Developing a Household Level MUWS Vulnerability Index for Rural Areas

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Abstract

An index, which helps identify vulnerable areas and communities for surveillance of water supply for human use and livelihoods in rural areas, is derived. The index helps compute the vulnerability of a household to health risks associated with poor water supply and sanitation. This composite index has six sub-indices, viz., water supply and use index; family occupation and social profile index; social institutions and ingenuity index; climate and drought proneness index; water resources availability index; and financial stability index. The number of "minor" factors which together are considered to have influence on the measure of these sub-indices, the underlying assumptions, the methods for methods and procedure to compute and the data sources are also discussed.

1.0 Water Supply Surveillance

Water supply surveillance is defined as: 'the continuous and vigilant public health assessment and oversight of the safety and acceptability of water supplies' (WHO, 1976; 1993; 2004). Many millions of people, in particular throughout the developing world, use unreliable water supplies of poor quality, which are costly and are distant from their home (WHO and UNICEF, 2000). Over the years, there is growing realization that communities in the rural areas need water for productive as well as domestic uses, indicating the need for an increase in the quantity of the water supplied from public systems along with quality (Renwick, 2008; Nicole, 2000; van Koppen *et al.*, 2006). This is important for meeting the millennium development goals (van Koppen *et al.*, 2006).

Traditionally, water supply surveillance generates data on the safety and adequacy of drinking water supply in order to contribute to the protection of human health. Most current models of water supply surveillance come from developed countries and have significant shortcomings if directly applied in a developing country context. Not only the socio-economic conditions, but also the nature of water supply services is different. Water supply services in developing countries often comprise a complex mixture of formal and informal services for both the 'served' and 'un-served' (Howard, 2005).

Many millions of households in India do not have access to "tap" connections at home. Only 24.2 per cent of the rural population have access to tap connections (source: based on Census of India, 2001), and as a result a majority of the rural population depend extensively on private wells, hand pumps, bore wells and ponds and tanks, that provide untreated water, for domestic water supply (NSSO, 1999), a trend found in many other parts of the developing world (Gelinas *et al.*, 1996; Rahman *et al.*, 1997; Howard *et al.*, 1999). Given the informal nature of the sources and 'services', the data on actual water use by the households by the communities are absent. The problem is compounded by the lack of clarity on the supply norms for fulfilling multiple water needs of rural population.

Nevertheless, the sources that are reliable and that can provide adequate quantity of water of sufficient quality to meet various productive and domestic needs seem to be far less than adequate. It is evident from the fact that the rural poor tend to compromise on their basic needs, with resultant undesirable outcomes on health and hygiene, and livelihoods of rural communities. Therefore, a well designed and implemented water supply surveillance in relation to domestic and productive needs of the community is important to provide input into water supply improvements. The key to designing such a programme is information about the adequacy of water supplies and the health and livelihood security risks faced by populations due to lack of it at national or sub-national levels. This will help identify areas that are vulnerable. But, as Nicole (2000) notes, there are a range of natural, physical, social, human, economic, financial, institutional factors influencing the vulnerability of the rural population to problems associated with inadequate supply of water for consumption and production needs. They are not captured in the traditional surveillance programmes.

2.0 Past Approaches to Water Supply Surveillance

The inextricable link between water security, health, livelihood and economic gains is quite well established (Botkosal, 2009; HDR, 2006; Nicole, 2000). Improving water security of the poor brings about significant health and poverty reduction benefits (DFID, 2001; HDR, 2006: 42; WHO, 2002). The economic losses due to deficit in water supply of sufficient quantity, quality and reliability are disproportionately higher for the poor communities. This is owing to greater risk of employment loss, health costs, loss of productive workforce and water-based livelihoods (HDR, 2006: 42).

As Nicole (2000) argues, a demand responsive approach to water supply requires that the livelihood needs of the community are also taken into account, rather than the supply requirements for human consumption and sanitation needs. Therefore, an assessment of water supply at the household level, based on the old norms worked out on the notion of water supplies that serve human health and hygiene needs would be grossly inappropriate. In India, the monitoring of rural water supply is based on simplistic considerations, involving data on number of households covered by different types of water supply systems; and the characteristics of the sources. The data gathered through such surveys are silent on the amount of water actually consumed by the population, and the quality and reliability of the supplied water, all of which determine the health and livelihood outcomes.

3.0 Why Vulnerability Index for MUWS?

The foregoing discussion suggests that comprehensive approaches to water supply surveillance were by and large lacking for quite some time. The approaches to water supply surveillance that allow targeting of surveillance activities on vulnerable groups were assessed by G. Howard using case studies from Peru and Uganda. The Peru case study attempted to incorporate some measures of vulnerability into the surveillance programme design through a process of "zoning" that was based on water service characteristics. Whereas the Uganda case study involved development of a semi-quantitative measure of community vulnerability to water-related diseases, to zone the urban areas and plan surveillance activities. The zoning used a categorization matrix, which was developed incorporating a quantitative measure of socioeconomic status (education, sources of livelihood, family size and type of housing), population density and a composite measure of water availability and use (Howard, 2005).

But, the main limitation of the approach is that they try to assess the vulnerability of the household against lack of water for human consumption and sanitation. They do not take into account the multiple water needs of the community, particularly the poor in rural areas. There are many factors such as the family occupations, social profile, financial stability which determines the household water needs for productive purposes.

Identifying the most vulnerable groups is not an easy task due to the complex interplay of a wide range of factors. Factors such as poor reliability (continuity of supply), costs (affordability) and distance between a water source and the home may all lead households to depend on less safe sources, to reduce the volume of water used for hygiene purposes and to reduce spending on other essential goods, such as food (Lloyd and Bartram, 1991; Cairncross and Kinnear, 1992; Howard, 2002). The evidence suggests that water interventions targeted at poor populations provide significant health benefits and contribute to poverty alleviation (DFID, 2001; HDR, 2006; WHO, 2002). Though it appears that poverty is a major factor deciding vulnerability, it is just one of the many complex factors which would eventually determine the outcomes of family's high vulnerability to lack of water for multiple uses.

The factors that can influence vulnerability of a household to problems associated with lack of water for multiple uses could be: 1] degree of access to water supplies for human consumption, personal hygiene and productive uses such as livestock consumption in terms of quantity and desired quality, and the level of use; 2] social profile and family occupations; 3] social institutions and ingenuity; 4] condition of water resources; 5] climatic factors; and, 6] financial condition (source: based on Lloyd and Bartram, 1991; Cairncross and Kinnear, 1992; DFID, 2001; Howard, 2002; Hunter, 2003; Nicole, 2000; Sullivan, 2002; WHO, 2002). The second and fifth factors influence the vulnerability by changing the household water demand. This may not be always in terms of the quantum of water, but in terms of the reliability of the supply. The third and fourth factors can change the external environment, which influences water supply. Here again, the degree of access depends on the presence/absence of social institutions and local custom and traditions, which are quite characteristic of poor and developing countries.

Now climate has a major bearing on the adverse effect of lack of water for hygiene and environmental sanitation. In arid and semi arid climates, breeding of water-related insect vectors would be less during hot weather conditions. In flood prone areas and areas receiving high rainfall, the occurrence of water-based diseases are likely to be more, and therefore more caution needs to be exercised in the disposal of human and animal excreta (Hunter, 2003: 37). At the same time, the demand of water for meeting livestock needs, and irrigating fruit trees and kitchen garden etc., would increase with increase in aridity and temperature. So is the demand for water for washing and bathing. Arid areas are also drought-prone. Hence, there is a need to develop a composite index which takes into account these complex factors in assessing the vulnerability of rural households to inadequate supplies of water to meet multiple needs so as to make surveillance more targeted.

4.0 Deriving a MUWS Vulnerability Index

We begin with the premise built on the knowledge from extensive review of past research studies dealing with related topics that the vulnerability of a household to inadequate supply of water to meet drinking water, sanitation and livelihoods needs is determined by four broad parameters: 1] capital assets and good; 2] sequencing and time; 3] institutional linkage; 4] knowledge environment. The capital assets can be further divided into natural capital, social capital, physical capital, financial capital (Nicole, 2000). It is evident that while some of the capital asset (physical capital and human capital) related parameters would determine the access to water supply and its use, the natural capital related parameters, institutional linkage and knowledge environment would change the external environment which influence the supply and use for water. On the other hand, the capital assets such as natural capital, social capital and financial capital influence the demand for water.

All these parameters are factored in six broad sub-indices we have discussed previously. They are: 1] water supply and use; 2] family occupation and social profile; 3] presence of social institutions and ingenuity; 4] water resource endowment; 5] climate and drought proneness; and, 6] financial stability. Each one of these six broad factors constitutes one sub-index. The number of "minor" factors which together are considered to be influencing the measure of these sub-indices, the methods and procedure for their computation, and sources of data are explained in the table below.

The composite index of "MUWS vulnerability" will have a maximum value of 10.0, meaning zero vulnerability; lower values of the index meaning higher vulnerability. It is composed of six sub-indices (from A to F: Table), each one will have unequal weightage in deciding the value of the index. The maximum value of sub-index A will be 3.0; that of B, C and D will be 1.0; and that of E and F will be 2.0 each. The sub-sub index also will have equal weightage (measured on a scale of 0 to 1.0). The sum of the values of all sub-indices under sub-index A would be multiplied by 0.30 to obtain the value to be imputed into the mathematical formulation for estimating the composite index. The sum of the values of all sub-indices under sub-index "B" and "D" would be divided by two (2) to obtain the value to be imputed into the mathematical formulation for estimating the composite index. The sum of sub-sub indices under sub-index "E" would be multiplied by 0.50.

Deriving a Household Level MUWS Vulnerability Index

Sr. No	Parameters	Quantitative criterion for measurement	Method of data collection
A	**Water Supply and Use**		
1	Access to water supply source (primary)	Vulnerability decreases with improved access. Access is an inverse function of the distance. The index is a function of the distance to the source from '0" within the dwelling to a maximum of 1km and above in gradations of 0.20[1]	Primary survey
2	Frequency of water supplies	Vulnerability increases with decrease in frequency of water delivery[2].	Do
3	Ownership of alternative water sources	Ownership of an alternative water source would increase the overall access and reduce the vulnerability[3]	Do
4	Distance to the alternative source "owned"	Distance to the alternative source, would increase the vulnerability. Often, the alternative sources are farm wells, which are located outside the village[4].	Do
5	Access to other alternative sources	Vulnerability decreases with no. of alternative sources[5].	Do
6	Capacity of domestic storage systems	Vulnerability to lack of regular water supplies decreases with increase in volume of storage	Do

		systems in place[6]	
7	Quantity of water used	The vulnerability increases with decrease in quantum of water used against the requirement. The vulnerability can be treated as zero when all the requirements in the household are fully met[7].	Do
8	Quality (chemical, physical and bacteriological) of domestic water supplies	Poor quality of drinking water increases vulnerability; Bacteriologically, physically & chemically pure is the best water[8]	Lab test results/ perceptions
9	Total monthly water bill as a percentage of monthly income	Vulnerability increases with increasing % of total family income spent on water. An expenditure level of 10% of monthly income is treated as highest and most vulnerable[9]	Primary survey
B	**Family Occupation and Social Profile**		
1	Family Occupation	Vulnerability will be low for families having regular source of livelihood that are not dependent on water. Those who are dependent on irrigated crop production are considered to be not vulnerable. But, those who are dependent on dairying will be vulnerable. The vulnerability will reduce if they depend on wage labour and other sources of livelihood that do not require water[10]	Do
2	Social Profile	Vulnerability is also a function of the social profile. The families having school going children are more vulnerable to inadequate quantity, quality and reliability of water supplies. So, is the case with families having office-going adult. But, The vulnerability would reduce with the presence of surplus labour availability[11].	Do
C	**Social Institutions and Ingenuity**	Community's vulnerability to the problems associated with lack of water increases in the absence of social/community institutions; social ingenuity[12]	Primary survey (but qualitative to be obtained from discussions)
D	**Climate and Drought Proneness**		
1	Climate (whether semi arid/arid/hyper-arid or sub-humid/humid	The vulnerability to lack of water for environmental sanitation is a function of climate. It increases from hot & arid to hot & semi-	Secondary data on climate

		arid to hot & sub-humid to hot & humid to cold & humid[13].	
2	Aridity and drought proneness	The vulnerability due to lack of water for domestic uses, livestock increases with increase in aridity as it would increase the demand for water for washing, bathing, livestock drinking and irrigation of vegetables and fruit trees. Aridity areas are also drought prone[14].	
E	**Condition of Water Resources**[16]		Do
1	Surface and groundwater availability in the area	A renewable water availability of 1700 m^3 per capita per annum is considered adequate for a region or town, estimated at the level of river basin in which it is falling[15].	Secondary data
2	Variability in resource condition	Higher the variability, greater will be vulnerability[16].	Do
3	Seasonal variation	Regions which experience high seasonal variation in water availability are highly vulnerable[17]	Do
4	Vulnerability of the resource to pollution or contamination	Surface water is more vulnerable to pollution than groundwater. Shallow aquifer is more vulnerable than deep confined aquifer[18].	
F	**Financial Stability**	Overall financial stability of the family would influence the vulnerability. This is different from the earnings from current occupations. The savings in banks/post office; ownership of productive land, which is not mortgaged[19].	Primary survey

Foot notes

1. Within the dwelling is “1.0”; within the premise is “.80”; within 0.2 km distance is “.60”; between 0.2 and 0.5 km is “0.4”; 0.5 and 1.0 is “0.2” and more than 1.0 km is “0”.

2. Frequency can be indexed as total hours of water supply in a week as a fraction of no. of hours.

3. It is assumed that the ability to manage water would be highest in the case of a functional open well, followed by bore well, hand pump and farm pond in the decreasing order. The value of the sub-index would be 1 in the case of ownership of a functional open well, followed by 0.70 for a bore well; 0.50 for ownership of a hand pump; and 0.30 for ownership of a farm pond.

4. Within the premise is "1.0"; within 0.2 km distance is ".80"; between 0.2 and 0.5 km is "0.6"; 0.5 and 1.0 is "0.4" and more than 1.0 km is "0.20".

5. The value of sub-index for this attribute would be "1.0" if there are four alternate sources & above, and the value would decrease proportionately with decrease in number of alternative sources.

6. It would decrease with increase in the ratio of the actual storage capacity available" to the "storage capacity required"; and the value of the index would be higher. The storage capacity required would be an inverse function of the frequency of water supply. If supply comes once daily but during odd hours, then it can be assumed that the volume of water for the entire day's use would be required to be stored. So, the storage capacity would be "n*f". If it comes during day time for less than an hour, then half the daily water use would be the storage requirement. For more than one hour, the storage requirement would be minimal (around 20 litres per capita). With alternate day water supply, it could be the 2*n*f. For once in three days, it would be 3*n*x f and likewise. For round the clock water supply, the storage requirement would be zero, and here the ratio can be assumed as 1.

7. This sub index is computed by taking the volume of water used (x) as a fraction of the minimum required (n), i.e., $\frac{X}{n}$ where n water requirement as per norms. The value of n should be estimated by considering the human requirement of 50 lpcd (basic survival need as suggested by Glieck, 1997); the animal requirements decided by the types of livestock and the size; and the requirement for kitchen garden.

8. The value of the sub-index "m" would be 0.33 if the water is pure either bacteriologically or physically or chemically. The value would be 1.0 if pure on all counts.

9. The value of the sub-index would be "0" if the family spends 10% or more of its monthly income on obtaining domestic water supplies, and would keep on increasing with reducing amount of money spent in water bill. The mathematical formulation for computing the index therefore is [1-W_C/MI]; where W_C is the monthly expenditure on securing water supplies, and MI is the monthly family income.

10. The vulnerability induced by family occupation is considered to be zero, if the adults in the family are engaged in livelihoods that are not dependent on water in the village. The vulnerability is also considered to be zero for families having crop production with own irrigation facilities. The families purely dependent on dairy farming would be assumed to have highest vulnerability (1.0), as the water for cattle drinking will have to be managed.

11. For families having school going children and office going adults, the situation could be treated as most unfavourable. Here, the sub-index could be assumed as 0.0 (lowest), meaning highest vulnerability. The families having either of these, the value could be assumed as 0.33. For families having neither of these, the

value would be treated as 0.67. For families, having surplus labour in the HH for fetching water from distance, the sub-index could be assumed as 1.0.

12. The value can range from "0" for the absence of social institutions or ingenuity to 0.50 for presence of either of these to 1.0 for the presence of both. Social institutions would include: WATSAN committees (Y=0.50; No=0). Social ingenuity would include: existence of water sharing traditions between households during crisis (Y=0.25; No =0.0) and practice of re-using water in households--using bathing/washing water for toilet flushing, use of sand & ash for cleaning utensils etc. (Y=0.25; No-0.0).

13. The value ranges from "0.0" for cold & humid to "1.0" for hot & arid with increments of "0.20"

14. The value ranges from "1.0" for cold & humid to "0.0" for hot & arid with reduction of "0.20"

15. A renewable water availability of 1700 m^3 per capita per annum is considered adequate for a region or town, estimated at the level of river basin in which it is falling. The value of the index is computed by taking the amount of renewable water as a fraction of the desirable level of 1,700m^3

16. The index is computed an inverse function of the coefficient of variation in the rainfall variability in that basin/sub-basin (1-x/100); where x is the coefficient of variation in rainfall.

17. For alluvial areas, the value of this index is considered as 1. For hard rocks, the value is considered as 0.3. For sedimentary and alluvial deposits, the value is considered as 0.65.

18. Shallow groundwater areas; river/stream/reservoirs in the vicinity of industries are highly vulnerable with a value of the sub-index equal to 0.0; distant reservoir in the remote virgin catchments and groundwater from deep confined aquifers has a pollution vulnerability index of 1.0; shall groundwater in rural areas to have medium vulnerability with a value of 0.50.

19. The family having 1.0 ha of productive land member in a semi arid, water-scarce region, or 0.5 ha of productive land per member in a water-rich area are considered to be financial stable, with zero vulnerability, and the vulnerability is assumed to increase gradually with reducing size of land owned, with highest vulnerability for landless. Again, the lack of ownership of land can be compensated by income savings, with a total saving of Rs. 20,000 equivalent to 0.5 ha in water-rich area and 1.0 ha in a water-scarce area. This index could be computed as "x/0.50" for water-rich areas, and "x/1."0 for water-scarce areas (where x is the land owned in ha).

5.0 Conclusions

A demand responsive approach to water supply requires that the livelihood needs of the communities are taken care of, rather than mere human consumption and sanitation requirements. This also means that the considerations for assessing the vulnerability of rural communities to problems associated with lack of adequate water supplies (in terms of quality, quantity and reliability) at the household level would change significantly from those used in the past. The development of an index that helps assess vulnerable rural population and pockets within is useful to target data collection in water supply surveillance. In this paper, we have attempted a household level MUWS vulnerability index. Computing the household level vulnerability index can assist a utility in targeting MUWS interventions into communities and strategies where public health gains are likely to be greatest.

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