into the information needs, sources and user profiles of the stakeholders involved.

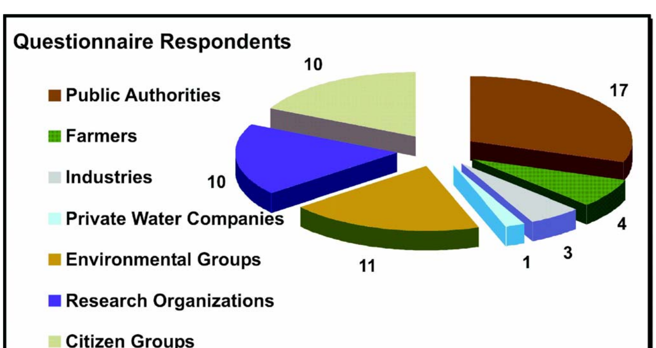

Figure 2: Stakeholder questionnaire respondents.

Subsequently three stakeholder workshops were organised together with the Hyderabad Metro Water Supply and Sewerage Board in Hyderabad with the aim to discuss user interests and objectives and to establish a joint information basis for water management issues. These workshops contributed to improving the social and political climate between the stakeholders involved, and in particular the residents of Patancheru and the public authorities concerned with water management in that area.

Furthermore, a group of experts from authorities, industry, and citizen groups formed an advisory panel to give direct feedback to the development of the Information System and to help formulate recommendations for the project's case study, Patancheru. This advisory panel met six times and was a forum for debate, information sharing and conflict resolution.

During the stakeholder workshops, stakeholders were offered the opportunity to engage in discussion through facilitated working groups. In each of the workshops, the stakeholders contributed information through working group activities or through open form discussion. The primary workshop outputs produced over the course of the project are the following:

1. "HyWaMIS - a co-operative Vision" which has three main sections that were produced by the respective working groups: Problems and Solutions for Patancheru; Information Needs and Sources, System Structure & Functionality; and Public Participation in HyWaMIS..
2. Chronology of important events, defining a historical skeleton for the Patancheru case study. This information was used as a framework to develop a participatory case study profile in the ongoing stakeholder process.
3. List of 28 state variables, elicited from the participants in the working group exercises were grouped and categorised under the headings "environmental", "economic" and "social". In a participatory decision process, this information was used to define decision criteria and elicit the priorities and preferences of the different stakeholder groups.
4. A set of recommendations for action in the Patancheru area and for continuing the project activities.

During the final workshop, recommendations for system extension and water management strategies were presented by advisory panel members. These activities brought together representatives from various institutions, independent experts, and local people who suffer from the consequences of industrial pollution to support the development of the Information System.

Data Collection

Data collection and analysis concentrated on the situation in the case study areas Patancheru and Bolaram focussing on industrial wastewater emissions and contamination of water bodies.

In addition to the collection of secondary data, during campaigns in May 2004, samples were taken from different surface water bodies and groundwater wells. The samples were analyzed for major ions as well as trace element concentrations. Spatial inconsistencies in sampling locations made it difficult to interpret temporal changes in water quality. Nevertheless, trend analyses for neighbouring sampling sites were used to reveal positive or negative changes in water quality.

The collection of industrial data proved to be difficult as the required information was scattered among various institutions and agencies. Complete information about industrial effluents was rarely available and mostly inconsistent. Of the 1166 industries registered at the Andhra Pradesh Pollution Control Board (APPCB) only 140 had complete information about products, water consumption, effluent discharge and the type of waste water treatment that is used. For 377 industries only partial information was available and 649 of the industries provided no information at all. Spatial information was available only for 314 industries. For these geo-referenced objects, the branch and partially the effluent discharge could be extracted from the database to be used for thematic maps.

Design and Implementation of the HyWaMIS Information System Prototype

Originally, HyWaMIS was planned as a web-based tool with access to distributed data sources. However, limitations in the local IT network infrastructure led to its development as a standalone application. Available data and databases were reformatted and collected on one central host which is located at the Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB). Nevertheless, the system design is suitable for online data access of distributed data and databases.

HyWaMIS was implemented based on Microsoft Visual Studio VB.Net framework as a 3-tier application using an Oracle Database. It is a Windows explorer kind of a tool for easy access of information and consists of a switchboard with an explorer tree for intuitive data access. The tool offers basic functions to insert, update, delete, query, and export/save data along with some analysis, summary and reporting facilities. Users can customize the application to suit their specific needs/frequently used queries. Access restrictions were also implemented in

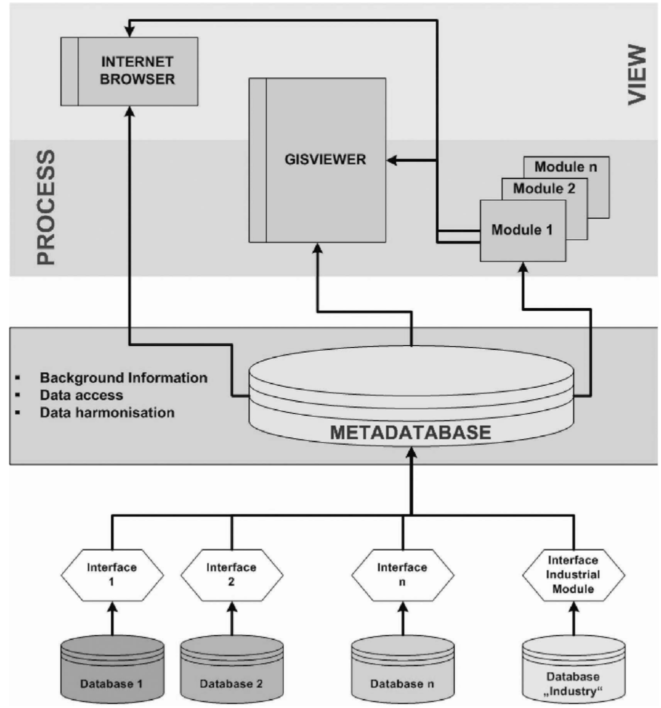

Figure 3: Information system concept scheme.

HyWaMIS using Oracle Database User Roles by which only authorized users can access the information. Based on the assigned privileges, different functions of the Information System have been enabled /disabled. A GIS viewer was integrated in the application for visualising the data in the form of thematic maps.

Focussing on pollution prevention in the industrial development areas of Patancheru and Bolaram, the first development stage concentrated on the establishment of an "industrial module" for the information system which provides harmonised data on industrial effluents and their effects on ground and surface water bodies.

For each company at least the following pieces of information, if available, were registered:

- Location
- Products
- Size (employees)
- Water demand (amount, water supply by private wells or central water supply system)
- Water relevant processes
- Amount of wastewater production
- Wastewater pre-treatment processes (if applicable)
- Wastewater composition (environmentally relevant parameters)
- Point of wastewater discharge (receiving water body)

This module was linked with a GIS-platform which allows user-, region-, parameter- and/or branch-specific

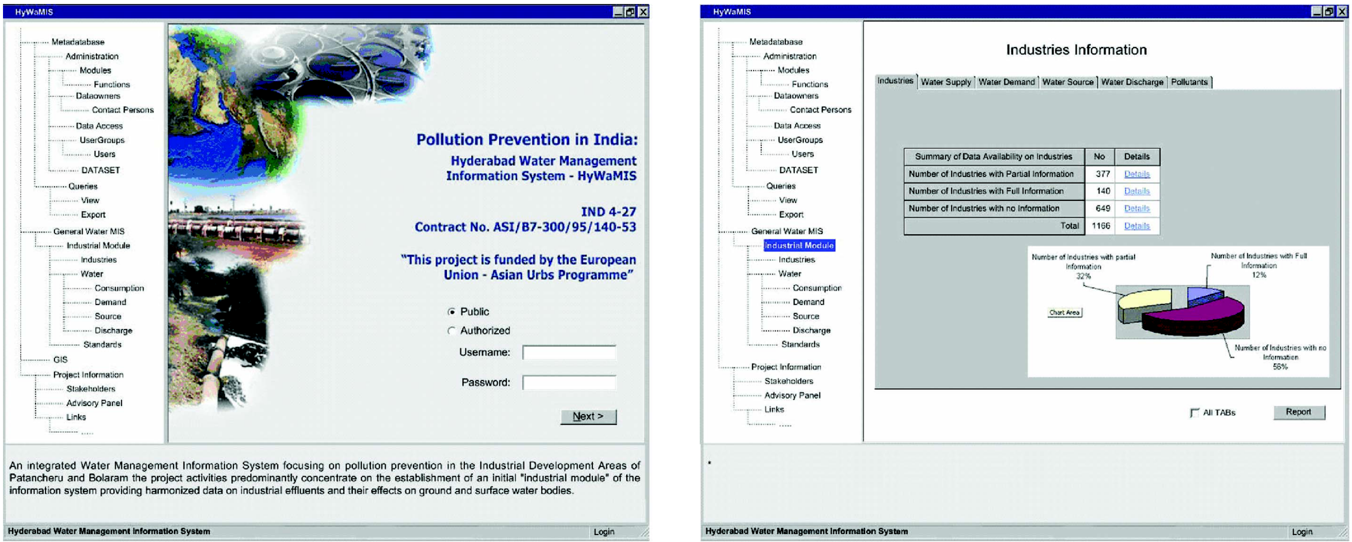

Figure 4: HyWaMIS graphical user interface–Industrial module.

queries. The application of the industrial module furthermore provides the possibility of pollutant-specific analysis and assessment as well as its graphical presentation and visualisation (e.g. thematic maps). This enables a transparent overview of the current status of wastewater emissions and water quality which, by identifying the key pollution sources, essentially contributes to the required pollution prevention approach.

Furthermore, the intention is that in the future the industrial module will be linked to surface and groundwater modelling components in order to analyse and assess different water management scenarios.

The prototype of the Information Systems provides data about industries and water quality in a central database. Through the industrial module interface the users can display industry information ordered by

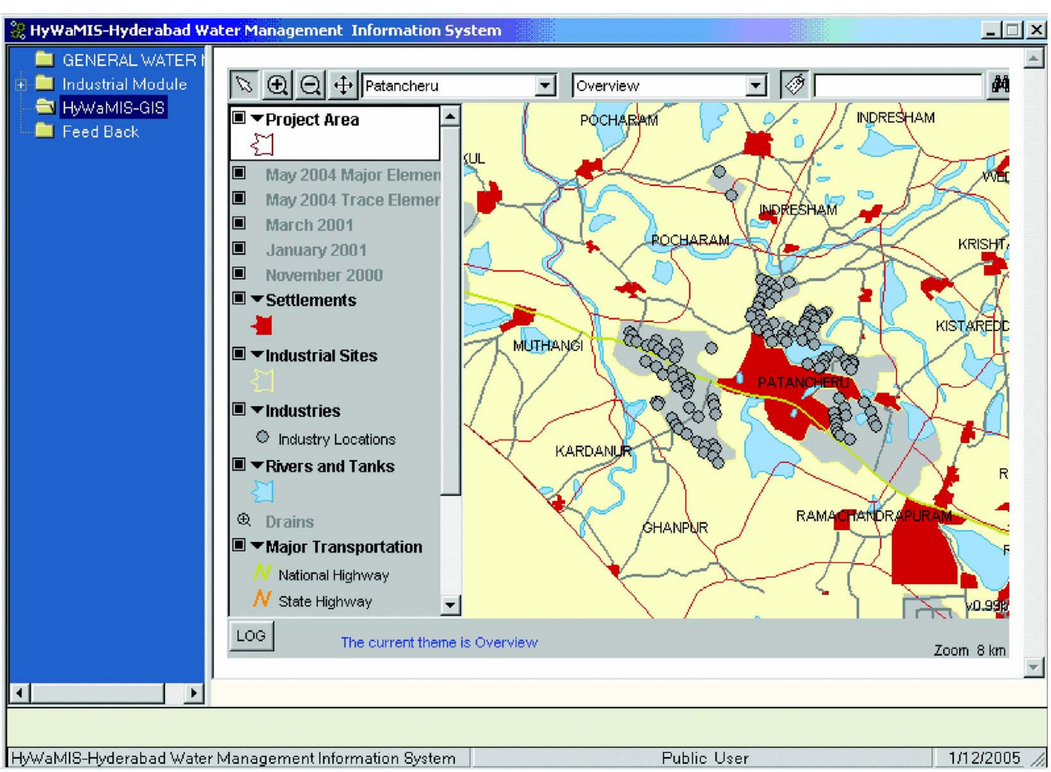

Figure 5: The integrated Alov Map GIS viewer showing a thematic map on lead contamination of groundwater and surface water.

geographical extent and completeness of the available information, define own queries and generate charts. Additionally, if spatial information is available, sampling sites and industries can be visualized and browsed through the integrated AlovMap GIS Viewer. Predefined thematic maps offer rapid access to relevant water quality parameters and industries.

Further results include different maps of the water quality situation around Patancheru and Bollaram Industrial Development Areas that were created with ArcGIS and presented to the stakeholders (Kingseisen et al., 2005).

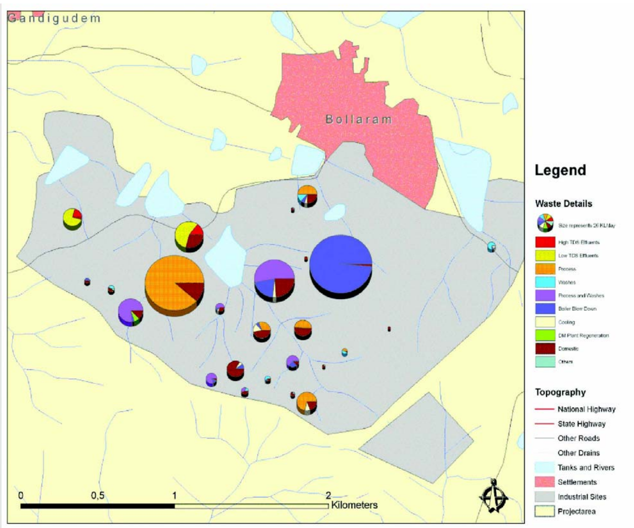

Figure 6: Thematic map: Discharge of effluents with regard to effluent type.

In fact, point measurements can only provide detailed information about local water conditions. Spatial interpolation was used to overcome this lack of information by estimating the spatial variation of parameter values. In this case the spatial interpolation method Kriging was applied, which is especially useful when point data density over an area is sparse. The generated surface was divided into eight classes, categorised according to the significance of the contamination parameter values with regard to health and environmental relevance.

Figure 7 shows the results of the hotspot analysis for the parameters arsenic and cadmium. It becomes obvious that arsenic concentrations are extremely high (indicated by red colour) covering most of the investigated area in Patancheru and Bolaram. In this context contamination by cadmium appears to be less relevant showing only one hot spot (yellow spot) in Bolaram.

Scenario Analysis and Environmental Impact Assessment

In order to apply a methodological approach of impact identification and assessment to the case study area Patancheru IDA, a discussion process among the stakeholders for identifying relevant assessment criteria was initiated. The issue of "groundwater quality" was identified during the 2nd stakeholder Advisory Panel meeting as a specific priority decision problem to be used in a subsequent multi-criteria analysis and impact assessment exercise. During the stakeholder workshop in September 2004, 28 parameters were identified as relevant state-variables for describing the water management situation in the case study area. The variables were subsequently grouped, ranked and categorised as either environmental, economic or social variables. A summary of the top three variables is listed in Table 1.

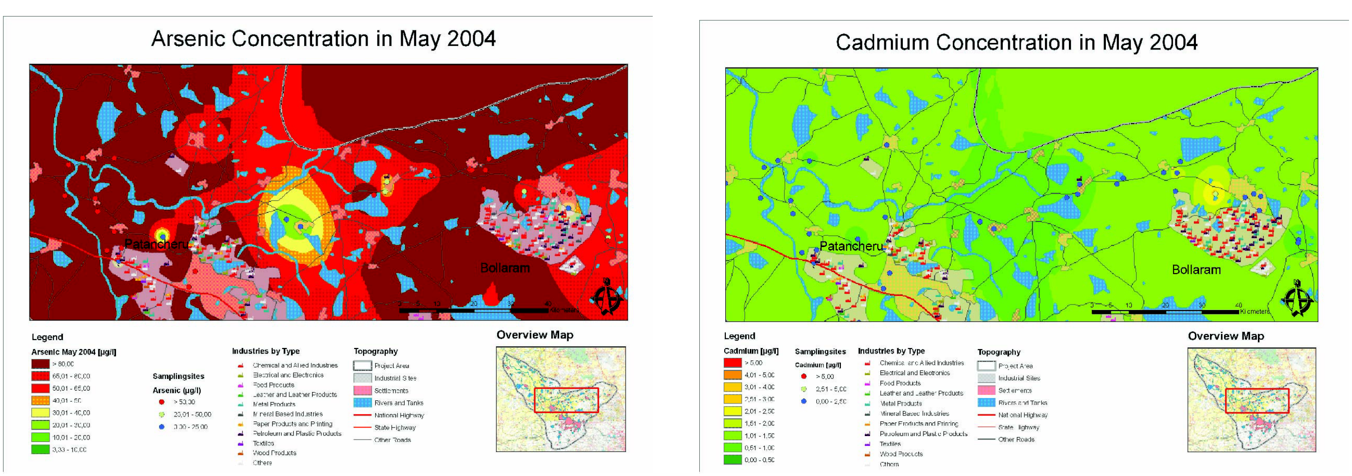

Figure 7: Hot spot analysis (thematic maps on groundwater and surface water quality).

Table 1: State variables that were grouped and ranked by the Stakeholder Advisory Panel

Environmental variable	*Economic variable*	*Social variable*
Quality of Water Supply	Agriculture Yield	Human Health
Quantity of Water Supply	Employment	Education Facilities
Air Quality	Land Value	Awareness on Improvement of technologies

Based on the discussion with stakeholders and the recommendations of the Stakeholder Advisory Panel the range of available techniques for improvement of the situation in the case study area Patancheru IDA includes the following options:

- Improvement of Industrial and Domestic Wastewater Collection – through new and reconstruction of sewerage system
- Reduction of wastewater contamination – through industrial wastewater pre-treatment systems and wastewater reuse
- Improvement of wastewater treatment performance (CETP)
- Remediation of lakes and tanks
- Education and awareness schemes

The following three options which are composed of a number of different water management interventions (actions) were developed and used as input for multi-criteria assessment:

1. Status quo–no intervention
2. Remediation of lakes
3. Reduction of wastewater emissions to surface and groundwater

A decision making framework was devised in order to subjectively rank each option on the basis of the defined set of criteria.

Out of the many approaches that can be used for an evaluation of water management alternatives, Compromise Programming (CP) (Bogardi and Bardossy, 1983) was selected for multicriteria assessment because it represents a good compromise between mathematical sophistication and methodological transparency. Compromise programming is an interactive method that identifies non-dominated solutions which are closest to the ideal solution by some distance measure.

The structure of Composite Programming (CP) was used by grouping basic indicators into successively broader clusters of higher level indicators, based on similar characteristics. In Table 2 the defined multicriteria assessment scheme (including environmental and socio-economic criteria at different levels) is presented.

This matrix structure was implemented into Decimaker Software V.2.0 (University of Nebraska-Lincoln, USA),

Table 2: Scheme of indicators for composite programming

	Composite indicators		
Set of basic indicators	*Second level*	*Third level*	*System*
CETP treatment efficiency Direct discharge Industry effluent pre-treatment	Effluent discharge	Environment	State of the System
COD Arsenic Chloride TDS	Water quality		
Coverage of water demand	Water quantity		
Costs Agriculture yield Employment Land value	Economy	Socio-economy	
Education facilities Awareness	Social issues		
People affected by environmental diseases	Public health		

which is an efficient computer aided tool for multicriteria decision making and composite programming (Bogardi and Bardossy, 1983).

A score was assigned for each option for each criterion on the basis of available data and subjective estimates. The graphic representation of the multicriteria analysis (using Decimaker V2.0 software) of the defined options is shown in Figure 8.

However, though the multicriteria decision making structure and applied scores that are shown in Figure 8 was formulated using information elicited from the Advisory Panel meeting, it needs further stakeholder consultation and discussion as well as a comprehensive sensitivity analysis to assess the behaviour of the MCDM matrix and validate the results.

In fact, these results should be seen as a demonstration example of the practical applicability of the multicriteria decision making methodology. It was commonly agreed by the Stakeholder Advisory Panel that multicriteria analysis in combination with a comprehensive information system (HyWaMIS) could serve as a decision support tool for defining strategies for solving the problems of environmental contamination of the case study area Patancheru.

Conclusions

Currently water management authorities are challenged to combine the required traditional objectives of water quality and supply with socio-economic needs, such as maintaining and upgrading the landscape, generating income, health issues as well as general environmental protection.

In the Patancheru case study (Hyderabad, India) the administrators of the Hyderabad Metropolitan Water Supply and Sewerage Board have experience in managing water in the area, and this knowledge is supported by suitable technical-engineering know-how. However, complex decisions should not be taken without taking into account the opinions and experience of others involved in the effects of that decision. This means that different criteria and objectives have to be taken into consideration, evaluated, weighted and integrated, and often multiple objectives lead to conflicts which require compromise solutions. The methods for managing a plurality of interests in decision-making processes are relatively new for the water management sector, such as the multi-criteria analysis methods used in this case study.

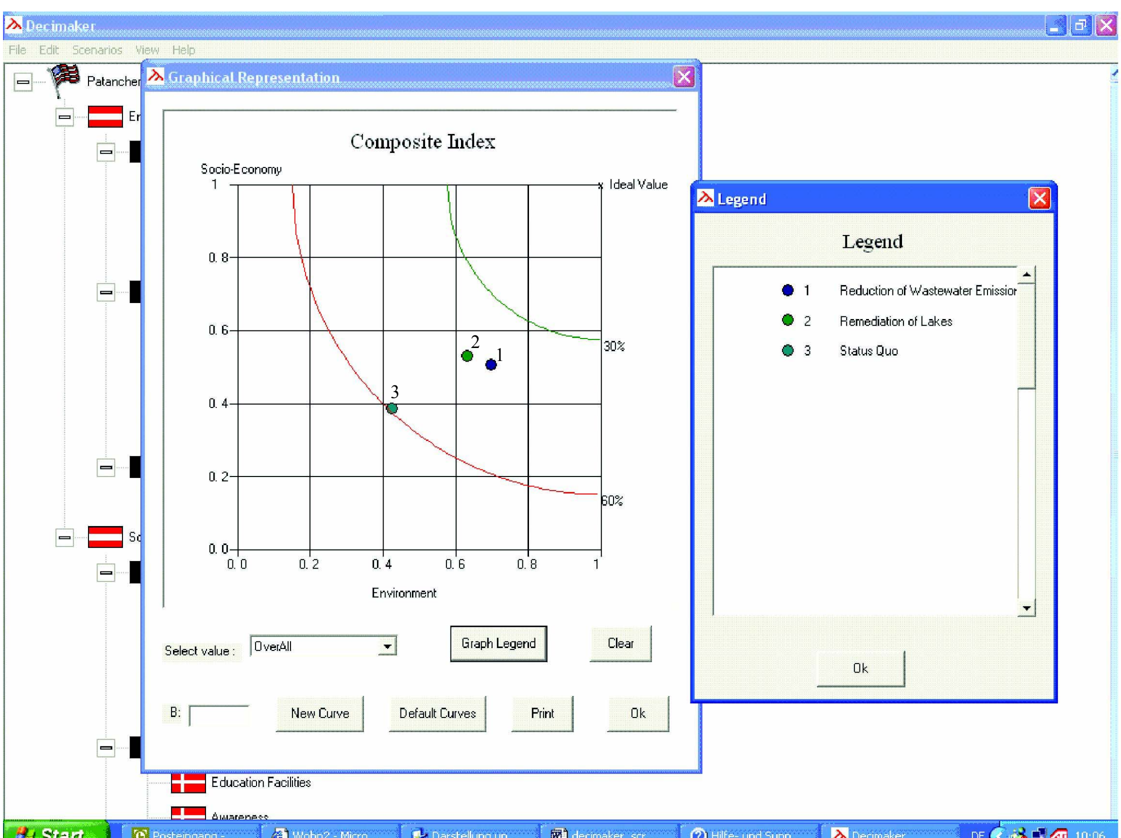

Figure 8: Composite index for the three selected water management options for the case study area Patancheru IDA (Decimaker V2.0).

For this reason, the tools for information management and decision-support based on multi-criteria analysis have great potential in aiding the choice between alternative solutions. They use methods that can be documented, and are therefore clear and can be understood by the different players involved in the decisional process (authorities, ordinary citizens). GIS is a significant support tool for data storing, documentation and visualisation. It provides many consistent methods for hydrologic and environmental scenario modelling and is an excellent medium to present and visualise the current environmental status and pollution hazards.

Future efforts shall be made to extend the information system for the case study area by including additional modules that cover other related thematic sectors (e.g. agriculture, land use, ecology) to deal more thoroughly with multi-dimensional problems and to develop increasingly advanced interfaces that are effective for the end-users. Another priority is the improvement of communication between the involved institutions and to agree on a common data exchange policy for environmental and industrial information.

Finally, the stakeholder process initiative will be continued by establishing a "Hyderabad Environmental Stakeholder Platform" which will continue to accompany and advise the future development of the information system.

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