Reflections on Groundwater Quality and Urban-Rural Disparity in Drinking Water Sources in the State of Haryana, India

Sriroop Chaudhuri[1] Mimi Roy[2]
[1,2]Assistant Professor
[1,2]O.P. Jindal Global University, Sonipat, Haryana, India

Abstract— The objective this study was to (a) provide an overview of groundwater pollution in Haryana, (b) illustrate major drinking water sources in urban and rural areas and (c) disparities therein. Out of 21 districts in Haryana, high fluoride and nitrate levels were detected in groundwater from 13 districts. Occurrences of multiple contaminants in groundwater –mainstay of drinking water- have serious implications towards human health. It is more apparent for rural households who use hand pumps, which rely on shallow groundwater resources, for potable purposes. In contrast, in urban areas treated tap water furnishes the bulk of potable water needs. Moreover, about half the rural households in Haryana still depend on external water sources. Overall, the study calls for a critical reassessment of 'safe' drinking water sources as several of these sources draw from groundwater resources which appear highly polluted and/or depleted.

Key words: Drinking Water, Water Quality, Fluoride, Nitrate, Salinity, Groundwater Level

I. INTRODUCTION

Over three-fourth of India's population lives in villages which face stiff challenges of severe infrastructural inadequacies including that of *safe* and sustainable potable water supply [1]. Beginning in the early 1970s, a series of reformative policies have been put in place to ensure equitable and safe drinking water supply in rural India [2]. A stumbling block in the development of the rural water supply sector to its full potential, however, is occurrence of a multitude of contaminants exceeding their maximum permissible limit (MPL) in groundwater, which furnishes bulk of the potable water need in India.

Groundwater is the mainstay of potable water sector in India furnishing to the needs of over 85% of the population. Groundwater quality impairment, however, is a staggering issue in the country, including the state of Haryana. Elevated concentrations of several species, with known human health risks, have frequently been reported from the districts of Ambala [3, 4], Chandigarh [5], Gurgaon [6], Jind [7]; Rohtak [8], Sisra [9], Bhiwani [10], Faridabad [11], Panipat [12], Panchkula [13], and Hisar [14]. Groundwater is also extensively used for irrigational purposes in Haryana, which have led to alarming decline in water-levels in several above-mentioned districts of the state which further undermines rural water supply infrastructure [15, 16, 17, 18].

Current study aims to provide a qualitative overview of groundwater quality impairments in Haryana that affects drinking water resources. The bulk of the study was focused on obtaining a holistic view of major drinking water sources in the state and how rural households compare with their urban counterparts therein in an attempt to highlight infrastructural disparities.

Studies are available on potable water availability from different parts of the world, but a bibliographic survey revealed a dearth of such efforts in Haryana, let alone rural areal areas which have well known concerns over 'safe' drinking water. Similar studies should also be carried out in other parts of India to help the concerned authorities identify the 'hotspots' of infrastructural inadequacies, especially in the rural areas.

II. MATERIALS AND METHODS

Haryana is a state located in the north-westerns parts of India with 21 districts, about 6841 villages and 154 towns. Total population of the state increased from about 211.5 to 253.5 lacs between 2001 and 2011 coupled with a rise in rural population from about 150 to 165 lacs. Over 65% of the state's total population dwell in the rural areas. Total literate population of the state stands over 166 lacs registering about 71% literacy rate among the rural populace (about 84% in urban areas).

Haryana is among the major agricultural sates in India and the hot seat of Green Revolution in the 1970s. It is known all over the world for its highly advanced Rice-Wheat Cropping System, and especially for superlative quality basmati rice production. Cereals, pulses, food grains and oil seeds constitute the bulk of agricultural products. Major part of the state's economy is hinged upon agriculture.

The geology of the state is dominated by the Quaternary alluvium and Aeolian deposits [19] with minor Proterozoic and Tertiary formations occurring in the southern and northeastern parts. The climates is arid to semi-arid with annual rainfall averaging around 55 cm. Majority of precipitation is received during July to September with rainfall decreasing gradually from north east to south west. Due to lack of precipitation coupled with paucity in surface water reserves, Haryana largely rely upon groundwater resources for potable and irrigational purposes (Sing et al., 2013; Kumar et al., 2006).

Data about drinking water for Haryana were obtained from two sources: (1) the Register General of India, Ministry of Home Affairs for the period 1981 – 2001 and (2) Census of India for 2011. From the first source data were obtained for the rural and urban areas for each decadal year and also for the state as a whole (rural and urban combined).

For 2011, district-wise data were obtained for rural and urban areas in eight water source categories: (1) tap water (treated and untreated), (2) hand pump, (3) tube well, (4) well (covered and uncovered), (5) tank, pond, lake, (6) river and canal, (7) spring, and (8) other for Haryana. Each category, were expressed as percentages (of all drinking water sources) for each district. Between 1981 and 2001, data were only available in form of 'safe' drinking water sources It is worth noting that in India, tap, hand pump and

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tube wells are generally considered as 'safe' drinking water sources. In addition, district-wise data for location of drinking water sources were also obtained for 2011 as follows:

– Within Premises
– Near the Premises: Source within a distance of 500 meters in rural areas (100 m for urban)
– Away: Source beyond 500 and 100 meters in rural and urban areas, respectively.

III. Results and Discussion

A. Groundwater Quality

1) Fluoride

Though several contaminants are of concern in Haryana, it is fluoride that enjoys crucial centrality [19], [8]. Out of 21 districts in the state, 14 have recorded fluoride levels above maximum permissible limit (MPL) for drinking water (1.5 mg/L) [20]. At the national level, fluoride appears a major contaminant that impairs groundwater resources in 20, out of 28 states in India, with some having two-thirds of their districts affected by high fluoride levels (>MPL) [21].

Elevated fluoride levels (>MPL) have been reported from 14 districts in Haryana (Fig. 1). Sub-district level assessment reveals 9 districts in Haryana have over 50% of their blocks affected by high fluoride levels (>MPL) (Table 1). Highest groundwater fluoride level (48 mg/L) so far from Haryana has been reported from Rewari district [22]. Fluoride levels above 10 mg/L in drinking water can lead to crippling fluorosis [23]. As rural households largely depend upon groundwater for potable water supply, this poses major threat to human health [19].

Cases of fluorosis have been reported from 17 states in India, affecting over 66 million people among which 6 million children are below 14 years of age [24, 25, 26]. Due to strong electronegativity, fluoride is attracted by positively charged calcium in teeth and bones leading to variety of deformations of bones and teeth [23]. In Haryana, cases of fluorosis have been reported for dental, skeletal as well as non-skeletal (soft- tissue), of which the former two types can lead to irreversible damages to human health [19].

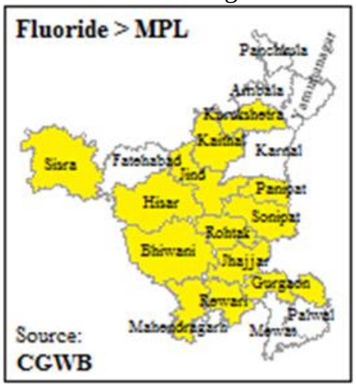

Fig. 1: Districts in Haryana from where fluoride levels > MPL (1.5 mg/L) have been reported

Fluoride can occur in groundwater 'naturally', via weathering of fluoride-bearing minerals and rocks (e.g. fluorite, fluoroapatite) [27]. Occurrence, transport and fate of fluoride is largely controlled by rock type, climatic conditions, regional hydrogeological framework and residence time. In arid to semi-arid regions, as that in Haryana, evaporative processes enrich groundwater resources with fluoride. Presence of other chemical species, particularly bicarbonate and calcium also affects the fluoride mobility in ground water [23]. Anthropogenic processes can also lead to elevated fluoride levels in groundwater. Intensive and long-term irrigation, as is the case in Haryana, leaches fluoride from the soils/weathered rocks [27, 28, 29].

2) Nitrate

Nitrate appears pervasively in Haryana Elevated nitrate levels have been reported from 19 districts of the state occurring over the MPL (45 mg/L) for drinking water (Fig. 2). Sixteen districts have over 50% of their blocks affected by high nitrate levels (Table 1).

Elevated nitrate levels can lead to fatal blood disorders in infants called methaemoglobinemia, commonly known as blue baby syndrome, in which hemoglobin loses its ability to carry adequate amount of oxygen. Haryana is among the leading agricultural producers in India and ranks among the top five states in nitrate-based fertilizer application rate [30]. High nitrate levels resulting from agricultural activities have been extensively documented from different parts of India [31] as much from around the world [32].

A major source of nitrate in Haryana is the nitrate-based fertilizers that get into water systems via agricultural runoff of leaching [30, 33, 34, 35]. However, other sources such as domestic effluents, leakage of septic tanks, animal excreta, and soil nitrate cannot also be ruled out.

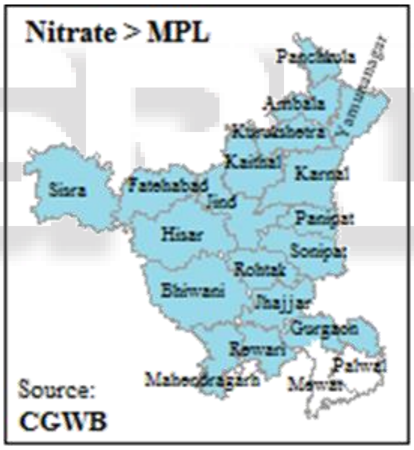

Fig. 2: Districts in Haryana with elevated nitrate levels > MPL (1.5 mg/L)

District	Total Blocks	Fluoride-affected	Nitrate-affected
Ambala	6	-	2
Bhiwani	10	7	8
Faridabad	2	-	-
Fatehabad	6	-	3
Gurgaon	4	3	4
Hisar	9	8	5
Jhajjar	5	1	4
Jind	7	4	4
Kaithal	6	3	4
Karnal	6	-	1
Kurukshetra	5	1	1
Mahendragarh	5	2	3
Mewat	5	-	-
Palwal	4	3	1
Panchkula	4	-	2
Panipat	5	4	3

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Rewari	5	-	4
Rohtak	5	4	4
Sirsa	7	7	5
Sonipat	7	6	4
Yamunanagar	6	-	1

Table 1: District-wise number of blocks in Haryana from where fluoride and nitrate were reported above MPLs (Source: CWGB)

3) Electrical Conductivity (Salinity)

Fourteen districts in Haryana exceed the MPL for electrical conductivity (EC >3000 µS/cm) (Fig. 3). Electrical conductivity expresses the combined effect of all dissolved species in water and thus represents overall salinity levels. High salinity levels can result from both natural as well as anthropogenic processes [36, 37]. Natural processes include surface water-groundwater influx in the unconsolidated alluvial formations, which facilitates salt accumulation in semi-arid climate. In addition, water-level fluctuations and perturbation of the natural hydraulic equilibrium probably have led to salt-mobilization from the unsaturated zone. Anthropogenic processes include canal-based irrigation which augments evapotranspiration and in turn waterlogging and salt deposition. Dissolution of different agrochemicals followed by irrigation induces leaching and salt-accumulation in the rhizosphere, leading to subsequent salinization of groundwater [38].

In addition to the above-mentioned, heavy metal contamination of drinking water resources have been widely been reported from several districts [39, 40, 41, 42]. Some studies have also found elevated levels of insecticides [43] and pesticides [44] that further escalate human health risks.

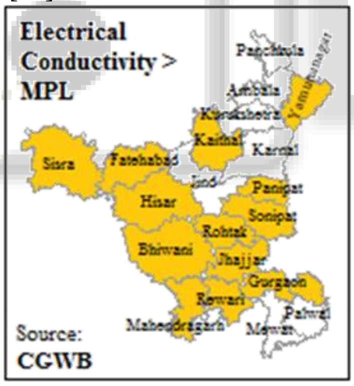

Fig. 3: Districts in Haryana with elevated EC levels > MPL (3000 µS/cm)

B. *Groundwater Level*

Added to water quality impairments another confounding factor that puts groundwater resources in great peril in recent times in Haryana is groundwater availability. It essentially ensues from appalling water-level declines observed in several districts of the state including Mahendragarh, Kurukshetra, Panipat, Gurgaon, Rewari, Panchkula, Karnal, Kaithal, Ambala, Mewat and Yamunanagar districts [15, 16 18]. Water quantity often 'influences' water quality as studies have found dropping water-levels led to increased salinization that affected overall potability of groundwater resources [45].

A recent study found that between 2002 and 2008 groundwater resources have depleted at an average rate of 4.0±1.0 cm yr-1 in the north-western states of India including Haryana, with a depletion equivalent to a net loss of 109 km3 of water [46]. Decline in 'fresh' groundwater levels (between 10 and 23 m) have been reported from Kaithal district which has led to salinization [48]. 'Unregulated' drafting for irrigational purposes is a prime cause of depletion in Haryana [47].

C. *Drinking Water Sources*

In India, 'safe' drinking water sources mainly comprise of three categories: tap water (both treated and untreated), hand pump and tube well. Following this scheme, percentages of 'safe' drinking water sources have been on the rise in Haryana over time (Fig. 4). As compared to about 75% households receiving safe drinking water in 1991, the tally soared up to cover about 92% households in the recent times.

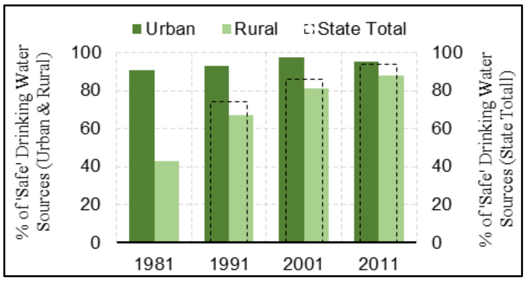

Fig. 4: Percentages of households with 'safe' drinking water sources for urban and rural areas in Haryana and state total (1981- 2011).

Results indicated that (1) even in the 80s, about 90% urban households had safe drinking water sources as compared to only 42% for the rural households, (2) between 1981 and 2011, the coverage has shot up to soaring highs in rural areas: from about 40% household with safe sources to about 88%, and (3) rural-urban disparity has diminished, from about 48 percentage points in 1981 to about 7 percentage points 2011.

Although the scenario appears promising, it needs a careful scrutiny of relative contributions of different 'types' of drinking water sources that make up the estimation of 'safe' sources. Fig. 5 presents a district-wise summary of 'safe' drinking water sources. It appeared that, as of 2011, round 90% of all households (urban + rural) in the state had 'safe' drinking water sources of which with tap water constituted the bulk.

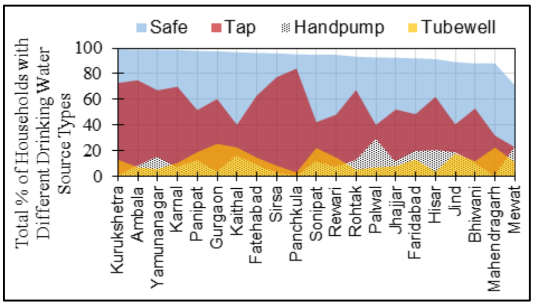

Fig. 5: District-wise total percentages of households with 'safe' drinking water sources in 2011. Total refers to the district-wise combined percentages of urban and rural sources. 'Tap' comprises of both treated and untreated varieties (Source: Census, 2011)

State-wide, the 'treated' and 'untreated' sources were available to around 55% and 13% households on average, respectively. In, Mewat (22%), Mahendragarh (31%), Jind, Sonipat, Kaithal, and Palwal (each about 40%), districts less than half of all households received treated tap

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water for potable use. In Mahendragarh, a third of households had 'untreated' tap water. In the above mentioned districts, untreated + hand pump + tube well served about 50% of households for 'safe' sources.

There are two important considerations in this regard, the first one relates to the very assumption of safety: How Safe Is Safe Indeed? It draws from the observation that untreated tap along with hand pump and tube well constitute significant proportion of 'safe' drinking water sources in Haryana, alike much of rest of India and the world. The latter sources, however, rely upon shallow groundwater. As multiple contaminants occurring above their MPLs in groundwater resources from several districts in Haryana, using hand pumps/tube wells for 'safe' potable purposes appears questionable.

The other consideration calls to question 'inequality'. Even though results indicate that the state as a whole it is approaching towards more a uniform scenario in infrastructural facilities over time (Fig. 4), the question is: How Equal is Equal? A comparative evaluation of district-wise rural and urban areas for 2011 revealed that in each district urban households enjoyed substantially greater access to treated tap water (Fig. 6).

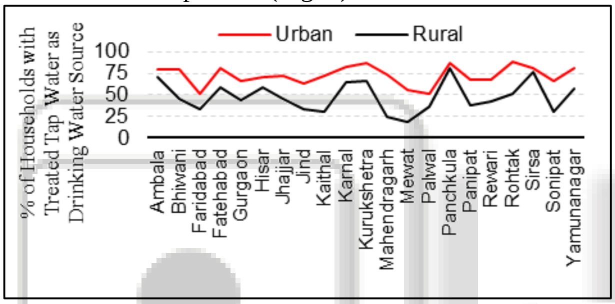

Fig. 6: District-wise percentages of households with treated tap water and hand pump/tube well as drinking water sources in 2011. (Source: Census, 2011)

As of 2011, a total of about 47% rural households in Haryana had access to treated tap water as against about 70% of urban counterparts which indicated a glaring disparity. The disparity appeared most striking in Mahendragarh (the former ahead by 47 percentage points), Kaithal (41% points), Mewat (38% points), Rohtak (38% points), Sonipat (35% points), Panipat (29% points), Jhajjar (27% points), and Rewari (25% points) districts (Fig. 6). In 12 districts in Haryana, over half the rural households lacked treated tap water for potable purposes while there was no district had similar 'underprovided' state of infrastructure for urban households. In Mewat, treated tap water was available to less than a fifth of rural households, while in the same district over 55% urban households had access to it. Overall there were in nine districts where over 80% urban households 'enjoyed' treated tap water as against only Panchkula having a similar tally for its rural households.

As of 2011, about a third of all rural households in Haryana relied on hand pumps + tube wells as against only about 19% of urban households.

About half the rural households of Yamunanagar and Kaithal, and about 40% of that of Jind, Panipat and Sonipat districts depended on these sources (Fig. 7). In essence, these figures reiterate the concerns that a large fraction of rural, as well as urban, households are potentially exposed to harmful chemical species in groundwater by using these 'safe' sources. To add to the concern, in Faridabad, Gurgaon, Jind, Palwal, Sonipat, Rewari districts, over a quarter of urban households could be at risk due to reliance on these sources for potable purposes.

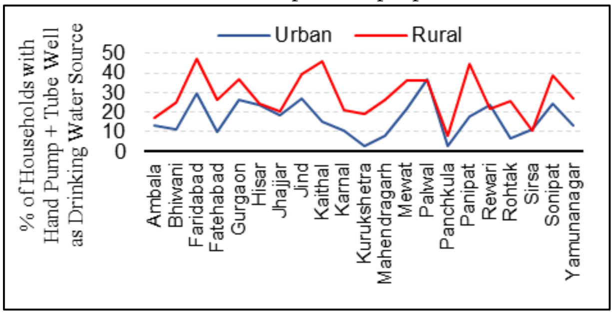

Fig. 7: District-wise percentages households having hand pump + tube well as drinking water source in 2011. (Source: Census, 2011)

As of 2011, 18 districts in the state had access to drinking water sources within remises in over half of all households (Fig. 8).

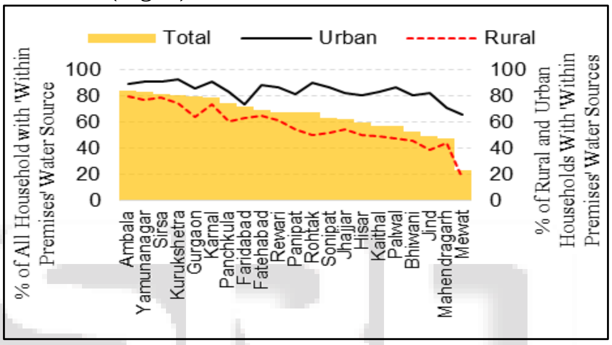

Fig. 8: District-wise percentages of all households (urban + rural) with drinking water sources within premises (Source: Census, 2011)

The impoverished state of rural areas were further apparent by assessing locations of drinking water sources. For example, in 14 districts over 60% urban households had water sources within premises while rural households had access to such facilities in only 9 districts. In Yamunanagar, Sisra, Kurukshetra, Rohtak, Karnal districts, over 90% urban households had sources within premises. No district had similar tally for their rural households. Overall, only about 56% of rural households in the state had drinking water sources within premises as compared to about 84% in urban areas. This indicated that over 40% of the rural population had to travel a certain distance to obtain potable water. About 17% of all rural households in the state had to travel about half a kilometer (source 'Away from Premises'). In Bhiwani, Hisar, Palwal, Mahendragarh, Rohtak, Jind districts over a fifth of households had to travel this distance to obtain drinking water. This can potentially introduce substantial uncertainty in form of handling and maintenance of hauled water. In addition, obtaining water from distant sources lead to wastage of valuable resources (e.g. time, money, human endeavor etc.) that might stand in the way of human development.

State-wide assessment of drinking water source types and locations indicated that water sources located Away From Premises (100m in urban areas; 500m in rural areas) comprised mostly of any but treated tap (Fig. 9).

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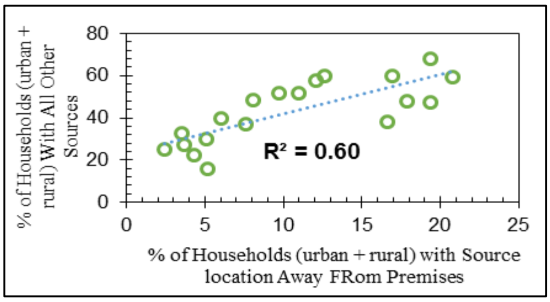

Fig. 9: Relationship between percentages of all households (urban + rural) in Haryana with drinking water sources located away from premises and all water source types except treated tap in 2011.

This draws from the observation that there was significant positive correlation ($r^2 = 0.60$; $p < 0.05$) between the above-mentioned parameters. This is further corroborated with statistically significant correlation ($r^2 = 0.67$; $p < 0.05$) observed between treated tap and within premises sources in rural areas (Fig. 10).

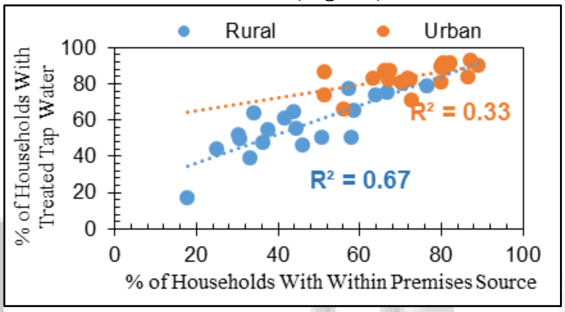

Fig. 10: Relationship between % of households with treated tap water and water sources within premises for rural and urban areas in 2011.

Interestingly, value of the correlation coefficient for the urban households for the same appeared less 'impressive', though statistically significant ($r2 = 0.33$; $p < 0.05$) (Fig. 10). Assuming treated tap water is by far the safest option, this indicated that at-home potable water sources in rural households were more quality-assured while those in urban areas were not constrained within households, which further underscored the disparity.

IV. HARYANA VIS-A-VIS INDIA

Though pitted with steep challenges to ensure 'safe' potable water availability, especially for rural areas, a comparative evaluation of the current state of affairs in Haryana against the national standards in India, however, shot up a few redeeming features (Table 2).

Drinking Water Facilities	India	Haryana
Treated Tap	32	55.9
Untreated Tap	11.6	12.9
Hand Pump	33.5	12.0
Tube Well	8.5	12.9
Within Premises	46.6	66.5
Near Premises	38.5	21.4
Away from Premises	7.6	12.1

Table 2: Percentages of total households in Haryana vis-a-vis India with different drinking water facilities in 2011.

Over half of all the households (urban + rural) in Haryana had treated tap water as compared to about a third of so across whole of India. On the other, hand pump + tube well accounted for over 40% of all drinking water sources in India compared to about a quarter of that in Haryana. Moreover, only about 47% households in India had drinking water sources within premises as compared to about two-thirds in Haryana.

Though it may appear redeeming for Haryana, in an indirect way, however, it revealed the dilapidated state of infrastructural facilities in India. Safe potable water is reckoned as a basic necessity. However results indicate that there is appalling inadequacy in the level of services made available to the citizens across the nation, alongside a glaring urban-rural disparity. As of 2011, only about 18% rural households in India had access to treated tap water sources with the urban-rural difference amounting to about 44 percentage points. In times of burgeoning crises over natural resources availability in India, these shortcomings have to be addressed with utmost haste and rigor to promote human development.

V. POTENTIAL RECOMMENDATIONS

In light of above observations that illustrate concerns over public health in several districts of Haryana arising from poor groundwater quality, especially in the rural households, some strategies that might be beneficial are:

- Periodic monitoring of water sources in rural areas, especially in regions from where elevated levels of contaminants have been reported. In this regard, a comprehensive digital database, complimented by spatial maps (if possible), should be maintained detailing the water sampling strategies, QA/QC protocols and data compilation methods. The database should be placed in the public domain to help researchers, NGOs, and general public to access and assess the data and provide necessary feedbacks (e.g. current data gaps) to the authorities.
- Involving the village communities in protection of 'safe' drinking water sources. This might involve:

1) Providing easy-to-use, inexpensive water testing kits to help in monitoring efforts.
2) Providing apt training in the operation and maintenance (O&M) of water sources (e.g. taps, valves, faucets, and other plumbing fixtures).
3) Building general awareness about the water-health nexus and precautionary measures.

- Replacing hand pumps/tube wells with piped water supply and maximize the aerial coverage by 'treated tap' sources over time. Concurrently, proportion of households that still rely upon 'untreated' tap water, covered/uncovered wells have to be minimized. Special caution has to be taken when using surface water sources including pond, river, tank etc. and village communities have to be made aware of potential sources of contamination therein.
- Establishing more water treatment facilities, especially in rural areas and provide 'bottled water' (wherever necessary) at subsidized rate, especially to the economically challenged section. Regions of the state where there is acute water shortage, especially due to unprecedented drought in recent times, safe drinking water should be provided using water tankers.

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- Providing apt knowledge to village communities about local hydrology, climate, land use etc. to identify key factors (especially, human-induced factors) that disrupt natural hydrologic processes and develop region-specific source water (e.g. groundwater) protection plans. For example, waste disposal activities around drinking water sources or using them for household chores (bathing, washing of clothes and utensils, sanitation, idol emersion etc.) have to be strictly regulated. In this regard, conscious attempts have to be made to 'keep off' agricultural runoff from entering water ways in rural areas. In urban areas, industrial waste disposal have to be regulated. Special attention has to be paid to protect the external water sources (near or away from premises) that are more prone to degradation and/or depletion.
- A disparaging reality about rural areas is that often a sole drinking water source feeds the whole community, which leads to conflicts over 'right to water'. Moreover, when this source goes dry (due to overexploitation) subsistence of the whole community comes under threat. Conscious effort (government as well as NGOs) have to be put into action to help the village communities look for alternate water sources and have them trained in latest innovations about water conservation strategies (e.g. rainwater harvesting, storm water management etc.), recycle/reuse of wastewater, and build awareness against water wastage.
- Drawing up region-specific budgets for O & M of drinking water sources and supplies while keeping adequate provisions to address emergencies.

VI. CONCLUSION

There are raving concerns over water-level declines, in several districts in Haryana, coupled with multiple contaminants occurring above their MPLs that challenges safe and sustainable drinking water supply. Results indicated that out of a total of 119 blocks in the state, elevated fluoride and nitrate have been reported from groundwater from 53 and 63 blocks, respectively. Alongside, there is widespread salinization of groundwater resources that affects overall potability. What adds to the aggravation is, still a considerable fraction of the population, especially in the rural areas, depend on groundwater resources which are under threat of availability as well as vulnerability. Moreover, compared to urban households, only a measly fraction of rural households have access to treated tap water sources and/or sources within premises. Substantial disparity still exist between urban and rural areas that need to be addressed with region-specific knowledge of natural processes and human dynamics that affect water resources availability and vulnerability.

In face of extreme climatic shifts, population explosion and mounting water demand, long-term strategic planning is necessary to address infrastructural inadequacies in the rural areas of Haryana, as much as in rest of the country, to promote human development. Last but not the least, the idea of 'safe' needs to be reassessed as a large fraction of 'safe' water sources still rely on groundwater resources.

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