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SITUATION ANALYSIS OF WATER SUPPLY SYSTEM OF AMRITSAR CITY, INDIA

Analys av vattendistributionsystemet i Amritsar, Indien

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Abstract

The city of Amritsar today is facing the scarcity of water resources due to change in urbanization and other external externalities. Drinking water supply of city is entirely dependant on ground water resources, and the latter has been increasingly exploited at a rate that exceeds its natural replenishment. Besides this, major portion of water is being lost in the process of distribution due to poor infrastructure and faulty operation and maintenance. The over-exploitation of groundwater along with the problems in the distribution system is making the situation worse. The focus of this paper is to analyse the water supply situation of Amritsar city by assessing the present situation of production and consumption and developing the performance indicators. The entire analysis brings forth findings such as poor level of performance of the water distribution network in the city, accounting for high water losses when compared to international norms.

Key words – Amritsar; Scarcity; water distribution, groundwater; over-exploitation; performance indicators

Sammanfattning

Amritsar riskerar att drabbas av vattenbrist på grund av urbanisering och andra faktorer. Dricksvattenförsörjningen är helt beroende av grundvattenresurser, vilka har blivit överexploaterade pga. att uttagen är större en nybildningen. Dessutom är förlusterna i ledningsnätet mycket stora pga. dåligt underhåll. Denna artikel fokuserar på att analysera vattenproduktion och konsumtion genom att beräkna olika nyckeltal. Analysen visar på dåligt underhåll och stora vattenförluster i jämförelse med andra distributionsnät internationellt.

1 Introduction

The metropolitan city of Amritsar (figure 1) is located along the border of India, adjoining Pakistan in the north western part of Punjab, spanning an area of 5056 km^2 (Central Ground Water Board [CGWB] Report, 2007). It is bounded by 32° 28' 30" to 32° 03' 15" north latitude and 74° 29' 30" to 75° 24' 15" east longitude (CGWB Report, 2007), see figure 2. The area forms a part of almost flat and level alluvial plains, with elevation ranging from 175 m in SW to 245 m in NE, with the general slope being towards SW. The perennial rivers of Ravi, Beas and Satluj, forming the northern and southern boundary of the district, constitute the district main drainage system. The area is also drained by Patti, Kasur, Naumnu and Sakhi Nalahs, found in the Upper Bari Doab tract, one of the inter-fluvial tracts of the Punjab plain, traversing the district. The Upper Bari Doab Canal (UBDC), the oldest canal systems of the state, along with its tributaries, also lies in this tract.

The normal annual rainfall of Amritsar district is about 680 mm unevenly distributed over the year. The southwest monsoon contributes to 75 % of rainfall between the last weeks of June to the middle of September, the rest 25 % occurs in the non monsoon months, owing to western disturbance and thunder storms (CGWB Re-

Figure 1. *The Golden Temple or Swarn Mandin/Harmandir Sahib (in Hindi) in Amritsar is surrounded by a large lake which is referred as Sarover and is said to consist of Amrit (holy water). It is a prominent place of worship for Sikh people in the city of Amritsar.*

port, 2007). The water supply of Amritsar city entirely depends on ground water sources, taking no inputs from surface water or any other source, though there seem no specific reasons for the same, taking into account the literature available and personal communication with Municipal Corporation of Amritsar's (MCA) officials. As a result, there are problems of declining water levels, reduced yield of wells, drying up of dug wells/shallow tube wells.

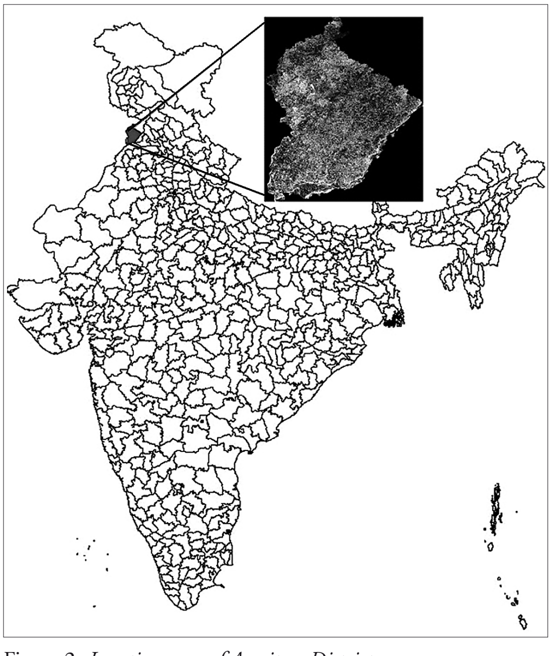

Figure 2. *Location map of Amritsar District.*

The long term water level trend in 10 years (1997–2006) has been declining at the rate of 0.27–0.74 m/year (CGWB Report, 2007). Average pumping depths are in the range of 21–24 m. MCA is lowering the pump depths with falling groundwater levels and increasing water demands. Apart from these, there are also a number of private motorized tube wells, hand pumps and public standpipes which are harnessing the ground water resources to fulfill the water demand of the city. All theses factors have contributed to unsustainable over-exploitation of groundwater. As a result, majority of the blocks in Amritsar today, stand in the over-exploited/critical category with respect to groundwater extraction.

Already faced with such a precarious situation at hand, assessment of the water supply in the city brings out many technical snags in the distribution system, which all together account for high water losses. Along with this, the supply itself is intermittent, with a low per capita consumption, high volumes of leakages at service connections, low average pressure, etc. Therefore, as expected, the tubewells are in a bad state, with the operation of most of them being unstable, and plagued with intermittent supply, water surging is often encountered from the surface. This quickly results in pump failure. Therefore, there is an immediate need to rectify the prevailing fallacies in the system. Metering of water being absent in majority of the connections, makes exact quantification of water volumes difficult. Water bills are primarily based on flat property basis. All these factors contribute to the inefficiency of the water distribution network in Amritsar, which hence contributes to unacceptable volumes of non-revenue/unaccounted for water. Such high losses in the water supply network, in an area which already facing declining ground water levels, and threats with respect to sustainability of water supply in the future, is a matter of serious concern. Therefore, where on one hand, the city is standing on the verge of a water crisis, water being lost in the distribution system, makes further abstraction unjustifiable, unless the present problems are not provided with a solution.

The focus of this paper is to analyse the water supply situation of Amritsar city by assessing the present situation of production and consumption and developing the performance indicators.

2 Approach Used/Methodology

The methodology adopted to complete this study is in terms of field work to collect various datasets and reviewing of literature for different accounting techniques. Firstly, a review of groundwater abstraction in the city was carried out from various books and official public records which were followed by data collection with respect to current water supply situation through field trips in Amritsar. It was then followed by assessment of existing supply sources including water production and sectorized water consumption. Database used in this analyse is mainly the secondary data, obtained from the MCA. It covers the broad overview of water production and consumption followed by development of water balance diagram, as per the International Water Association (IWA) IWA format, based on collected and analyzed supply and consumption data and evaluation of losses.

3 Water Resources Situation

Amritsar today faces a critical situation with respect to over-exploitation of groundwater and sharply declining groundwater levels. Large scale development of groundwater through rapid deployment of tubewells has resulted in rapidly declining water levels. The fact that Amritsar falls in the dark category, with respect to groundwater extraction can be exemplified from the fact that 11 out of its 16 blocks fall in the over-exploited (O.E.) category, with stage of development exceeding 100 %, i.e. the groundwater extraction being more than 100 % of its annual replenishment. The Verka district of Amritsar, has a water table depth of 22.6 m, much higher than the critical depth of 10 m (Hira, 2004). Also, a critical water table depth below 10 m has been reached in 28 % of the area of the state. Districts so affected include Ludhiana, Sangrur, Jalandhar and Patiala. Detailed information on the blocks of Amritsar, with respect to groundwater abstraction, is presented in Table 1. The detailed situational statistics of Amritsar with respect to groundwater resources is illustrated in Table 2.

Table 1. *Block-wise details of utilizable resource, net draft, level of development and category, with respect to groundwater abstraction in Amritsar city (MCM – Million Cubic Meter).*

S. No.	District/ Block	Utilisable GW Res. Potential For Irrigation (MCM)	Net Draft (MCM)	Balance Irrigation Potential (MCM)	Level of GW development (%) as on 1/4/98	Category
1	Patti	92.3	92.0	0.4	99.6	Dark
2	Gandiwind	118.1	139.9	–21.8	118.4	O.E.
3	Naushera Pannu	83.1	76.6	6.5	92.2	Dark
4	Chogawan	151.5	127.1	24.5	83.9	Grey
5	Rayya	91.1	127.4	–36.3	139.9	O.E.
6	Ajnala	89.9	144.0	–54.1	160.2	O.E.
7	Verka	108.2	108.8	–0.6	100.6	O.E.
8	Taran taran	90.8	161.6	–70.9	178.1	O.E.
9	Khadoor Sahib	121.4	109.5	11.9	90.1	Dark
10	Valtoha	74.9	103.2	–28.3	137.8	O.E.
11	Majitha	141.1	101.8	39.3	72.2	Grey
12	Tarsika	83.7	106.4	–22.7	127.2	O.E.
13	Chola Sahib	79.0	56.2	22.8	71.2	Grey
14	Jandiala	79.6	100.5	–20.8	126.1	O.E.
15	Bhikiwind	139.8	160.5	–20.6	114.8	O.E.
16	Harsha Chhina	67.0	82.6	–15.5	123.2	O.E.
			1611.5	1797.9	–186.3	111.6

(Source: Department of Soil and Water Conservation, Punjab, 1998)

Table 2. *Groundwater resources of Amritsar (in MCM – Million Cubic Meter) (ham – Hectare Metres).*

	Amritsar
Annual Replenishable Groundwater Resources	129956 ham
Projected allocation for domestic and industrial uses upto 2025	5242 ham
Net Annual Groundwater Draft	190691 ham
Stage of Groundwater Development (%)	147 % (Over-exploited)

(Source: CGWB, Report 2007)

3.1 Water supply situation under MCA

The water supply system operated by the MCA incorporates a total of 301 tubewells, which pump ground water, for supply purpose, directly to the distribution mains. The water distribution system though comprises of a collection of discrete, small diameter pipe networks, centered on the tubewells along with the Over Head Water Reservoirs (OHSR's), with a very basic level of interconnection, though the latter are not currently in use. The entire system is subject to fallacies like high pressure near the tubewells, causing pipe bursts, steep hydraulic gradients, leading to very low pressure, at a distance from the source and old and poor maintenance, which accounts for high water losses (JBIC, 2006).

The 301 tubewells operated under the MCA can be divided into two categories:

1. 111 small wells, fitted with a pump having a rating capacity of approximately 11 l/s
2. 190 large tubewells, having a rating capacity of approximately 28 l/s

The entire water supply in the city is through tube well installations all across the city. MCA reported data classifies the tubewells, into small and large ones, which accordingly differ in their production capacity. The details are presented in Table 3. The Punjab Water Supply and Sewerage Board (PWSSB) and MCA, commonly hold the view that due to the above circumstances, most pumps are no longer working at their duty points. Also, the actual water production volumes are only 70 % of that theoretically indicated, i.e., per the rated capacity (JBIC, 2006). Therefore, an approximate assumption of the water production capacity can be taken as 70 % of 259 MLD (mega litres per day, 1 m^3/s = 86.4 MLD), i.e., 181 MLD.

MCA expect the tubewells to have a useful life of 10 years, though many have already been in operation for about 15–20 years, accounting for the poorly maintained system (CDP). Typical pump depths are 21–24 m, with the levels being lowered by 2–3 m over a decade, with the declining groundwater levels (pers. comm.). Estimates of water production from the tube wells are based on the recorded pump rating, since they are generally fitted with air valves and non-return valves and not flow meters. MCA operate the pumps for 11 h/day, with approximately 60 % of the tubewells being controlled via automatic timers and the rest manually (JBIC, 2006). This intermittent operation is known for its harmful effects on tubewell pumps and motors and also well integrity, but this problem has not been seriously addressed by the MCA.

Apart from the MCA operated tubewells, many households, industries and commercial/institutional organizations have installed their own private motorized tubewells on account of the limited coverage and inadequacies of the water supply under MCA. As per the CDP estimates, there are approximately 8850 private household and commercial/institutional tubewells and about 2200 private industrial tubewells. These are typically up to 50 m in depth, with MCA charging a nominal amount of Rs.160/quarter for this service (CDP). The two largest users of groundwater through private tubewells being Khanna Paper Mills (approximately 10 MLD, located outside MCA boundary) and the canton-

Table 3. Water production (MLD – Million Litres Per day).

Tube Well type	Number	Pump rating (l/s)	Operation time (h/day)	Production (MLD)
Small	111	11	11	48
Large	190	28	11	211
Total	301			259

(Source: MCA)

Table 4. *Sector wise water consumption (MLD – Million Litres Per day).*

Consumption category	Number of service connection	Key information	Estimated consumption (MLD)
Domestic	1,21,796 (out of this, 70 connections are metered)	1,21,796 connections, 6 persons per house connection, with per capita supply of 85 lpcd	62.1
Commercial/Institutional	11021 (out of this, 40 % of the connections are metered)	168 million litres consumed over a 3 month period	1.9
Industrial	933 (out of this, 40 % of the connections are metered)	-do-	1.9
Public standpipes	–	747 in number, with 3500 l/day consumption from each	2.6
Tractor pulled water tanks	–	13 in number, with two deliveries per day (6000 l/day consumption)	0.1

(Source: MCA)

ment area (approximately 9 MLD, located inside MCA boundary) (CDP).

The poorer sections, residing in colonies like Indira Basti, are not able to afford the motorized tubewells and hence are totally reliant on hand pumps, installed at common locations (CDP). No records are available regarding their present number in the city. In addition to the above, MCA report the supply system to include 747 public standpipes, delivering 2.61 MLD of water. They are unmetered, delivering water free of charge. Along with this, water is also delivered by water tankers. They are 13 in number, delivering 2 times a day, having an estimated consumption of 6000 l/day.

The sector wise water consumption was calculated on the basis of some key information provided by the MCA, the details of which are presented in Table 4. As per the JBIC study, the current level of per capita consumption in Amritsar city is about 85 l per capita per day (lpcd), which is also agreed to, by the MCA. Metering of water supply is absent in majority of the service connections. Therefore, approximation of exact water consumption becomes a difficult process, with water bills being calculated in accordance with the land area of the property. This faulty policy perspective is also adding to the misuse of groundwater in the bargain, worsening the situation.

3.2 Water distribution network

The water distribution network in the city comprises of isolated, small diameter pipe networks, centered on the tube wells and the OHSR's. Thirty OHSR's have been constructed in the city, having a combined storage capacity in the order of 24 million litres (JBIC, 2006). But at present, they are not in use because the MCA staff reports that little water actually reaches any of the over head reservoirs because of the low pressure in the rising mains resulting from the installation of the low head pumps by the MCA and the direct pumping of groundwater through tubewells to the distribution mains. Many of the reservoirs are rendered inoperable due to leakage problems. The rising mains were originally intended to deliver water to the nearby reservoir. But as already stated, at present it has become a common practice to connect distribution pipes directly to the mains, and hence pump water straight to supply.

The water distribution system is about 30–40 years old and consists of approximately 1000 km. of pipelines, made up of material such as cast iron, asbestos cement, ductile iron etc. Many boreholes have submersible motors and shaft driven pumps, majority of which are in a poor state of repair (JBIC, 2006). Also, each network is characterized by high water pressure near the tube wells, which results in frequent pipe bursts, which is evident by the high amount of leakages taking place at service connections. The hydraulic gradient in the distribution system is also so steep that the water pressure is less than 0.2 bars within 300 m of the source (CDP). As the MCA reports, the standard operating pressure for water supplies in Amritsar city is 10 m, though it can go down to as low as 2 m, as reported by the ADB benchmarking of water utilities, conducted in the year 2007.

3.3 Water accounting

With complete absence of domestic meters, only 40 % of commercial/institutional and industrial meters working and public standpipes being totally unmetered, an assessment of the MCA water supply in terms of water

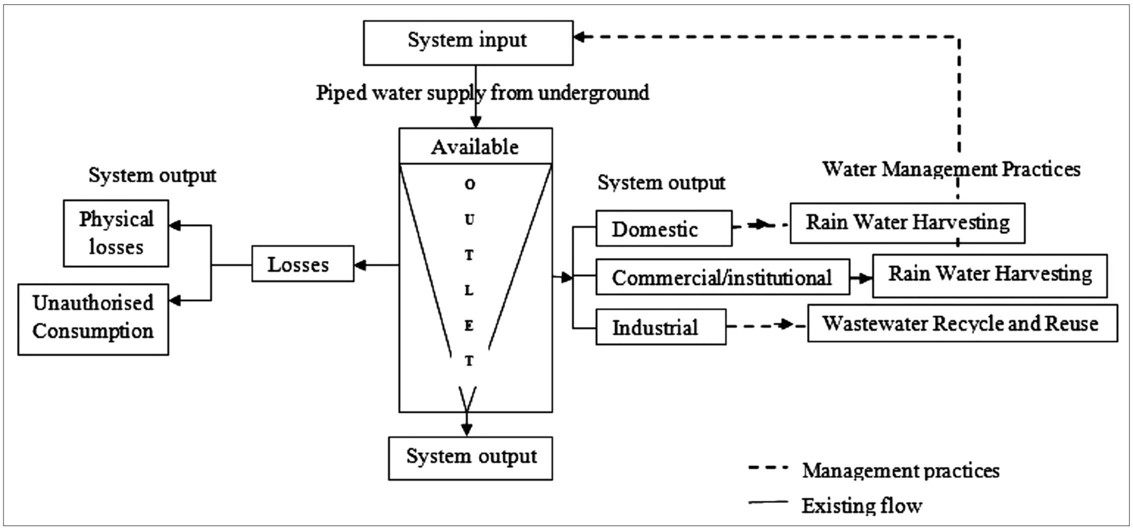

Figure 3. *Water accounting framework for Amritsar city.*

balance becomes a difficult process. But, an attempt has been made to summarize the results for water production and consumption, for the estimation of losses in the current distribution system. The details are presented in Table 5.

Therefore, the losses being as high as 62 %, forms the major drawback of the water distribution system of the MCA. The MCA staff admits that most of the pipelines in the walled city are as old as 30 yrs, and badly in the need of repair. This forms a prime reason for leakage during distribution. Another faulty policy directive being followed in Amritsar is the payment of water bills, at a flat rate in accordance with the size of the property. This encourages people to misuse the precarious resource, to their own individual advantage. All these reasons account for the huge amount of losses occurring in the water distribution system.

3.4 Supply and demand framework

The accounting of water use in Amritsar city, with respect to supply and demand framework, traces the flow of water, right from the source, i.e., groundwater reserves, to its use in the corresponding sectors such as domestic, commercial, industrial etc. This entire framework can be pictorially represented as in Figure 3.

Table 5. *Estimate of water flows (MLD – Million Litres Per day).*

Category	Volume (MLD)
Production (70 % of rated capacity)	181
Total consumption	68.5
Losses	112.7
Losses as a percentage of production	62 %

4 Water Balance

A water balance can be considered as a tool for understanding inflow, consumption and losses in a water distribution network. Therefore, a water balance can be considered as a framework for assessing a water utility's status of service delivery. It creates awareness about of the availability of data, regarding water supply, and is a must for prioritizing attention and investments. Therefore, construction of a water balance gives an idea and a direction in which water management programs should be structured.

4.1 International Water Association (IWA) best practice water balance

A clearly defined water balance is the first essential step in the assessment of volumes of non-revenue water and the management of water losses in potable water distribution systems (Mackenzie and Seago, 2005). Any assessment of the water losses must be preceded by a clear definition of the components of water balance. Keeping in mind, the wide diversity of formats and definitions, the practitioners have identified the need for a common terminology and have come forward with the IWA standard water balance format with standardized definitions of each of the water balance components. It takes into account all complementary data used in water supply and is primarily used to assess non-revenue water in a water supply network. This water balance format has been increasingly recognized by water utilities across the world and has been adopted as an international best practice. An assessment of the entire water supply system, from available data of Amritsar city can be reproduced in the IWA format as in Table 6.

4.2 Assessment of real water losses

The amount of water lost is an important indicator of the positive or negative evolution of water distribution efficiency of any particular system (Lambert and Hirner, 2000). Therefore, the level of water losses, both real and apparent is one of the most important efficiency issues for water utilities across the world (Radivojevic, et al., 2007). The high amount of water losses in the water distribution pattern for Amritsar city, makes active water loss management, a matter of prime urgency. For taking up the management issue, an assessment of its components is necessary. Considerable advancement has been made in the past years in the assessment and benchmarking real losses in potable water distribution systems. Some standard methodology and performance indicators used by the IWA can be used to report the situation in Amritsar as follows:

4.2.1 Technical Indicator Real Losses (TIRL)

The basic traditional performance indicator with the greatest range of applicability for real losses, as recommended by the IWA, is referred to as Technical Indicator Real Losses *(TIRL)* (Radivojevic, et al., 2007). The IWA recommends that the basic *TIRL* should be the annual volume of real losses, divided by the number of service connections *(Nc)*, allowing for the percentage of the time the system is pressurized (Lambert and Hirner, 2000).

$$TIRL = (10{,}000*1000)/133750 = 747.66\ l/connection/day\ w.s.p \quad (1)$$

The values are calculated to be w.s.p, i.e., when the system is pressurized, to facilitate comparisons between different utilities having different units. The major disadvantage associated with *TIRL* is that it does not take into account local factors and therefore its individual values may be influenced by operating pressure, location of customer meters and low density of connections.

4.2.2 Unavoidable Annual Real Losses (UARL)

The calculated *TIRL* value for a water distribution system can be further improved by incorporating local parameters and interpreted by comparing it with a calculated value for *UARL*. *UARL* accounts for separate influences of real losses from local factors such as density of connections, location of customer meter on service

Table 6. *IWA best practice water balance (MLD – Million Litres Per day).*

System input volume (Production) (181MLD) (66065000 m^3/year)	Authorized consumption (69 MLD) (25185000 m^3/year)	Billed authorized (67 MLD) (24455000 m^3/year)	Billed metered (2 MLD) (730000 m^3/year)	Revenue water (67 MLD) (244550000 m^3/year)
			Billed unmetered (65 MLD) (23725000 m^3/year)	
		Unbilled authorized (2 MLD) (730000 m^3/year)	Unbilled metered (0.1MLD) (36500 m^3/year)	Non-revenue water (114 MLD) (41610000 m^3/year)
			Unbilled unmetered (2 MLD) (730000 m^3/year)	
	Losses (112 MLD) (40880000 m^3/year)	Apparent losses (12 MLD) (4380000 m^3/year)	Unauthorized consumption (12 MLD) (4380000 m^3/year)	
			Metering inaccuracies (0)	
		Real losses (100 MLD) (36500000 m^3/year)	Leakage on mains (20 MLD) (7300000 m^3/year)	
			OHSR overflow(0)	
			Leakage on service connection (80 MLD) (2920000 m^3/year)	

connections and average operating pressure. Leakage management practitioners realize that it is impossible to completely eliminate real losses from a large distribution system. Therefore, there must be some achievable value of *UARL* at operating pressures, subject to no financial or economic constraints (Radivojevic, et al., 2007). *UARL*, therefore, as recommended by the IWA can be calculated according to the following equation (2) (Lambert et al., 1999):

$$UARL = (18*Lm + 0.80*Nc + 25*Lp) * P \qquad (2)$$

Where, *Lm*= length of the distribution mains = 1000 km. (Data source: MCA), *Nc* = Number of connections = 133750, *Lp* = Total length of the underground pipe between the edge of the street and customer meters (Since an average distance from the street to a particular customer meter = 5 m) (Data Source: MCA), *Lp* = 5*133750 = 668750 m = 669 km., *P* = Average operating pressure in m = 10 m (Data Source: MCA)

The equations and the parameters 18, 0.80 and 25 are based on statistical analysis of international data, including 27 different water supply systems in 20 countries (Lambert and Hirner, 2000). These parameters, used to calculate *UARL* components are based on background loss rates, typical burst flow rates (reported and unreported) in distribution networks. Therefore,

$$UARL = (18*1000 + 0.80*133750 + 25*669) * 10 = 1417250\ l/day \qquad (3)$$

The UARL in the same units as *TIRL* is then = 10.5 *l/conn./day w.s.p*

4.2.3 Infrastructure Leakage Index (ILI)

ILI is a non-dimensional figure, got from rationing *TIRL* to *UARL*, which allows overall infrastructure management performance to be assessed independent of the influence of current operating pressure (Radivojevic, et al., 2007). The difference between *TIRL* and *UARL* represents the maximum potential for further savings in real losses. Being a ratio, *ILI* has no units and thus it facilitates comparisons between water utilities with different measurement units. A system with value close to one can be rated as excellent, while higher values correspond to poorly maintained utilities. As far as Amritsar is concerned, the *ILI* value for its water distribution can be calculated by equation (4):

$$ILI = TIRL/UARL \qquad (4)$$

Using the previous calculated *TIRL* and *UARL* we get *ILI*= 747.66 /10.5 = 70.6. *ILI*, as a performance indicator gains importance since it can be used for benchmarking water supply systems in different areas and countries, and in knowing the efficiency level of a given utility. Therefore, looking at the exceedingly high *ILI* values for Amritsar utility, introduction of active leakage control programmes, flow and pressure management are concerns that demand immediate attention. A four fold benchmarking criteria has been proposed by Liemberger and McKenzie 2005, in accordance with the *ILI* values. The details are presented in Table 7. With Amritsar falling in category D, it can thus be justified that how urgently the city is in need of proper water conservation and management programs.

4.3 Operational performance of the water sector

After analyzing the state of water distribution network in Amritsar city, the water losses, high volumes of non-revenue water, it can be inferred that just acquiring sustainable water supply for people is not enough. Sustainable access requires efficient operation and maintenance of the water sector network and utility. In order to allow for a better understanding of the state of operational

Table 7. *ILI target matrix and technical performance category.*

ILI	Technical Performance Category	
1 – 2	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost effective improvement
2 – 4	B	Potential for marked improvements; consider pressure management; better active leakage control practices, and better network maintenance
4 – 8	C	Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
>8	D	Horrendously inefficient use of resources; leakage reduction programs imperative and high priority

(Source: Liemberger and McKenzie, 2005)

Table 8. *Operational performance indicators for water sector.*

Operational indicator	Key information	Indicates about	Value
Continuous water supply	Average hours of access to tap water in hours per day	Indicative of both availability and quality of water	11
Estimate of UFW	Amount of water lost through pipes (%)	Indicative of quality and level of maintenance of water utility network (MCA)	62 %
Per capita consumption	Liters of water consumed by a person per day (lpcd)	The level of consumption in the city, as against India design norms	85
Operating cost coverage ratio	Total annual operational and maintenance cost divided by total annual revenues	Measures the extent to which consumer tariffs and other fees and subsidies contribute to overall operation and minor maintenance cost.	1.35 (ADB Report, 2007)
Staff per 1000 connections	Number of water utility employees per 1000 connections	Indicative of labour productivity. It gives a crude estimate of the efficiency of network management	4.8 (ADB Report, 2007)

management of water system facilities in Amritsar city, five operational indicators have been identified. The details are tabulated in Table 8.

5 Discussion and conclusion

The state of affairs in Amritsar is undoubtedly heading towards a major water supply crunch. The high level of ground water exploitation in Amritsar, backed by sub optimal planning has resulted in the creation of deleterious effects in terms of ground water depletion. Uncontrolled exploitation of ground water, accompanied with the high volumes of losses in the water distribution system, has brought in serious issues of water management. The focal points of a sustainable water resources management strategy, in relation to the city of Amritsar, include regulation, management and development of water resources. Keeping in view, the rapidly declining levels, steps for water conservation and ground water replenishment needs to be taken up, along with rectifying the current faulty water tariff structures, which is at a flat rate, encouraging misuse. Metered water at an appropriate tariff will induce farmers to cultivate less water intensive crops and thereby reduce over extraction of water. A judicious combination of government, community control and private water rights, varying from macro, meso and micro level, is perhaps desirable. Sustainable use of ground water is possible only when users restrict average extraction to long term recharge. Even when recharge is augmented artificially, restraint on use will be required in water scarce regions.

Water resources management options can be looked at, from two perspectives: supply augmentation and demand management. But, keeping in mind the situation in Amritsar, demand management needs to be given greater emphasis, owing to the over-exploitation of ground water and water wastage by consumers. At the user's level, out of several options, volumetric rationing of water, coupled to unit pricing can result in effective reduction in demand for water as well as ground water draft. But, instead of banning further exploitation in critical blocks, government should offer incentives for community management of new wells, construction of recharge structures, adoption of micro irrigation techniques etc.

Also, on a priority basis, a base map indicating the location of tubewells should be developed which can facilitate easy maintenance of water supply network and provide an input for management programs. An integral component of water supply, its distribution network and loss determination is reliable metering of all water volumes. But, as far as water accounting and auditing in the city of Amritsar is concerned, the major disadvantage in this regard, is the inaccuracy in the metering of connections. This results in inadequate quantification of water flows, with respect to abstraction, input volumes and inflows to sectorized distribution systems, which thereby hampers implementation of efficient management strategies. Wherever, actual metering is not possible, every effort should be made to estimate each component of water use accurately to determine realistic quantities of water balance. Along with this metering inaccuracies should be monitored and properly reported, so that steps for rectification of such errors can be initiated. This process of measuring water use, in conjunction with volumetric pricing, also provides an incentive for water conservation. Therefore, by detecting water leaks in the distribution network, it also provides a basis for reduction of non-revenue water.

The amount of water lost is an important indicator of the water distribution efficiency of a water utility. The unacceptably high water losses in Amritsar city, indicates ineffective planning and a low level of operation and maintenance activities. Though, a low level of water losses is unavoidable even in the best operated systems, the main aim should not be to achieve an unrealistic leak free network, but to reduce the losses to an acceptable limit. Some steps that can be taken to manage losses in Amritsar, can be pipeline and asset management, owing to the fact that some pipelines in the city are as much as 30–50 years old and understandably deteriorated with time, pressure management owing to the low pressures in the distribution system, which also forms the basis of an effective leakage management strategy. An active leakage control programme should essentially have three components: awareness of the utility, in relation to the occurrence of a leak, the exact location of leaks in the distribution network, and its consequent repair efforts. Also, efforts should be made to quantify the leaks in the network, both on the mains and the service connections so that exact volumes lost can be quantified, and a sound water balance can be developed. This can therefore, provide a way forward as to in which direction, the water management programs should be structured.

As a matter of fact, Amritsar is blessed with perennial surface water sources in the form of river Ravi, Beas, Sutlej. These surface waters can be easily mobilized through the Upper Bari Doab Canal (UBDC), which traverses the city. Apart from this, there is also the Sakhi Nalah, a perennial drainage stream, which offers great potential in serving as a water supply source. It is indeed surprising that the option of using these resources for drinking water purpose, in spite of offering good promise, has been left totally unexplored, even amidst the current crisis situation. Therefore, these alternatives need to be looked at with a positive perspective, in order to harness its water resources, as per city's demands. Along with this, identification and promotion of other simple, conventional techniques like rain water harvesting, artificial recharge, needs to be exploited, in order to create alternative resources, which can serve to de stress the ground water reserves and ensure sustainability in the provision of water facilities in the city. Also, the need to create awareness among the users, regarding the critical nature of the situation and the need for taking up water conservation practice, is equally important.

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