A Study on Global Water Consumption and Improved Sanitation Facilities: India's Plight in Contrast to Other Countries

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Abstract

The effect of poor and unhygienic water on health is a pandemic problem across many nations. As per the estimations, approximately 37.7 million Indians are suffering from waterborne diseases annually; diarrhea is observed to be worst illness that is causing huge child mortality. The bad sanitation and hygiene also affects poor productivity which in turn cripples the economy. The economic burden due to poor sanitation and unhygienic drinking water is estimated at $600 million a year. 700 million people residing in rural India comprise more than about 1.42 million habitations spread over 15 diverse ecological regions. In fact, providing drinking water to such a large population is an enormous challenge. Hence, in this very context, a study have been undertaken so as to study and visualise the global water consumption and improved sanitation facilities to know about India's predicament in comparison to other countries. Certain powerful statistical tools like principal component analysis and itemised cluster analysis were employed to realise the study objectives. The countries were identified in certain important groups lying in similar situation with respect to sanitations and hygiene drinking water facilities. Most importantly the α (chronbach alpha) and β (factor saturation) are very fair to the clusters identified, whereby, affirming that the study variables, i.e. both urban and rural populations with respect to sanitation facilities and availability of hygiene drinking water could strongly characterise the countries under study.

Keywords: *Sanitations Facilities, Hygiene Drinking Water, Public Health, Urban and Rural Populations*

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INTRODUCTION

As it is widely known that water is one of the big essentials of human and animal lives and therefore should be treated with special emphasis while using. The United Nations Committee on Economic, Social and Cultural Rights, in November 2002, officially declared that water is a human right. Water is not only individual exigency but also a social good, availability of which will serve the greater benefit of society.[1,2] Water resources are becoming increasingly scarce due to growing demands and unscrupulous use. In fact, these shortages have led to conflicts and competitions over water resources. Certain corporate firms had swung into this industry (retailing water) launching their products successfully to the markets (Haran, 2007).

As per Marvas (2007), the retail water market is going to be very profitable business by 2015 owing to many reasons. As per the statistics 884 million people do not have access to safe and hygienic drinking water, 2.6 billion people lack access to basic sanitation, which approximately accounts to 40 percent of world's population. Due to its value and scarcity, water is considered an economic good. Hence, recognising water as an economic good implies that of economic value of water and as such it does not call necessarily for the private ownership of and control over the resource as in the mineral industry. Ultimately, the foremost challenge now is to treat water sustainably, as an economic, environmental and social good. It is to assure access to and use of water for all people while respecting the limits imposed by ecosystems.

As per Center for International Trade Development, the size of India's total water market is worth more than USD 4 billion, growing by 10 - 12 percent annually (Hughes, 2009). Water companies from all over the world have established presence in India. If the latest count is correct, these companies are pursuing around 70 projects spread across 20 Indian cities. Projects launched by governmental bodies contribute over 50 per cent of revenues in this market. The private sector contributes the other half of the market (Marvas, 2010). As far as the infrastructure for treatment of used or wasted water is concerned, it is abysmally inadequate. Only about

1 In fact, the UN by virtue of "*Resolution A/RES/64/292*" declares that safe and clean drinking water and sanitation are human rights unto the full enjoyment of life and all other human being.

2 *Ban Ki-moon*, UN Secretary General, in deed, mentions that "safe and drinking water and adequate sanitation are crucial for poverty reduction, crucial for sustainable development and crucial for achieving any and every one of the *Millennium Development Goals*".

60 percent of industrial wastewater and 26 percent of domestic water is treated. Only 29 percent of wastewater is treated in 423 Class I cities (i.e. cities with a population of more than 100,000). Even worse, Class II towns (i.e. towns with a population between 50,000 and 100,000) are able to treat just 4 percent of wastewater. Even India's national capital, New Delhi, treats less than half of the 3,267 million liters of wastewater it generates every day.

Drinking Water Scenario in India

In recent times, both documentation and activism on water have increased in India. But awareness at the primary consumer level (i.e., the citizen) remains very low. Only a thin minority knows about the benefits of the conservation of water and water resources (Marwas, 2010). One reason is that water has been coming virtually free of cost. Farmers tap water from nature itself, industries pay a pittance as water cess (a tax specific to the consumption of water), while most households pay nothing at all. In fact, many Indians see groundwater in particular as a "democratic resource" (The Economist, 2010). The government, generating very little revenues from water, is unable to operate and maintain the existing infrastructure or even create fresh capacity. Most water utilities perform poorly at operations and maintenance.

But there are improvements that should be introduced urgently: metering, applying appropriate user charges, reducing water losses, increasing water availability, coverage and access in partnership with customers, stakeholders and donors (MUD, 2013). Although India is endowed with sufficient water, there are significant variations in its spatial and temporal availability. There are areas where water is available in excess only to become a shortage within days or weeks. There are significant variations in water availability even within a river basin. Overall, the annual per capita availability of renewable freshwater in the country has fallen from around 5,277 cubic metres in 1955 to 2,464 cubic metres in 1990. Given the projected growth of population by the year 2025, the per capita availability is likely to drop to below 1,000 cubic metres (Sharma, 2003 & Kumar, 2003). If the availability drops below this level, water will become a scarcity across the country.

Of all cities in India, only 50 percent are supplied with piped water. None of the municipal authorities of the 35 cities with a population of between one and five million distribute water for more than a few hours per day (Marwas, 2010; Shaban, 2008). When water becomes available, people struggle to get water because of insufficient pipe pressure.

The present capacity to treat sewage is insufficient, too (Kaur *et al.*, n.d.). Domestic sewage from cities and towns is the biggest source of pollution of water bodies in India (CPCB, 2005). According to the census of 2001, all large Indian cities together generated an estimated 29,129 million litres per day sewage (as per population in 2001 census). But the installed sewage treatment capacity was only 6,190 million litres per day. The gap of 22,939 million litres per day was closed since 2001 only marginally. At present, a capacity addition of around 1,700 million litres per day is under planning or construction.

It is likely that by 2025, 50 per cent of the Indian population will live in *urban* areas (UN, 2008). If coupled with ever increasing disposable income, there is sufficient empirical evidence that water usage per capita is higher in urban areas (UN, 2006; Sankhe *et al.*, 2010). Ground water contamination and surface water pollution further necessitates requirement for more quality water which in turn demands more water treatment. From the inception the water sector is under the supervision of Government, hence, due to the inability to solve problems by itself, more private participation become imperative under strict regulatory supervision (Snell, 1998; OECD, 2008).

Approximately 5 percent of total available water is under the consumption of domestic households and the same is going to increase to approximately 11 percent by 2050 (Marvas, 2010). Hence, the per capita consumption might increase to 167 litres a day which is only 89 litres at present. Marvas (2010) finds that, in 2005, in Ahmedabad, Delhi, Hyderabad, Kanpur, Kolkata, Madurai and Mumbai, around 65 percent of households faced water deficiency; hence, such cities got to find a necessity for distance water sources. For instance, in Delhi public receives water from rivers almost 250 kilometres away, while in Chennai water comes from rivers that are 450 kilometres away (Marvas, 2010).

Regarding sources, there is abundant of difference in between urban and rural populations regarding hygiene drinking water sources. At urban places public resort to taps for drinking water that gets supplied from local administrations. These government bodies source most of their supply from surface water (lakes and rivers) as well as from reservoirs. In addition to drinking water from taps, urban citizens get water from open and closed wells, bore wells (both legal and illegal), hand pumps, small water bodies like springs, ponds, lakes or rivers and, in few cases, harvested rain water. Traditional methods of purifying water are simple, using cloth for filtering, decantation or boiling. In order to cool it, water is stored in earthen pots and urns even today in many towns and cities in India. Many middle class households have acquired electronic refrigerators.

RESEARCH METHODS

The research is broken down into three different phases, the first phase is only to study about global water consumption in general and influence of sanitation facilities upon this very consumption, the second phase is to know the effect of hygienic water consumption habits and their influence on public health, which in turn culminates by studying and forecasting various business opportunities from hygienic drinking water needs of public.

Objectives and Hypothesis

As the study is in primary phase; hence, the main goal is to study global water consumption in general; the following are objectives to the study:

1. To examine countries with respect to sanitation and drinking water facilities, with special reference to India.
2. To understand as how different countries can be compared with respect to sanitation and drinking water facilities in between urban and rural population.
3. To study sample individuals (countries) with respect to study variables (urban & rural).

The data for this study are obtained from public data repositories of WHO (World Health Organization). The data are extracted such a way that it is comprising of two main study variables, namely (1) population using improved drinking water facilities, and (2) population using improved sanitation facilities. These variables again divided into two different classes, viz. urban and rural. The numerical data which is obtained is in the form of percentage of population of different countries. Hence, the data is conveniently organised such that population sanitation habits and consumption of drinking water can be studied with respect to two different types of population known as urban and rural. These types are very important and significant sub-variables to the study. The total dataset or data frame to the study is in fact a 188×7 data matrix for analysis. As far as, sampling is concerned there are 187 countries in the dataset all of them are treated as study samples or sample individuals.

ANALYSIS

As the title reflects, the theme of the research work is to find nexus in between hygienic drinking water consumption and sanitation facilities, to realise the objectives it was felt that certain important statistical tools could do justice. They are namely, *principal component analysis* and *cluster analysis*. Although, the analysis is not so vigorous in terms of numerical methods, a moderate attempt was made to realize objectives.

Principal Component Analysis

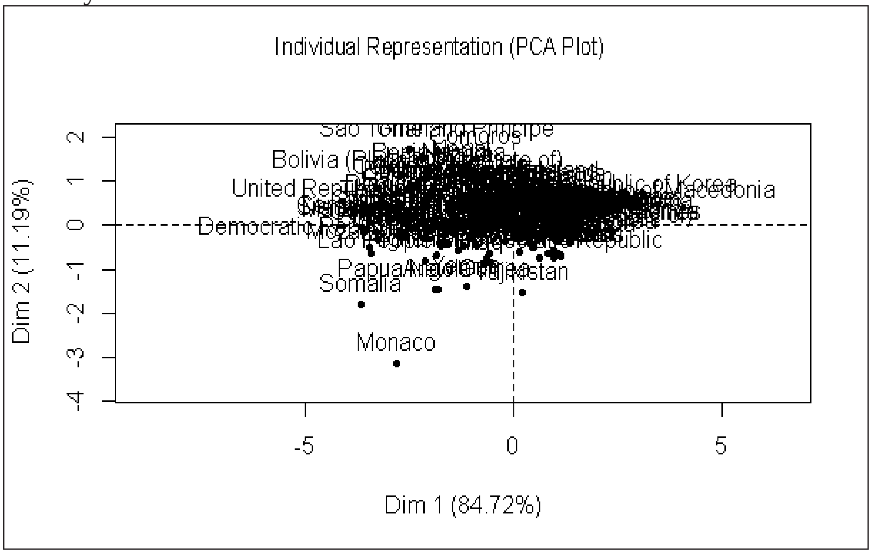
There are three components in the study all components are seamlessly contributing to the model. Table 1 describes contributions of components, i.e. which component is highly significant to the study.

Table 1: Number of Components and Their Respective Eigen Values

Component	*Eigen Value*	*Percentage of Variance*	*Cumulative percentage of variance*
Component 1	2.5416950	84.723167	84.72317
Component 2	0.3357569	11.191897	95.91506
Component 3	0.1225481	4.084936	100.00000

Component 1 contributes at almost 84.72317 percent to the study construct or model, which is followed by Component 2 at 95.91506 percent and Component 3 at 100.00000 percent. Hence, first two components alone could serve as better descriptors as their cumulative contribution is high/fair, i.e. 95.91506 percent. Although, all three of them contribute well (to the tune of 100.00000 percent), but for practical reasons only first two can be considered for analysis (as the graphs or plots tend to be 2 dimensional in nature). Fig. 1 illustrates the nature of these components more lucidly.

Fig. 1 explains first two components (Component 1 & 2), which comprises 95.91506 percent of variance, in which the first component alone could account for 84.72317 percent of variance to the model. Most of the individuals (countries) could comply with first component or Dim 1, for that matter to both components (as most of the individuals are near to origin). Certain countries, viz. Monaco, Somalia, Papua, Bolivia, Republic of Korea, Comoros, could display their deviance from rest of the countries. There is other category like Argentina, Dominica, Panama, Romania, Sri Lanka, Thailand, Columbia, Cuba, Ecuador, Gambia and etc. are on and around the origin. This cluster obeys both the dimensions, i.e. they exhibit same behaviour or tend to contribute alike.



Source: obtained from statistical analysis on sample data

Fig. 1: Individuals factor map

India's plight

As far as India's situation is concerned, it appears to contribute (positively) to second dimension (Dim 2), as the coordinates are identified as -1.01907361 and 1.1102237203. Certain other countries (peers) having same characteristics are Eritrea, Malawi, Mongolia, Namibia, Nepal, Nicaragua, Zimbabwe etc. Table 2 could give better illustration regarding their respective coordinates, cos^2, contributions etc. of India and like countries. Fig. 2 could give visualisation to various groups (like countries) in detail.

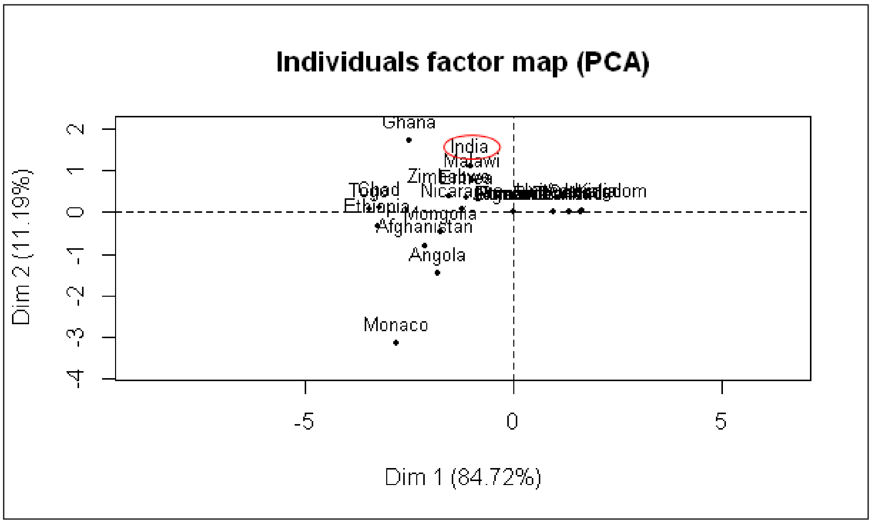
Table 2 depicts about sanitation and drinking water facilities to public compared with other countries that alike in characteristics. The first column shows country name, the second column, of course, most interesting and important, shows coordinates upon PCA space, that are identical (more

Table 2: India's Plight to Sanitation and Drinking Water Facilities (sorted to Dim 2 coordinates)

Country	***Coordinates***		***Cos²***		***Contribution***	
	Dim 1	***Dim 2***	***Dim 1***	***Dim 2***	***Dim 1***	***Dim 2***
India & like countries						
Namibia	-1.15274651	1.1690233118	0.41457894	4.263693e-01	0.279577743	2.176606e+00
India	-1.01907361	1.1102237203	0.39548775	4.693998e-01	0.218497298	1.963154e+00
Zimbabwe	-1.54660295	0.3983238876	0.93774199	6.220115e-02	0.503260245	2.527005e-01
Mongolia	-1.73659108	-0.4693345720	0.92048682	6.723378e-02	0.634497753	3.508315e-01
Nepal	-1.23509351	1.2421293214	0.48812303	4.937001e-01	0.320947975	2.457350e+00
Nicaragua	-1.22054057	0.0758840775	0.98185263	3.795274e-03	0.313429158	9.171381e-03
Malawi	-0.98113464	0.7726394751	0.56155168	3.482461e-01	0.202531311	9.507957e-01
Eritrea	-1.12106117	0.3632764029	0.35938532	3.773776e-02	0.264419559	2.101880e-01
Countries contributing to first dimension						
Sri Lanka	0.97480860	-0.0003866715	0.88948911	1.399543e-07	0.199928020	2.381319e-07
Thailand	1.32668146	0.0095268841	0.97932241	5.050032e-05	0.370312420	1.445557e-04
Togo	-3.45418153	0.0715788066	0.99488834	4.272213e-04	2.510297961	8.160229e-03
United Kingdom	1.64949909	0.0598222990	0.99399478	1.307393e-03	0.572452053	5.699800e-03
Australia	0.572452053	5.699800e-03	0.99399478	1.307393e-03	0.572452053	5.699800e-03
Belgium	0.572452053	5.699800e-03	0.99399478	1.307393e-03	0.572452053	5.699800e-03
Countries contributing to second dimension						
Angola	-1.81544893	-1.4658901686	0.54409603	3.547402e-01	0.693430644	3.422444e+00
Chad	-3.19959343	0.1130030974	0.99598035	1.242344e-03	2.153895122	2.033828e-02
Afghanistan	-2.10130696	-0.8003202547	0.87307249	1.266482e-01	0.928996242	1.020143e+00
Ethiopia	-3.24706402	-0.3207708500	0.95699512	9.339375e-03	2.218281527	1.638790e-01
Ghana	-2.48010566	1.7228754255	0.67383412	3.251774e-01	1.294122310	4.727605e+00
Monaco	-2.80419061	-3.1433727937	0.41053985	5.158602e-01	1.654436190	1.573712e+01

Source: statistical analysis on sample data or less) to each other.[3] The third column shows the data of Cos^2, this is of course, much more interesting aspect of PCA methodology, which is regarded identical to *r*, i.e. correlation coefficient. Finally, contribution, i.e. how each country obeys first component or dimension.

To put it precisely, the Indian situation regarding improved sanitation facility and drinking water facilities, somehow, can be compared with few other countries shown in Table 2 and Fig. 2. In other words, drinking water and sanitation facilities in these countries are alike or identical. The coordinates are more or less for all these countries with certain exceptions. Nepal, Namibia and India are foremost in contributing to second dimension, whereas, Mongolia and Zimbabwe are best demonstrating first dimension. India's contribution is not so fair compared to few of the rest.



Source: obtained from statistical analysis on sample data

Fig. 2: Groups of Countries Explaining Dimensions

Itemised Cluster Analysis (ICA)

3 In R editor, all rows are considered to be individuals to a given data set, so the columns as variables. In this study, the individuals are countries with respective populations (*urban* & *rural*). Hence, in Table 2, the first column shows the information of individuals (countries) with the help of their respective row names (numbers). In precise, the data set, consist of rows and columns, the rows are identified with their serial numbers (first column in Table 2) and the columns are identified with respective column names. Although, *improved sanitation facilities* and *drinking water* are study variables, these variables are studied with respect to *types of population*, i.e. *urban and rural*. Hence, each of these variables tends to have two other sub-variables that are *urban* and *rural*.

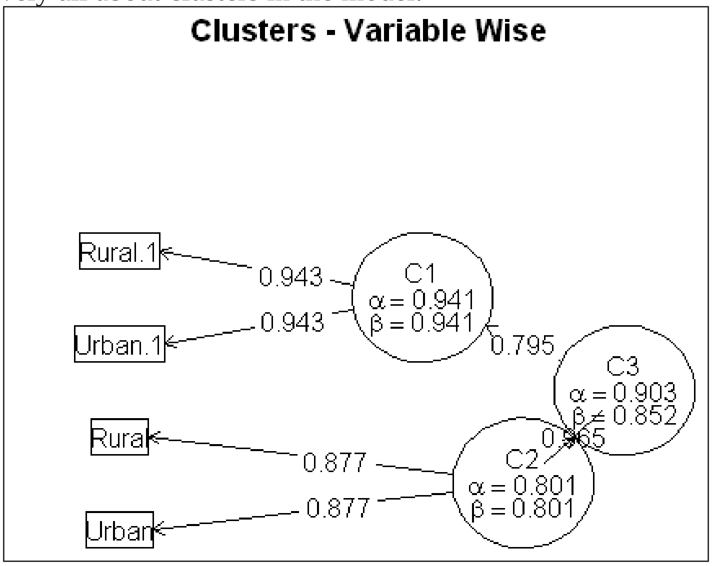
It needs cluster analysis to study about the variables. Table 2 illustrates as how the variables have been contributing to constructs.

Table 3: Itemised Cluster Analysis on Study Variables

Cluster/ Item			***Similarity***	***Correlation***	***alpha***	***beta***
C1	V3	V2	1.0000000	0.8888617	0.9411612	0.9411612
C2	V2	V1	0.9318980	0.6678829	0.8008751	0.8008751
C3	C1	C2	0.8564212	0.7435357	0.9029622	0.8519598

Source: statistical analysis on sample data

The itemised cluster analysis is a model that which describes about items or variables (sometimes even objects). ICA is an alternative to factor or component analysis as the goal is the same.[4] Fig. 3 could describe effectively all about clusters in the model.



Source: obtained from statistical analysis on sample data

Fig. 3: ICLUST Graph of Cluster Analysis on Study Variables

The first cluster (C1) is composed of variable 4 & 3, i.e. rural and urban populations with respect to sanitation, the factor loadings are very

4 The model *(iclust)* that which is used in psych package of *R language* does so much of job; viz. finding the proximity, pairs, fulfilling criterion, forming the clusters and etc. In fact, the *iclust* forms clusters using hierarchical clustering algorithm until one or two measures of internal consistency fails to increase (i.e. *alpha* and *beta*). The alpha (α) is average split half reliability and beta (β) is worst split half reliability (Revelle, 2011).

high (0.943, 0.943) compared to the other cluster, i.e. rural and urban populations of drinking water. The both clusters could form into final cluster C3.[5] The alpha and beta of clusters are fair enough to describe the variables, i.e. all beta values are not greater than respective alpha values, whereby, negating any lumpy property (Revelle, 2011). As far as α is concerned the test criterion (reliability) is excellent for all values are more than 0.8. The β values shows the factor saturation, which is very fair as the value is greater than 0.8.

CONCLUSION

The sanitation and hygienic drinking water facilities are very fair in certain countries like Argentina, Dominica, Panama, Romania, Sri Lanka, Thailand, Columbia, Cuba, Ecuador, Gambia and etc. Certain interesting groups have been realised besides outliers (showing huge deviation from other countries). The countries like Sri Lanka, Thailand, Togo, United Kingdom, Australia, Belgium appear to form a cluster as they oblige first dimension. The countries like Angola, Chad, Afghanistan, Chad, Ethiopia, Ghana, Monaco group into a cluster as they oblige second dimension. There are countries that idealise the entire model by being at origin, i.e. Argentina, Dominica, Panama, Romania, Sri Lanka, Thailand, Columbia, Cuba, Ecuador, Gambia, Thailand, Columbia etc. Finally, the outliers being, Monaco, Somalia, Papua, Bolivia, Republic of Korea, Comoros etc. share huge deviance from the rest or the model. As far as India is concerned, the country is more alike to certain other countries like Eritrea, Malawi, Mongolia, Namibia, Nepal, Nicaragua, Zimbabwe etc. The condition is neither fair nor worst, as it seems and in spite of being near to origin. As far as, the variables or populations are concerned; the urban and rural populations who have fair sanitation facilities are very stronger (high degree of influence) to the first cluster (of countries) than those with hygienic drinking water facilities.

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5 Hence, this is called hierarchical cluster analysis (algorithm).

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