AN INTEGRATED APPROACH TO WATER QUALITY MANAGEMENT

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ABSTRACT

Most of the Indian rivers starve for water during the non-monsoon period, which extends at a stretch for almost nine months. Groundwater as a source is also dwindling due to over-exploitation of this resource for increased agricultural use, to support an exploding population and industrial growth. A situation of fresh water sharing from surface water to groundwater reserves below aquifers is virtually non-existent during the non-monsoon period due to non-availability of water in rivers. Thus, the rivers quench their thirst with whatever discharge they receive in the form of polluted waste waters from households and effluents from industries (seldom treated) as point sources. A recent survey of CPCB indicated that only about 22% of the total sewage generated in the country are treated before it is discharged to water bodies and the rest 78% receives no treatment. Discharge of untreated or inadequately treated industrial wastewaters, which could be more lethal, make the situation worse. The rivers thus can no longer serve fresh water to humanity as their self-assimilative capacities are exhausted. As a result, water famine, especially during summer months, has become a non - news item in this vast sub-continent.

To add to the miseries, untreated polluted wastewaters are discharged on land without any rationale, which increases their potential to percolate and contaminate groundwater, which would be beyond any contention for remediation at a later stage.

Water quality is being monitored since decades by several premier organisations, like the Central Water Commission, the Central Ground Water Board, the State Water Resources Development Agencies and the Central & State Pollution Control Boards through their extensive and also expensive networks of monitoring stations, with no virtual co-ordination among these organisations to initiate a concerted effort in improving the quality of life through supply of potable water.

Being seized with the problem, the Ministry of Water Resources, Government of India, has taken up the Hydrology Project in collaboration with the Government of the Netherlands to develop a national Hydrological Information System (HIS) with user-friendly software for the benefit of concerned agencies, and to evolve an integrated approach for water (quality) management.

The present paper attempts to bring to the fore the need for such an approach and how to make such a scheme successful.

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1. Introduction

Fresh water, which is so essential for our life, is only a small portion of the total water available on this earth. According to the global hydrological cycle, 97 percent of water always remains in the sea. Of the left-over 3 percent, nearly 1.998 percent is locked in the masses of ice caps and glaciers in the Poles and mountains and in the clouds, 0.85 percent falls directly on the sea as rainfall and 0.152 percent is available to humanity as utilisable water in the form of precipitation on land. However, out of the 0.152 percent, 0.15 percent flows through the rivers back to the sea as surface run-off, and only 0.002 percent of water is available as surface water in lakes / rivers and groundwater reserves, which could be harnessed to meet the demand for various designated best uses. Thus, for every 250 litres of global water, only one teaspoonful of fresh water (5 cc) is available to mankind, rendering it a scarce and precious resource.

2. Water Resources of India

The annual rainfall over India, based on the daily data from more than 3,000 rainfall recording stations for a period of 50 years (1901-1950), is computed as 105 centimetres. It is the largest anywhere in the world for a country of a comparable size. From precipitation alone, India receives 4,000 km^3, including snowfall. Of this, 75 percent occurs only during three monsoon months. A good part of it is lost through the process of evaporation and plant transpiration, leaving only half of it on the land for use. After allowing for evapo-transpiration losses, the country's surface flow is estimated as 1,880 km^3. Due to topographical, hydrological and other constraints, it is assessed that only about 700 km^3 of surface water can be put to beneficial use by conventional methods of development. The annual replenishable groundwater resource is assessed to be about 600 km^3 , of which the annual usable resource is estimated at 420 km^3. The distribution of water resources in various compartments is shown in Table 1.

Table 1 Estimated distribution of water resources of India

Compartment	Quantity (km^3)	
Total precipitation	4,000	
• Immediate evaporation	700	
• percolation in soil	2,150	
- Soil moisture		1,650
- Groundwater		500
Surface water	1,150	

Almost the entire country is criss-crossed by rivers. There are fourteen major river basins in the country, which occupy 83 percent of total drainage basins, contribute 85 percent of the total surface flow and house eighty percent of the country's population. They are Brahmaputra, Ganga, Indus, Godavari, Krishna, Mahanadi, Narmada, Cauvery, Brahmani, Tapi, Mahi, Subarnarekha, Pennar and Sabarmati rivers. These rivers have been grouped into three categories based on drainage basin area as shown in Table 2.

Table 2 River basins of India

Category	Basin Area (km^2)	Number of Basins	Percentage of Total Drainage Area	Percentage of Flow Contribution	Percentage of Population living in the basin
Major	More than 20,000	14	83	85	80
Medium	Between 2,000 and 20,000	44	8	7	20
Minor	Less than 2,000	55	9	8	

There are also several non-basin coastal rivers, the lengths of which are small, besides a few rivers, which originate and get lost in the deserts after traversing some distance.

3. The Problem

Going by the number of rivers in the country, there is no dearth of it. But the problem of water availability/scarcity is serious on account of diversity in geo-climatic conditions, limited rainy season and inadequate water-holding capacity in terms of dams/reservoirs to store excessive run-off during the monsoon. This has resulted in the country's hanging between two natural calamities—the drought and the flood. Under both situations, the quality of the water resources is threatened from contamination. During dry months, most of the rivers carry mainly untreated wastewater from human habitation/industries. The status of waste water generation, collection and treatment in class I cities and class II towns, as studied by the CPCB, revealed that only about 22% of the total sewage generated in the country is treated before it is discharged to water bodies, as shown in Table 3. During this lean period, also there is neither any flow in the river nor there is any regenerated water from groundwater reserves, due to depleted groundwater table on account of over - exploitation, to dilute or assimilate the waste load. During this period, there is also wide scale use of untreated / partially treated wastewater for irrigation increasing the potential for ground water contamination during this period. In case of flood, the problems of surface and ground water contamination pronounce as the floodwaters recede, on account of decomposed human bodies and carcasses and other organic matters lying almost everywhere awaiting safe disposal.

The municipal solid wastes are disposed in low-lying areas in all the cities and towns without any precaution against percolation of leachates contaminating groundwater. Several such instances have come to light where the groundwater has shown degradation in quality due to such casual method of disposal of garbage in unlined pits/low-lying areas.

With the growth of agriculture, there is also large-scale use of organic and inorganic fertilisers, which have potential for groundwater contamination.

Under such a scenario, there is a need for a strong mechanism for monitoring of the quality of groundwater and surface water, for the benefit of the user agencies participating in the environmental protection programmes.

Table 3 Status of water supply and wastewater generation & treatment in class I cities and class II towns of India

Parameters	Status
Number of class I cities	299
Population (million)	128.1
Distribution of population of class I cities according to catchment area (million) • Major river basins • Non-basin coastal • Non-basin, non-coastal	 97.4 23.3 7.4
Water supply (million litres/day, mld)	20,545
Per capita water supply (litres/day)	182
Wastewater generated (mld)	15,772
Wastewater treated (mld)	3,740
Number of Class II towns	245
Population (million)	22.4
Distribution of population of class-II towns according to catchment area (million) • Major river basin • Non-basin coastal • Non-basin, non-coastal	 17.2 1.0 4.2
Water supply (mld)	1,936
Per capita water supply (litre/day)	103
Wastewater generated (mld)	1,650
Wastewater treated (mld)	61.5

4. Strategy for Protection of Water Resources

In its wisdom, the Indian Parliament enacted ‘The Water (Prevention and Control of Pollution) Act’ in 1974 with the sole objective of ‘maintaining and restoring wholesomeness of water bodies’, and Pollution Control Boards (PCB) were constituted at the Central and State levels to perform the functions delineated in the Act. Water being a State subject, the Central Pollution Control Board (CPCB) has inter alia been given the mandate of an advisory role (1) to evolve water quality standards for inter-State rivers and to solve inter-State disputes on pollution matters, (2) to develop guidelines and manuals for prevention and control of pollution arising out of any municipal/domestic or industrial discharge into water bodies, for implementation by the State Pollution Control Boards (SPCB), and (3) to plan and cause to be executed nationwide programmes for pollution control. CPCB has also been empowered to perform functions of the State Pollution Control Boards on the directions of the Central Government in case of development of a grave situation on account of pollution at any location in the country at the cost of the State Government. However, CPCB and SPCBs being autonomous bodies under the Central and State Governments respectively, there is no direct institutional/organic linkage among the Pollution Control Boards to perform in an integrated manner to solve the pollution problems through a holistic approach.

The PCBs have adopted the following strategies for prevention and containment of pollution:

- control of pollution at source with due regard to techno-economic feasibility;
- utilisation of assimilative capacity of water bodies in allocating waste discharge loads in stead of aiming at preserving pristine quality;
- proper siting of industries;
- recycling and reuse of treated waste water for agricultural purposes;
- introducing discipline in water abstraction and waste water discharge to effect water conservation; and
- regulation in river flow/discharge

The above strategies have not only been drawn to tackle the problem of water scarcity and preservation of quality of the available water resources, but also aims at promotion of a co-ordinated effort among the concerned agencies at the Central and State levels.

5. Mechanism for Control of Pollution of Water Bodies

The mechanism for prevention and control of water pollution, as adopted by PCBs on the basis of afore-mentioned strategies, approaches the problem from the following angles:

- Control at source; and
- River basin-wise control

5.1 Control at source

This mechanism is applied by means of 'Granting of Consent' to polluting sources after they comply with the standards notified by the PCBs by providing adequate treatment to their effluents before discharging into water bodies. These 'Consents' are renewable at regular intervals, to be decided by PCBs, subject to compliance with the standards and any other condition imposed by the Board.

For specific large industries, with capital investment above Rs. 50 crore, there is a provision under 'The Environment (Protection) Act, 1986' for submission of the 'Environmental Impact Assessment (EIA)' report and 'Environment Management Plan (EMP)' to the Ministry of Environment & Forests for obtaining environmental clearance.

This approach requires frequent surveillance monitoring by PCBs at the final outlet of industries to ensure compliance with the effluent discharge standards and its impact on the river water quality.

5.2 River basin-wise pollution control

In case of multiple sources of pollution, even if the individual compliance with the standards is ensured, the total quantum of the pollution load generated may exceed the assimilative capacity of the water body warranting imposition of location-specific stricter standards. For this purpose, the following procedure has been adopted by the CPCB:

- The rivers including their tributaries are classified stretch by stretch into five categories according to their designated-best-uses. A river stretch may be subjected to a number of simultaneous uses. The stretch will be designated by that particular use which demands the highest quality. Accordingly, the 'Water Use' map is prepared to project the desired quality to sustain various uses.

- Water quality criteria for different designated-best-uses are defined for sustenance of the quality (Table 4).

Table 4 Designated-best-use Classification of fresh water

Designated-best-use	Quality Class	Primary Quality Criteria *
Drinking water source without conventional treatment, but with chlorination	A	6.5 to 8.5 (1); 6 or more (2); 2 or less (3); 50, 5%-200. and 20%-50 (4); Nil (5 - 8)
Outdoor bathing (organised)	B	6.5 to 8.5 (1); 5 or more(2); 3 or less (3); 500, 5%-2000, and 20%-500(4); Nil (5 - 8)
Drinking water source with conventional treatment	C	6.5 to 8.5 (1); 4 or more (2); 3 or less (3); 5000, 5%-20000, and 20%-5000 (4); Nil (5 - 8)
Propagation of wildlife and fisheries	D	6.5 to 8.5 (1); 4 or more (2); Nil (3 - 4); 1.2 (5); Nil (6 - 8)
Irrigation, industrial cooling, and controlled waste disposal	E	60 to 8.5 (1); Nil (2 - 5); 2250 (6); 26 (7); 2 (8)

*Note: (1) pH, (2) dissolved oxygen in mg/l, (3) $BOD^{20\,C}_{5\,day}$ in mg/l, (4) total coliform (MPN/100 ml), (5) free ammonia in mg/l, (6) electrical conductivity in μmho/cm, (7) sodium adsorption ratio, and (8) boron in mg/l.

- A network of 'Monitoring Stations' is established to ascertain the actual quality of water through sampling and analysis.
- The 'Water Quality' map is prepared based on the water quality data.
- The 'Water Quality' map is superimposed over the 'Water Use' map to identify river stretches under stress in terms of quality requiring measures to be taken upstream for improving the situation.

The above-mentioned approach is universally accepted. However, it needs establishment of an efficient network of stations for reliable monitoring of the quality of water for pollution-related parameters with accuracy at a regular frequency.

6. Present Monitoring System and the Water Quality Database

Several agencies in the country viz. the Central Water Commission (CWC), the Central Pollution Control Board (CPCB), the Central Ground Water Board (CGWB) etc., are monitoring the quality of surface and ground waters, through their Regional Offices or their counterpart agencies in the States according to their requirements/concern and store their data for departmental use, observing secrecy at times. Sometimes data are compiled and published as ‘Data Year Book’ with limited copies for their own use. The type of data collected by the agencies and their usefulness are shown in Table 5.

Table 5 Water Quality Data and their Usefulness

S.No.	Monitoring Agency	Type of Data	Usefulness/Purpose/ Limitations
1.	CWC/State Agency	Rainfall, Evaporation, Humidity, Temp., Wind, River flow, W.L., Flood & Sediment character-istics, Water quality (except pollution para-meters)	Water resources development, Water sharing among States, Flood forecasting, Sediment transport, Suitability For irrigation etc.
2.	CPCB/SPCB	River water quality	Limited network for pollution trend monitoring for enforcement of pollution control regulations etc.
3.	CGWB/State Agency	Hydrogeology, Aquifer characteristics, Groundwater level, yield and quality etc.	Groundwater potential evaluation and resource development, suitability for irrigation etc.
4.	India Meteorology-cal Dept.(IMD)	Diurnal temperature, wind direction and velocity, rainfall intensity and duration	Weather forecasting, climatic trends and behaviour
5.	National Informatics Centre (NIC)	National economic growth, industrial and agricultural production	Easy flow of information to users in different parts of the country through a network

The Central Water Commission (CWC) and its State counterpart Agencies are monitoring water quality mostly at the river gauging stations, which are situated on major rivers, and the focus of attention is to observe ionic balances and suitability of water for use in irrigation. The monitoring network is not extensive and the laboratories are not well equipped.

The Central Ground Water Board (CGWB) and its State counterparts on the contrary have huge networks, so much so that they do not have adequate infrastructure to analyse the samples within a reasonable time.

The Central Pollution Control Board (CPCB), on the other hand, have a very nominal network of 480 water quality monitoring stations under the Global Environmental Monitoring System (GEMS) of the World Health Organisation (WHO) and the Monitoring of Indian National Aquatic Resources System (MINARS). Under these systems, the respective State Pollution Control Boards (SPCBs) monitor water quality in respect of their State at the locations identified by CPCB. Most of these Boards have state-of-the-art laboratories with infrastructure facilities and trained manpower to analyse water quality parameters including toxic substances, like heavy metals and pesticides. However, with the rising pollution level, their thrust area is industrial pollution control with respect to management of solid & liquid wastes and gaseous emissions.

Each of the afore-said agencies has historic databases at their possession in files, and some of them have already developed computerised databases and user-friendly soft-wares. However, there is lack of co-ordination among the concerned agencies in data sharing, and the agencies are working in a mutually exclusive manner in the absence of a national database.

It is evident from the above analysis that there is an imminent need for an integrated system for water quality management.

7. The Hydrology Project

Realising the problems and constraints of the agencies involved in water (quality) management and the need for integration of efforts being made by them, the Ministry of Water Resources, Government of India has taken up the Hydrology Project (HP). The project is being implemented with an International Development Association Credit (No. 2774 –IN) for US $ 142.0 million. The primary objective of the project is to improve the facilities and staff capabilities of the Central and State agencies involved in surface and groundwater hydrology, for the collection and management of hydrometric and water quality data, and use of such data for evaluation of water resources. The project, therefore, involves network rationalisation of surface water gauging stations, climatological stations and groundwater observation sites. Furthermore, it introduces standard procedures for data collection, processing, validation and management including the development and use of software for water resources evaluation.

The project area covers almost the entire Southern Indian peninsula. It comprises the States of Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Maharashtra, Gujarat, Madhya Pradesh and Orissa. The Government of The Netherlands finances Technical Assistance, under the Indo-Dutch Bilateral Programme, for the required consultancy services and overseas training amounting to US $ 17.4 million.

The Hydrology Project aims at developing comprehensive, easily accessible and user-friendly databases covering all aspects of the hydrological cycle, including surface water and groundwater in terms of quantity and quality and climatological measurements, particularly of rainfall. Each database will be embedded in a **Hydrological Information System (HIS)** which covers the hydrometeorological infrastructure and comprises resources for the recording of the parameters and the required data validation, processing, storage, dissemination and presentation. The HIS structure at the State/Regional level is shown in Fig.1. While the immediate goals for the Hydrology Project are better quality of data and a user-friendly HIS, there is also support for demand-driven research in water resources development and hydrology. This will assist in the development of more reliable and spatially intensive data on water resources. The project further aims at making the hydrological information available for planning and management of water resources and other legitimate uses, and promoting its utilisation for the same. These goals are to be achieved by improvement of institutional and organisational arrangements, technical capability and physical facilities available for collection, processing and dissemination of hydrological and hydrometeorological data.

Hence, the ultimate objective of the project is to deliver a functional HIS and improve the institutional capacity of implementing agencies to build, operate and utilise the HIS, to the benefit of the different user groups, and to support major elements of the country's **Water Policy.**

8. Water Quality Management under HP-Programme

The water quality management programme, as conceived under the Hydrology Project, is based on the premise that although there are multiple agencies involved at the Central and State levels in the programme, the data generated are reliable. To achieve such an objective, it is essential that (1) the sampling locations for water quality are representative, (2) samples are preserved before transportation to laboratory to avoid deterioration in quality, (3) samples are analysed for designed parameters at pre-decided frequency following unified standard laboratory procedure by all the participating agencies, (4) scientists/chemists are trained in operating state-of-the-art instruments being procured for analysing pollution- related parameters, (5) analytical laboratory data are validated before storage following unified data entry system, (6) within-laboratory Analytical Quality Control (AQC) exercises are conducted in each laboratory as a routine, and inter-laboratory AQC exercises are conducted at least once a year to improve the reliability of data and to develop confidence level of the laboratory analysts, and (7) interpretation of data is done in association/co-ordination with the pollution control agencies for initiating action programmes, if needed.

With the above objectives in view, the following activities have been taken up to integrate the water quality monitoring systems so that efforts made by various concerned agencies are unified for a concerted action programme for mitigate measures:

- A rationale has been evolved for designing surface and groundwater monitoring networks to locate baseline, trend and trend-cum-surveillance stations.

- Monitoring locations have been finalised and indicated on maps of suitable scale for the preparation of digitised maps to facilitate the application of a Geographic Information System (GIS) in data interpretation.

- A 'protocol for water quality monitoring' has been documented, which streamlines the procedure for selecting the parameters and the monitoring frequency based on the type of stations, parameters to be analysed at site, preservation and transportation of samples to the laboratory for analysis of remaining parameters, data validation and reporting.

- Guidelines for standard analytical procedures have been evolved.

- Training modules have been prepared for each parameter.

- Hands-on-training is imparted for sampling and analyses of field parameters at site.

- AQC exercises are being conducted among the laboratories in association with the Central Pollution Control Board.

- Computer softwares are developed for data entry and interpretation systems.

- To promote co-ordination among the agencies participating in HP and the agencies, like the Central and the State Pollution Control Boards, municipalities etc., which would be the ultimate users of the data generated under the HP, in planning their programmes for pollution prevention and control to protect the national water resources or deciding about conjuctive use of available water resources, interactions are being made with the afore-said agencies, individually and also collectively, to develop a good working relationship in mutual exchange of information available with the respective agencies. This is being effected through constitution of State Level Review Committees comprising members from all the HP- agencies and the State Pollution Control Board in respect of the concerned State.

9. Concluding Remarks

The Hydrology Project (HP), taken up by the Ministry of Water Resources, Government of India, with the technical collaboration of the Government of The Netherlands and financial assistance from the World Bank, is the first of its kind in the country to promote interaction and co-ordination among various Central and State Government agencies involved in monitoring of hydrological parameters, to avoid duplication of efforts, and develop a national database, i.e. a 'HIS', and to facilitate sharing of information for the benefit of user agencies. A schematic diagram of the integrated approach for water quality management is shown in Fig. 1.

The Hydrology Project interacts with the Central and State agencies concerned with the monitoring of water quality, individually and also collectively, to design the monitoring network (avoiding duplication) and group the monitoring stations into background, trend or surveillance stations according to quality requirements. Parameters and frequency of monitoring for each category of stations have also been specified. To ensure a unified procedure for monitoring and analysis, HP has also developed a 'protocol for water quality monitoring' and 'guidelines for standard analytical procedures' to be observed by all the concerned agencies.

Efforts are being made for analytical quality control so that the water quality data generated are of acceptable quality for the interpretation and subsequent utilisation by user agencies through the software developed. This will strengthen the understanding of water quality, both for surface and groundwater, as a basis for deriving action programmes for maintaining/restoring water quality for sustainable use and protection of aquatic resources in an integrated manner. This will also help in fulfilling the prime objective of the Water (Prevention and Control of Pollution) Act-1974 in maintaining and restoring the quality of the national water resources through concerted efforts towards integrated water quality management.

Acknowledgement: The authors are thankful to Dr. J. G. Grijsen, Team Leader, Hydrology Project, for his guidance and encouragement in preparing the manuscript of this paper.

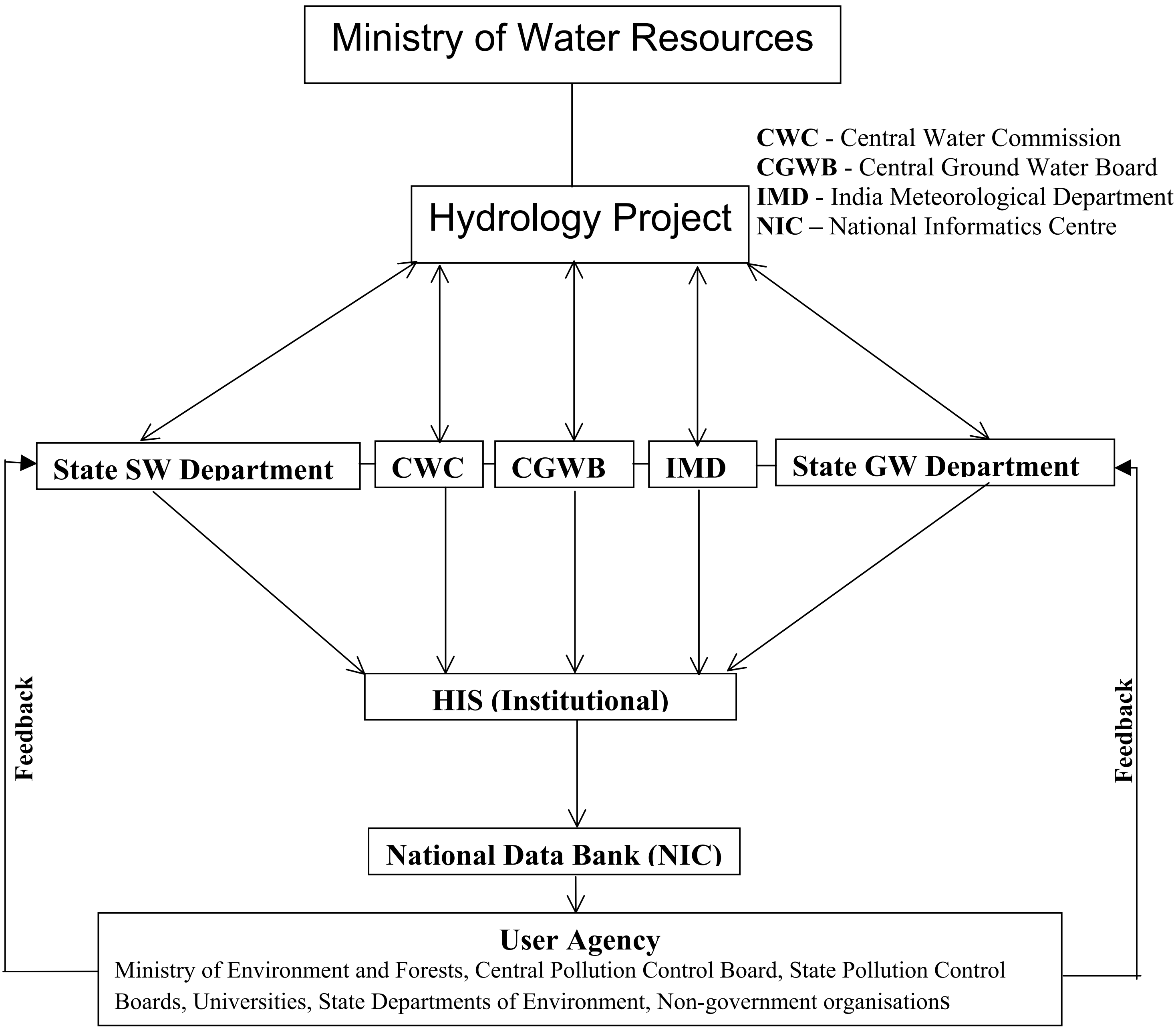

Fig. 1 Schematic Diagram of Integrated Approach for Water Quality Management