QUANTIFICATION OF MUNICIPAL WATER SUPPLY AND ROLE OF METERING IN LARGE INDIAN CITIES

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ABSTRACT. Quantification includes working out flow measurements and recording in the water table or water account to the size of ULB. Role of metering is limited, properly quantified data is needed for efficient management.

Domestic water supply in India needs attention on both, adequacy and quality. The evidence, however, points to inefficiencies in water management Bangalore (metered) and Ahmedabad (non-metered) cities. The role of metering is important but limited in terms of system reform. A water account was developed on the idea that accountability breeds responsibility. Integrated Water Accounting Platform-IWAP was conceptualized as a tool.

Keywords: *Quantification; Account; Efficiency; ULB*

Introduction

This study was carried out at two levels, macro concept building, and micro concept testing. At the macro level, the literature review opens various insights into the water supply techniques, planning issues, management, and scope for improvement. The outcome clearly shows that- fresh water scarcity, supply cost and recovery, judicious use, citizen rights and other stakeholder's requirement are the key drivers to generate the information on the water supply management. They direct the ULBs to enhance domestic water supply system for optimum and judicious use of water as a natural resource in a cost effective manner. A solution may be a simultaneous functioning of the market for water working and rationing system. Such system can be designed based on quantified supply. Quantification can be done by tabulation or accounting method. Tabulation method-it is complete idea of water balancing in the diagram table format, where both data and variables defined at each stage and component wise, mapped processes and quantified water losses, generally using excel sheet. Water accounting is similar to financial accounting, which is discussed further page 5 and 6. Very few cities are practicing Tabulation method sincerely. Water accounting method is in its infant stage and very limited information is available even in literature. Quantification is a concept based solution which can meet the ULB requirements but its implementation requires system reforms and scientific knowledge for the cities having metered or non-metered water supply arrangements. This concept should be tested before use. It is challenging.

Measurements are a mandatory requirement for quantification. Wherever accurately metered measurements are not available or are costly, estimated measurements can be used for accounting with reference to the reliability scale. This is meaningful and serves the purpose. It is possible to measure the water quantity discharge/delivered by using apparatus like Pitot tube, Venturi meter. Open Pipe Discharge method can also be used with the application of the formula which has a relationship between discharge Q, head H, velocity of water flow V etc. but the accuracy may be less. (Bajwa, 2003)

Water meters also have limitations of errors and functional problems. Developing a metered system is costly; requires much time, political will and social acceptance. As such, in reality, even at present in 2016 very few Indian cities that have developed a 100% metering facility. This reality demands alternative methods other than metering for quantification. Thus, it is very important to know about the role of metering, its limitations, and linkages with other aspects of quantification. This requires exploratory and a systematic study. Australia, Spain, China and Africa have adopted water accounting in line with financial accounting at basin level, linked to the national economy. India has not ventured to adopt water accounting. Neither literature nor field experience gives clarity on the role of metering in relation with the quantification of urban water supply. This requires a conceptual framework, United Nations Standard Economic Environmental Accounting (SEEA) structure referred for physical and monetary applications.

'NWF Bill 2013' shall give legal status to national water policies and enforce state and ULBs to start the practice for water accounting, auditing and publishing the reports. Present circumstances demand that changes in policy and reforms are essential to developing the system as a market (Alagh Y. K., 2013). All these lead to the necessity of research-based studies and solution.

Study Design

Research Gap Inadequate knowledge on the role of metering and its linkages with quantification aspects and conceptual framework required for water accounting to develop the quantification practice for water supply system of the city for its developmental aspects.

Research Concept 'Quantification' means a complete process of measurement for domestic water supply system of the city, which includes working out measurements of water at various stages in the system and recording it in the water table or water account to the size of ULB. This generates reports required for the auditing and publishing purpose for various stakeholders including decision-makers working on system improvements. 'Quantification' is a concept. It was explored and tested for metered and non-metered water supply system.

Aim was to study developmental aspects of quantification of domestic water supply system and to develop a conceptual framework for water accounting based on financial accounting and auditing principles in the Indian context.

Objectives (1) To develop an approach to quantify domestic water supply particularly by water accounting method. (2) To explore the role of metering in quantification (3) To identify the planning issues and work out possible solutions and recommendations for the system reforms. (4) To apply theory and methodology required to design and develop a sample water account.

Material and Methods

Methodology Expert interviews and focus group presentations were planned to verify and outline the concept. Questions were designed to check the importance of the quantification and adaptability for the water accounting were result were the groups were found aware on the importance and agreed on water accounting in principle.

Two case studies in depth carried out for Bengaluru and Ahmedabad cities which have metered and non-metered water supply arrangements respectively. Comparison of the various parameters has generated an outcome for the role of metering with its limitations and linkages to quantification. Insights and ideas have been developed based on which the water accounting framework was set applying the stock and flow theories, which was tested by an example of water account for an imaginary city named CEPTABAD.

A brief note on the cities selected Bangalore now renamed as Bengaluru is the largest city in Karnataka, high population density, a growing economy, and grappling with the issues of water scarcity of nearby water resources. Bengaluru has very limited groundwater because of its hilly topography; more than 900 MLD raw water is procured from the river Cauvery, which is 97 km away pumping against a head of 500 m, treated and supplied at a huge expenditure. The Water supply is quantified for the billing and collection purpose. Total quantification is an issue because of lack of adequate systems. As a result, complete accountability of the system is still not achieved. Operated by BWSSB-a state level board, financially strong and have expertise to develop the system, limited water reuse in practice, able to satisfy the very goal of the establishment.

Ahmedabad the largest city in Gujarat with a high population density, a growing economy, and grappling with the issues of water scarcity and pollution of the river and lakes with improper disposal of wastewater, no water reuse in practice, falls under the 'Over Exploited' category due to very high illegal ground water consumption, mainly by the industries. More than 1000 MLD water is treated and supplied for domestic purposes at a cost of Rs. 300 core on operation only. The water supply is not quantified scientifically. As a result, inefficiency and accountability of the system is an issue. Few facilities developed year on year without holistic planning. The AMC-local self-government operates, trying for the pilot project, yet incomplete, hence the very goal of their establishment fails.

Comparison Bengaluru v/s Ahmedabad

- Bengaluru water supply is facing a more difficult situation compared to Ahmedabad; its source is 98 km away with a pressure head of 500m and the city area has a hilly topography. While Ahmedabad has an advantage of a near source-Narmada canal just 5 km away and topography is planar. Therefore, the energy costs and the capital expenditure per connection Rs. 19166 is high in Bengaluru as compared to Rs.1899 for Ahmedabad. Hence the tariff structure is also found to be higher in Bengaluru.
- Bengaluru has sufficient measurements required for the quantification, which facilitates proper billing against the quantity served and thus helps the management to keep a better financial control by proper billing and collection. While Ahmedabad doesn't have the measurements, the management is left to choose from other complicated billing options to keep a financial control e.g. by the way of merging service charges with the property tax bill on the basis of the type of water use, connection size, and area of the building/unit.
- BWSSB practice water balancing basis on the few assumptions adjusting losses but, it has a limited meaning. Whereas, AMC does not practice, this is not the desirable situation at all.
- BWSSB has precise measurements determine the UFW and NRW to be 33% and 47% respectively. While, AMC takes a judgmental approach, results in inaccurate calculations.
- NEWS Analysis shows that people in Bengaluru have adopted metering and measurements for payment against the service, high public awareness-people accurately quote bulk water quantity while filing complaints. While people of Ahmedabad are not so familiar.
- The budget analysis shows that BWSSB has achieved 99.9 % billing recovery, good financial control over O&M and capital expenditure. Whereas AMC has a poor billing recovery (8 months outstanding) and has hardly met the O&M expenditure, capital cost is subsidised.
- BWSSB has developed partial quantification practice, work out the accountability and the valuation for losses according to the water zones, reviewed on a monthly basis. AMC can work out at the city level and the quantification practice was not found satisfactory.
- BWSSB has achieved a reasonable level of equity in distribution (94 to 138 LPCD with a mean of 125 LPCD) but, AMC has no specific data, the inequity exists, which is a social issue.
- Bengaluru has a board level organization set up under the state as BWSSB,

exclusively for providing water related services. Whereas, Ahmedabad has a department level set up under ULB as AMC which provides all the statutory services including water. This level difference in governance is one of the major affecting factors for the performance.

- BWSSB has an excellent decision support system with an IT center, which keeps database up to date and provides required analytical reports for the decision making; while AMC has yet to develop the scientific support system, present working is very subjective.
- Financial analysis shows the deficit, increasing capital cost and revenue expenditure, lack of political will to raise tariff and correct financial deficit are the matter of serious concern for both the organizations. They are dependent on government grants and loans making difficult for the state to achieve sustainable development goals. Money can be saved by reducing losses and increasing system efficiency, this opportunity is a major driver to practice quantification.

Economic and Environmental Water Uses in Sabarmati Basin This perspective view shows that water is required mainly for domestic, industrial, agriculture, ecological and environmental purpose. India, Gujarat and Ahmedabad all three are facing water stress situation and had faced water scarcity in every decade. Agriculture economy and industrial development in Gujarat are highly dependent on canal irrigation and north Gujarat additionally uses a large amount of ground water. Land holding pattern shows that a large number of the farmers approx. 86 per cent belong to the marginal, small and medium segment. These farmers are also dependent on industrial and other works. Industrial and agriculture development is driving economy and water is important to run the business, which creates pressure on the other usages. Industrial waste pollutes water resources in the downstream of Ahmedabad in Sabarmati basin and creates conflicts among the users. Farmers prefer water demanding crops for better income that too in water scarce region by extensively using ground water, thus hampering environmental water balance. Therefore, it is necessary to plan and optimise water use in a transparent, judicious and sustainable manner. For that, proper assessment of available water with spatial and temporal reference with the consumption details is important to decide on proper allocation and optimum water use.

Overall availability of water including Narmada water in Gujarat and Ahmedabad is limited by nature and the legal award, which drastically reduced during drought periods, water demand across the sectors is high. It is very difficult to meet the domestic water demands and at the same time to achieve economic and environmental goals. Further, infrastructure has the limitation in storage, handling, carrying and distribution of water to their designed capacity. In these situations, water management becomes crucial and information plays the vital role: to meet production requirements, to avoid people's struggle and conflicts and to achieve the developmental goals keeping the environmental and ecological balance at center.

Ahmedabad is growing fast and has continually struggled to procure water for domestic purpose, textile, and other industries are totally dependent on ground water and facing issues like ground water exploitation; growing demand has increased the pressure on Narmada canal. This shows that how city life and economy is dependent on water. Water is dynamic in nature and city mainly uses water for economic growth and to nurture life. So, it is important to track its flow and recording its vital information scientifically, account consumption and develop applications. AMC and other users

procure a large amount of water from the resources nearby city as well transferred from the regional resources, which affects surrounding and regional ecology and environment. Hence, water use should be looked into a larger environmental perspective and accounted. Study analysis on Narmada water use shows that there is a deviation across the sectors from what was planned in 'Planning for Prosperity' (Narmada Planning Group, 1989), which is a matter of serious concern.

SEEA-A perspective view study suggest, publication of standard water balance statement for each hydrological cycle, showing the stock for each source, consumption and reuse of water for each purpose, including water conservation details. All the local water account should be prepared using the standard formats in such a manner that it can be integrated for the river basin, complementary to each other and with other relevant economic and environmental information. It should be mandatory to declare compiled SEEA statement for each river basin for the concerned authority. For this purpose, arrangements may be developed: Bureau of Water Efficiency as an apex body for water use, Office of the Water Accountant General monitoring and keeping certified water accounts, Chartered Water Accountant to certify the water accounts. Uniformity in water accounting terminology and data is necessary to work out the assessment of its availability, accessibility, distribution and usages. Hydrological year, calendar year and financial year may be different but it is important to align data/information properly with the reference periods. Municipal water accounting should be complementary to and be part of SEEA.

Water Accounting as System The water accounting, as system framework comprises to meet three broad aspects: standards, regulations and assurances. Standards are set by apex body which shall be regulated by the independent agency for the assurance given for water services by the Organization. Assurance in terms of quality, quantity, timings, pricing, rights, efficiency, data accuracy, water footprint, cost & risk, conflict & claims etc.

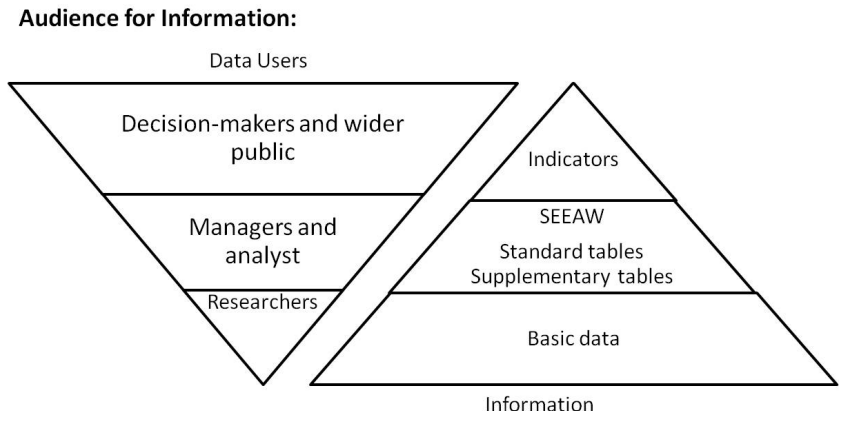

Figure 1Audienceforinformation,

Source: Water Accounting Godfrey &Chalmers, Page-34

There are various stake holders which have different role and interest in the system and accordingly require data, information reports or indicators. This is explained in the figure 1 which shows reverse pyramid relationship between data users and information. In spite of the limitations, experience has shown that even a gross estimate of water balances for use in water accounting can be quite useful to managers, farmers & researchers. (Moldan, 1997)

A system of accounts should be designed that facilitates record-keeping, report preparation and provides for control and accountability. Double Entry system for

financial accounting is suitable for this purpose. Sinclair Knight Merz (2006 p. 2) have defined 'Standard Water Accounting' (SWA) as 'the application of a consistent and structured approach to identifying, measuring, recording and reporting information about water'. (Tello, Melendez^, & Hazelton, 2012)

Water accounting involves the systematic measurement, recording and reporting of relevant information about water. A robust system of water accounting which produces general purpose water reports will provide support for investment decisions made by governments and private investors and will help stakeholders to more clearly assess the stewardship of the resource. (Lowe, 2009)

David Moldan defines three levels for water accounting but at basin level- (Moldan, 1997)

Macro level: basin or sub-basin level.	Covering all or part of water basin.
Mezzo level: water service level.	Irrigation.
Micro level: use level.	Field.

Similarly, Water Accounting can be developed for domestic water supply system at three levels- (1) Source level which covers Source & Production (2) Distribution level- Distribution by piping which covers Trunk Main, Distribution Main and Area Network (3) Consumer level- Residential/Commercial/Industrial/Horticulture & Others.

Key drivers for the development of SWA are (1) as a discipline include the inability of external users of information to command water information from the Organizations (except from the Australian Bureau of Statistics), (2) the fact that water information collected and reported has to be prepared under consistent standards and (3) the need for public confidence in water accounting information. (Tello, Melendez^, & Hazelton, 2012)

Water accounting offers Stocks and Flows of the water supply during the period and linking the system components like Water Treatment Plant-WTP, Pipe network, Ground Service Reservoir-GSR, Elevated Service Reservoir-ESR etc. It also generates various tailor-made water account reports. This can be developed with due care in line with financial accounting by using Double Entry system based on Cash or Accrual method of transactions. Water Accounting gives a better understanding of present pattern of water use, improving communication among professionals, improving the rational of water allocation among uses, identification of means to achieve water savings and increase in water productivity. It also supports project implementation in Phases, Planning, Internal control and Financial Budget control.

Water Account as Financial Account There are several key similarities in the focus of water accounting and financial accounting. Both approaches- record and report information on the stocks and flows of scarce resources for use by a range of interested parties. While financial accountants report in dollars, water accountants are concerned presently with the physical volumes of water. (Lowe, 2009)

There are similarities between Financial Accounting and 'Water Accounting'. However, it is clear that some basic differences exist between them**.** They are: flow of Money

v/s Material, Manmade V/s Natural, Production control for availability-possible v/s Not possible as it depends on climatic condition. Therefore Financial Accounting application rules should be used carefully to develop the 'Water Accounting' concept.

Results and Discussion

The case study comparison and literature review helped in shaping the paradigm of this research; new insights developed for quantification, a rejection of thinking (Broadening of perspective) in terms of ideas; 'that metering is necessary to have water account, concepts enriched that 'Water Accounting' can be developed in line with 'Financial Accounting', new ideas to develop sample water account and guidelines. Bengaluru, use of bulk and household meter in quantification practice, billing and recovery in making water management efficient is limited and non-DMA as its limitation to developing water accounting. The budget analysis shows financial implications and impacts on the system in relation to quantification practice. Overall metering provides flow measurements; by keeping scientific records various analytical reports can be generated required for the system monitoring. These reports facilitate management to review the water distribution in the city as well keep command over billing and collection. However, it has the limited role in controlling UFW mainly because of not solving accountability issue in the background of improper design of the pipe network and weak approach towards practicing leak detection and prevention. Therefore, a new approach for quantification is required. Increasing dependency on Narmada water, arbitrary allocation issues hampering Gujarat economy.

Conclusions

The study has yielded quiet a lot of data like water stock and flow, losses from the source to user, financial- billing and collection, expenditure etc., fair to draw general considerations and conclusions:

Metering-Network Design In Bengaluru 100 per cent 'metering' system has been developed over a period of time in a planned manner, with infrastructure changes at a huge cost but DMA was not formed. Proper quantification approach could not be established because of the problems in distribution network design. Hence it is difficult to address accountability and reduce losses in spite of hundred percent 'metering'. Which resulted in an inefficient water management, metering, and monitoring water distribution leads the system to increase its efficiency. Only metering is not good enough to have optimum water use as a natural resource, proper water distribution through designed pipe network backed by water accounting, efficient O & M are equally important which can address accountability.

The role of Meter in quantification is to facilitate measurements. Measurements are necessary to practice quantification by any method. We cannot manage that which we cannot measure. Water meter facilitates easy reading required for flow measurement but there are other engineering methods for flow/quantity measurement which gives approximate measurements less accurate as compared to metered measurements. Quantification can be worked out by approximate measurements with an appropriate reliability scale. It gives some control on the non-metered system, which is better than no control. During this period, declaration of UFW etc. is not recommended in order to avoid credibility issues with the management. This approach facilitates ULB to improve system cost effectively for the accuracy of the measurements.

Authority is responsible With reference to the study report for Bangalore, the pie chart shows that the main cause of leakages are Main pipe-38.1%, Service Pipe-32.8 % and Stand post-17.6 % which is the responsibility of the ULB, as the loss occurs before the water connection, where the citizens are not responsible! Citizens are the concern with the household meter cost which is a major part of transformation project cost. Therefore authorities should control major losses by installing bulk water meters or using other modes of measurement to improve the system efficiency without metering at household level.

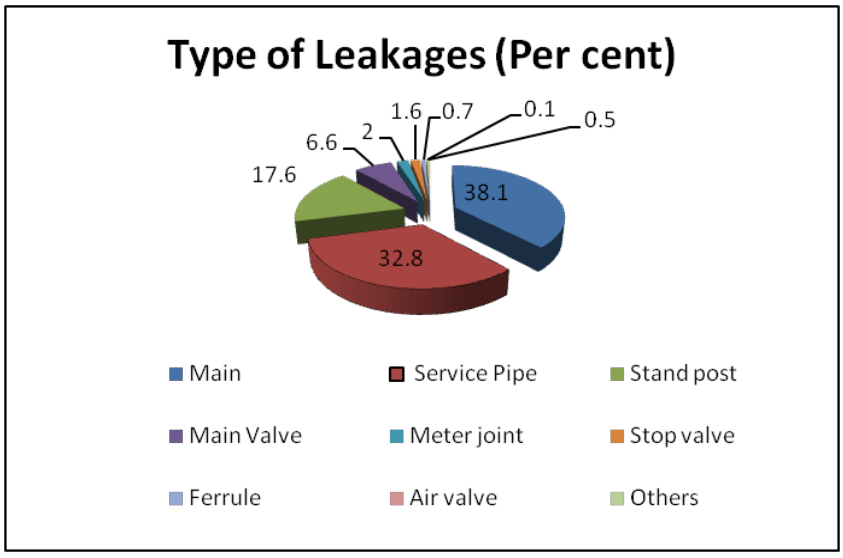

Figure 2 Type of Leakages

Source: Scientific research report (SciRes December 2013 (http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=40955), Page 159))

Water accounting framework comprises of three broad aspects: Standards, Regulations, and Assurances. Tabulation method can give only a one day account; linking of a day to day accounts and report generation does not fit this method. While 'water accounting' can be done on an annual basis and facilitates these features- offers stocks and flows at any point of time, at any component of the system. Financial accounting and stock and flow theory, Double Entry system and Cash transaction method are found suitable.

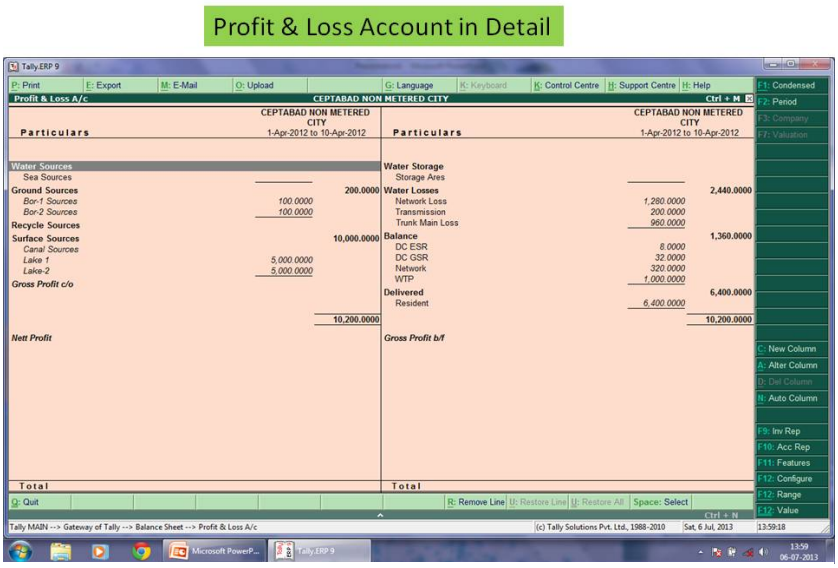

Figure 3 Water Account computer screen shot Source: Author

Ledger account is the basic entity to record the stock or the flow of the water between the system components and delivery to the user as the transactions. Subgroup and Group of the water supply system can be formed in such a manner that it suits the local water supply system spatial layout and operational needs to ease the understanding.

Water accounting practice needs the conceptual framework, the rules, and guidelines

and setting up of a system which may be run by setting standards, regulations, and assurances. Author has developed the water accounting frame work and CEPTABAD water account Figure 3 shows that the details like losses, supply and balance can be recorded meaningfully. Accounting structure, modular design facilitates implementation in parts and offers consistent data and useful analytical reports.

Metering and development stages Author explored the water supply arrangements in the two cities, evidence proves that'100% Metering' is not the final solution, at least ULBs can start the quantification practice in stages. Start with the 'tabulation' method using other modes of measurement, which helps reasonably to control and understand the system losses with minimum infrastructure changes at negligible expenditure. Once the system monitoring is established metering can be done later on in a planned manner in two stages-(1) bulk metering for the flow measurements of distribution system to improve the measurement accuracy and (2) at user level metering to have complete quantification, proper billing and to improve revenue collection.

Implementation and Goals Quantification practice can be done in stages as per the scale of the water supply system and availability of funding with ULB. Its implementation requires a multidisciplinary approach. Water audit provides required information to control subsidy and to keep equity in the distribution of the water as a natural resource. Subsidy should be issued to the poor only. Thus quantification supports to achieve social and other organization goals.

Planning and Reforms Planning issue analysis shows that the overarching goal of water resource management has been defined as the achievement of the optimal use of water in the public interest. The apparent simplicity of this goal is deceptive (illusive) because of issues mainly related to infrastructure, management, finance, planning, and policy. Possible Solutions suggest requirements for Infrastructure changes and capacity building for the management. These reforms are essential for the enhancement of the present domestic water supply system. It should be carried out in such a manner that the transaction cost remains low and delivers high pay-offs. The system can be transformed by long-term planning reinforced by good governance.

Ahmedabad case study shows that in spite of political will and administrative decisions to develop a metered water supply system, the fact is that it is the city level reforms which may affect individual expenditure and the habit of water use. As per lump sum cost estimation, such reforms require a large investment of about Rs. 12500 Cr, for infrastructure change to develop a fully metered water supply system. Present practice failed in service delivery and financial cost recovery, the system can be transformed by planning and public policy which can anchor public trust.

The thrust of this study is that the water supply system is facing challenges of quantification that cannot be addressed in the current ULB practice and the state policy framework. Reforms are not only to include the re-orientation of present practices & policies but also in the restructuring of the system by making it a multi-disciplinary system with proper planning.

This study inferred that a scientifically quantified database and various analytical reports are necessary for the decision process to maintain and enhance the system. These are useful to all the stakeholders. Quantification can be practiced with or without metering by using tabulation or accounting methods, preferably accounting as it addresses accountability issues. From another point of view, a substantial part of the population is looking forward to knowing how much water can be saved cost effectively,

by reducing UFW and how fast can it be done.

Recommendations

Quantification cannot be practiced in isolation; shortfalls in public awareness, ULB financial-statistical capacity, willingness and ability to pay by the users and its relation with other stakeholders are mutually interactive. Following actions are suggested in the timeline.

A. For Immediate Actions:

- Center to declare SEEA Water Accounting Principles based on Standards and Procedures.
- States to declare water quantification mandatory for all, establishing control mechanism for, who accounts to whom and for what- main actors are public policy actors, corporate actors and environmental advocacy actors, their interest may be conflicting in nature.
- ULBs to start quantification practice on a daily basis, restructuring to deal with reforms.
- Promote Accounted for Water (AFW) as terminology to UFW.

B. Actions within next two years:

ULBs-quantify using bulk flow meter measurements, publishing of daily water balance, Water Audit for limited aspects by the third party.

C. Actions within five years:

ULBs-quantify by water accounting, water audit for all the aspects and publishing audited reports.

D. Issues Requiring Immediate Review and Subsequent Action:

The state may do remodeling of Narmada water use plan as per UN SEEA framework.

This research demonstrates how 'Quantification' concept is useful to an active water management to improve the transparency and efficiency of the system. The novelty of this research is that useful for both metered and non-metered water supply system, transformation can be done stage wise. It is not the intention to argue the concrete merits of the quantification practice, but the idea is to suggest that new multi-disciplinary approach can be a solution to open the deadlock of inefficient water management practice.

Way Forward

IWAPintegrating leak detection and prevention using GIS and GPS technology with water accounting. This shall be useful to optimise municipal water supply system by reducing water losses through proactive management approach and capacity building. Internet of Things (IoT) should be considered for the next generation applications. Developing IWAP is multidisciplinary work; I intend to develop such platform as post doctoral research work, looking for appropriate organisation support.

Economic Level of Leakages- utility spends a large amount of money to conduct the periodic surveys to control the leakages to the extent economically viable.

Water accounting can help to narrow down the search for the leakages and reduce the survey cost. A pilot project is suggested. **Acknowledgement**

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