Assuaging Human Health Concerns Through Analysis of Physicochemical Parameters of Potable Water Samples in Delhi

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Abstract: Water is a critical component for life and is an indispensable natural resource containing minerals required for human nutrition. However anthropogenic activities related to rapid industrialization, effluent discharges, overpopulation, atmospheric pollution etc. have stretched water reserves to alarming levels wherein the situation has come to a breaking point. Water quality parameters including pH, turbidity, hardness, presence of calcium, chloride, sulphate, ammonia, total dissolved solids (TDS) and magnesium are evaluated in the present study to elucidate apprehensions about potability of water being consumed in day-to-day life. Eleven water samples from areas in Delhi were investigated for the aforementioned physicochemical parameters to identify water potability issues. A few samples exhibited ultra-high values of TDS (~15,000+ mg/l) while standard value is prescribed at 2,000 mg/l by Bureau of Indian Standards (BIS). Water samples with high TDS values are reported to be potential harbingers of bacterial contamination. In eight of the eleven samples the hardness coefficient was found to be higher than WHO baseline value of 100 mg/l. Three samples from Faridabad, Govindpuri and Pushp Vihar had either more or values approaching BIS standard of 300 mg/l, thereby indicating that the so called potable water was unfit for human consumption. High hardness values can be conjectured to be arising from rusted water supply pipes and/ or mixing of effluents from industries running from homes.

Keywords: water quality, drinking water, turbidity, TDS, Delhi.

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1. Introduction

Worldwide researchers are increasingly concerned about the quality of drinking water (Gulson et al., 1997; Ozturk and Yilmaz, 2000). Over the last few decades, burgeoning anthropogenic activities have led to fast depleting natural resources and steeply falling ground water levels. Simultaneously indiscriminate use of pesticides and insecticides for achieving bumper production levels has affected both quality and quantity of drinking water (Sillanpaa et al., 2004). Quality of potable water is also reported to significantly impact the human health and has paved way for various gastrointestinal problems, cancer, eye and skin diseases etc. (Ikem et al., 2002). Even the storage and supply of safe potable water has a significant impact on water borne diseases (Virkutyte and Sillanpaa, 2006).

One among the 17 Sustainable Development Goals of the UN adopted in *2030 Agenda for Sustainable Development* is to provide clean water and improved sanitation facilities to all. Assurance of drinking water safety is a foundation for the prevention and control of water-borne diseases, especially when the World Bank estimates that 21% of communicable diseases prevalent in India are due to unsafe drinking water. Moreover, world over approximately 8,46,000 deaths occur annually due to diarrheal disease. Diarrhoea remains the most prevalent water borne disease in India. It mostly affects children under the age of 5 often leading to death.

Scarcity of fresh, clean and safe water is thus seen to rank amongst one of the most urgent environmental challenges facing humankind. Primary cause of waterborne diseases as a result of microbial contamination is reported to be the disturbance in the raw water and/or distribution networks (Craun and Calderon, 2006; Risbero et al., 2007). Viruses like Noroviruses and protozoa i.e. *Cryptosporidium* play a significant role in affecting human health primarily due to long persistence and high infectivity as per the statistics available with WHO (WHO, 2011a). One of the primary aims of WHO is to ensure general access to adequate supply of safe drinking water under formulated Guidelines for Drinking Water Quality (WHO 2011a).

Suitability of water for human consumption is best indicated by its chemical, biological and physical characteristics which together epitomize quality. Human body is known to comprise about 50-60% water, hence pH level of water has a direct impact on all the chemistry associated within the body as also general health. Digestion, breathing, hormonal production, blood circulation and other regulatory mechanisms in the body perform the basic function of balancing pH. Typically for a human body, the fluids clock a 7-7.2 level of pH value (Avvannavar and Shrihari, 2008). Although pH has no direct impact on water consumers, it is one of the most important operational water quality parameters. A pH value of more than 8.5 conforms to a bitter taste and at the same time negatively impacts disinfection of water with chlorine (a process routinely practiced in India). High pH water is also known to affect the mucous membrane, skin and even the eyes. Further, if the pH value falls lower than 6.5 then acidic nature of the water corrodes drains and pipes of the household water supply systems leading to contamination of drinking water.

Turbidity, a key parameter to test the efficacy of drinking water is a measure of relative clarity of a liquid and can be attributed to presence of phytoplanktons, small algae, waste discharge, urban run-off etc. Although turbidity is generally associated more in the aesthetic sense, however pathogens encased in particulate matter can stay protected and survive multiple decontamination processes undertaken. Hence measurement of turbidity is an indirect indicator of existence of pathogenic organisms and directly impacts the human health. A contaminant level of 5-10 NTU (depending on treatment process used) is considered safe for human consumption (Sawyer et al., 1994; Burden et al., 2002; De, 2003). WHO recommends turbidity levels to be less than 1 NTU and not more than 5 NTU whereas Bureau of Indian Standards (BIS) specifies a recommended maximum turbidity of 10 NTU. Turbidity can provide food and shelter for pathogens in the distribution system leading to out-break of water borne diseases (EPA, 1999). Presence of micro-organisms like *Cryptosporidium* in drinking water, even in low concentrations can pose a health hazard. The high turbidity levels observed in potable water may be attributed to the common occurrence of sewage water somehow getting mixed with potable water due to faulty pipelines, negligence and official apathy which is expected to give rise to water borne diseases. As mentioned earlier, clarity of drinking water is important; and significant evidence exist which supports the view that controlling turbidity is a competent safeguard against pathogens in drinking water.

Quality of potable water is also crucially dependent on the balance between the cations (Calcium and Magnesium) and anions (Sulphates and Chlorides) present in it. The principle of electroneutrality requires that the sum of positive ions (cations) to be equal to sum of negative ions (anions). It is a widely accepted truth that cations are primarily responsible for the secondary attributes of salts whereas anions modify perceived intensity (Marcussen et al., 2013). The sensory attributes of a cation may further depend on its concentration with sweet taste being more dominant at lower concentrations whereas the salty taste often but not always dominating at higher concentrations (Koseki et al., 2005; Marcussen et al., 2013).

Sulphates are present in all body tissues, with highest concentration in the connective tissue and also in active areas of bone and teeth development. The average daily intake of sulphate (500.0 mg/l) in humans is met through water, air and food. WHO does not identify a level of sulphate in drinking water but its presence above 500.0 mg/l in water leads to a noticeable taste. High concentration of sulphate can be problematic as it makes water corrosive and is further capable of being reduced to hydrogen sulphite. Calcium and magnesium are both essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences. If high concentration of calcium affects bones then low levels may cause osteoporosis. Magnesium is the fourth most abundant cation in the body and the second most abundant cation in intracellular fluid involved in the synthesis of proteins and nucleic acid and is needed for normal vascular tone and insulin sensitivity (WHO, 2011b).

Drinking water provides small daily doses of calcium and other essential minerals and may be an important source throughout the life span (Bonjour et al., 2009). Minerals are more readily absorbed from water than food. Water samples low in magnesium and calcium are associated with higher incidence of hip fracture in both men and women (Dahl et al., 2015). Recommended daily intakes of each element have been set at national and international levels. Deficiency of calcium and magnesium results in cardio-vascular diseases, tiredness, weakness and muscular cramps. When these both combine with carbonates, bicarbonates, sulphate etc, they contribute to hardness of water. Ammonium being corrosive by nature is another ion of concern. Though it is not of direct importance for health, it can be toxic if its intake becomes more than the capacity of the body to detoxify. Also, taste and odour problems are likely to occur if ammonium concentration goes more than the desirable limit as it binds with chlorine after which it becomes unavailable for disinfection.

The palatability of drinking water is also affected by the Total Dissolved Solids (TDS), which is a combination of calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions. TDS is broadly a term used to describe the inorganic salts and small amounts of organic matter present in water. The quality of water is rated as excellent, when TDS levels are less than 300.0 mg/l; good when TDS falls between 300.0 and 600.0 mg/l; fair with TDS between 600.0 and 900.0 mg/l; poor between 900.0 and 1200.0 mg/l; and unacceptable when TDS levels are greater than 1200.0 mg/l.

Certain components of TDS, such as chlorides, sulfates, magnesium, calcium, and carbonates affect corrosion or encrustation in water-distribution systems leading to excessive scaling in water pipes, water heaters, boilers, and household appliances such as kettles and steam irons which can shorten the service life of appliances. The Bureau of Indian Standards (BIS) fixes the upper limit of TDS in drinking water at 500.0 mg/l. Crucially the standard also mentions that in case no alternative source of drinking water is available, then this upper limit can be relaxed to 2,000.0 mg/l (BIS, 2012).

In the wake of current situation it becomes important to test the quality of drinking water available in regular households on which 1.8 crore of Delhites rely. In the current study, various physicochemical parameters of potable water from eleven different locations across Delhi, India are evaluated as a routine monitoring exercise so as to reassure the general populace about the adequacy of the quality of drinking water. Besides this, the endeavor is expected to detect deterioration in the drinking water quality so as to facilitate timely and appropriate corrective approach with minimal impact on the environment. A correlation is established between contaminants and the likely sources of contaminants based on the areas where maximum deterioration in quality of water is found.

2. Materials and Methods

For the current investigation, samples of potable water from eleven different places in Delhi (Table 1) were acquired in sterilized capped bottles (500.0 ml each). One sample was also collected from Faridabad in the Delhi NCR.

Table. 1: Water sampling sites.

S. No.	Abbreviation	PLACE
1.	NR	Naraina
2.	PV	Paschim Vihar
3.	KN	Krishna Nagar
4.	SV	Sangam Vihar
5.	TU	Tughlakabad
6.	PUV	Pushp Vihar
7.	GP	Govindpuri
8.	JP	Jahangirpuri
9.	LN	Lajpat Nagar
10.	SN	Sarojini Nagar
11.	FBD	Faridabad

Physicochemical water quality measurement for potable water was undertaken on the basis of nine water quality parameters of pH, chlorides, sulphates, calcium, magnesium, turbidity, ammonium, TDS and hardness and obtained values have been enumerated in Table 2. The procedure for analysis was followed as per standard methods of analysis of water for chlorides, sulphates, calcium, magnesium, TDS and hardness (APHA, 1998). Testing of the water samples for pH, turbidity and ammonium was carried out using commercial sensors available from Vernier Inc., USA and data measured by the sensor was acquired using LabQuest interface from Vernier Inc., USA. The LabQuest data acquisition system is a stand-alone data collection and analysis device. However, in the present study it was interfaced to a computer using Logger Pro 3.0 software for data integrity purposes and circumvent memory limitations. All the different sensors including pH, turbidity and ammonium were interfaced with LabQuest and automated data was acquired onto the computer. Measurements for different characteristics of water were carried out after due precautions including using borosilicate glassware and washing of the sensor probes with double distilled water before and after every measurement.

3. Results and Discussion

The physicochemical examination reflected alarming values questioning the potable quality of water (Table 2). The pH of all the water samples conform to the desirable range (6.5 to 8.5) prescribed by BIS and to WHO (Table 3) except sample from Jahangirpuri which was slightly acidic (6.2) probably because of proximity to a landfill.

Table 2: Physicochemical characteristics of eleven potable water samples.

Place	pH	Cl (mg/l)	Sulphate (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Turbidity (NTU)	Ammonium (mg/l)	Hardness (mg/l)	TDS (mg/l)
NR	7.3	9.9	5	40	2.13	11.6	0.5	108.68	2,040
PV	7.7	79.9	30	50	6.24	11	0.5	150.58	16,920
KN	7.2	9.9	27	20	1.70	11	0.3	56.95	1,240
SV	7.7	79.9	25.5	40	2.78	10.4	0.4	111.36	15,640
TU	7.7	79.9	11.5	50	3.24	13.3	1.1	138.23	15,760
PUV	7.5	129.9	4	90	4.80	13.2	1	244.57	6,440
GP	7.4	89.9	15.5	120	3.02	12.4	0.7	312.19	920
JP	6.2	19.9	0	10	3.66	7.9	0.3	40.04	4,800
LN	7.2	29.9	0	30	1.56	16.4	0.1	81.36	3,720
SN	7.3	59.9	9.5	40	2.25	10.8	0.1	109.18	5,560
FBD	7.3	0.31	31	90	8.71	15	1.7	260.67	3,800

Abbreviations: Cl – Chloride; TDS: Total Dissolved Solids

Table 3: Permissible drinking water quality standards prescribed by WHO and BIS.

		BIS Guidelines		**WHO Guidelines**
S. No.	**Parameters**	**Desirable limits (mg/l)**	**Permissible limits (mg/l)**	**Limits (mg/l)**
1.	pH	6.5 - 8.5	No relaxation	6.5 - 8
2.	Turbidity (NTU)	5	10	0.1 5
3.	Sulphate	200	400	No value issued
4.	Chloride	250	1000	200 - 300
5.	Calcium	75	200	In the form of $CaCO_3$
6.	Magnesium	30	100	No value issued
7.	Ammonium	-	0.2	1.5
8.	Hardness	300	600	100 - 300
9.	TDS	-	500 - 2000	600 - 1000

At Jahangirpuri, toxic metals in the form of leachates from the unscientific landfills could be adding to the acidity of ground water. This can cause premature damage to metal pipes and can lead to a metallic or sour taste of water, besides staining of laundry, sinks and drains. Anionic concentrations of chloride and sulphate in all the water samples were very low as compared to desirable limits (Table 3). The highest recorded concentration of 129.9 mg/l for chloride is obtained from Pushp Vihar and the highest recorded concentration for sulphate is 31.0 mg/l from Faridabad. Though it is a common practice to add chlorine tablets for disinfecting water, concentrations over 100 mg/l of chlorine give water a salty taste and thus make it unsuitable for human consumption which is true for water from Pushp Vihar and also Govindpuri. Calcium levels were found to be lower than the prescribed permissible limits in most samples. The calcium ion concentration was reported to be more than the desirable limits in the samples obtained from Pushp Vihar (90.0 mg/l), Faridabad (90.0 mg/l) and also Govindpuri (120.0 mg/l). The lowest concentration for calcium is recorded in the sample from Jahangirpuri (10.0 mg/l).

Magnesium also follows calcium in being within the permissible limits in all samples. Sample from Lajpat Nagar had drastically low value of 7.8 mg/l and that from Faridabad had magnesium more than the desirable limit. It is further speculated that people residing in Krishna Nagar are more susceptible to osteoporosis and bone injuries as both calcium and magnesium are very low in drinking water available in this area. The total hardness which is a mean of total of calcium and magnesium for each sample lies within desirable limit of 300.0 mg/l as per the BSI Guidelines. Though most samples are soft in nature, samples from Govindpuri and Faridabad are moderately hard. A large number of studies have investigated the potential beneficial health effects of drinking-water hardness. Most of these have reported an inverse relationship between water hardness and cardiovascular mortality (WHO, 2011b). Humans need minerals to stay healthy, and the National Research Council (National Academy of Sciences) states that drinking hard water generally contributes a small amount toward total calcium and magnesium human dietary needs.

Drinking water samples analysed in this study do not boast of any such claims. It is alarming to note that even in supposedly potable water, the minimum noted turbidity is way above the desirable limits prescribed by Bureau of Indian Standards (BIS) and is also more than the permissible limits laid down by World Health Organisation (Table 2 and 3). In fact, turbidity is 2-3 times the WHO guidelines in all 11 samples. Since turbidity is caused by suspended particles, phytoplanktons, bacteria or colloidal matter, it is responsible for microbial contamination. Turbidity can provide food and shelter for pathogens and can promote growth of pathogens in the distribution system, leading to waterborne disease outbreaks throughout the world. The particles of turbidity provide *shelter* for microbes by reducing their exposure to attack by disinfectants. Microbial attachment to particulate material has been considered to aid in microbe survival. High turbidity could be resulting from faulty and degrading pipelines coupled with mixing of sewage with potable water. Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and represents a major health concern.

With respect to Ammonium, only the sample from Lajpat Nagar and Sarojini Nagar noted values within the permissible limits (0.2 mg/l) while the other nine samples exhibit ammonium ions concentration more than the permissible limit prescribed by BIS. This is a matter of concern as ammonium is both corrosive as well as toxic in nature. It is a biologically active compound found in most waters as a normal biological degradation product of nitrogenous organic matter (protein) and may find its way to ground and surface waters through discharge of industrial process wastes containing ammonia and fertilizers. It is concluded that high levels of ammonium ions in water samples from Tughlakabad, Pushp Vihar and Faridabad could be due to mixing of industrial effluents in the ground water in these areas which could also be contaminated by organic waste as we do not have stringent laws to manage the solid waste.

The amount of Total Dissolved Solids in all samples studied are seen to exhibit values varying from the borderline to alarmingly high in the range of 920.0-16,000 mg/l. It is important to keep in mind that drinking water needs to have optimum TDS for it to be palatable. High TDS makes water unfit for drinking while water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste.

4. Conclusion

Overall, the quality of water samples collected from Delhi in this study leaves a lot to be desired as indicated by the measured physicochemical parameters. Specifically, TDS values noted in all the water samples (9 out of 11) besides Govindpuri and Krishna Nagar were seen to exceed even Indian BIS values. It is alarming to note that TDS values from Paschim Vihar, Sangam Vihar and Tughlakabad surpassed the BIS standard by around 8 times.

Coincidentally, in all these three cases water, sample collection points had major drains in the immediate vicinity thereby indicating a possible mixing of potable and sewage water supplies. Furthermore the total hardness in eight of the eleven samples crossed the baseline limits of 100.0 mg/l prescribed by WHO while water samples from Govindpuri, Faridabad and Pushp Vihar had either more or values approaching BIS standard of 300.0 mg/l, thereby indicating that the so called potable water was unfit for human consumption.

Corroded water supply pipes and/ or mixing of effluents from industries running from homes can be attributed for the high hardness values. Further, it is disturbing to note that turbidity, which is responsible for providing food and shelter to pathogens is much above the prescribed desirable limits. It is envisaged that market for individual water processing units like Reverse Osmosis (R.O.) plants would continue to grow till the time quality of potable water being supplied to households matches internationally set standards.

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6. References

American Public Health Association (APHA) 1998. Standard methods for the examination of water and waste water (10th Edition). Washington, DC: American Public Health Association.

Avvannavar, S. M. and Shrihari, S. 2008. Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India, Environ. Monit. Assess. 143:279-290.

BIS 2012. Drinking water specifications. Bureau of Indian Standards, New Delhi.

Bonjour, J.P., Gue guen, L., Palacios, C., Shearer, M.J., and Weaver C. M., 2009. Minerals and vitamins in bone health: the potential value of dietary enhancement. Br. J. Nutr. 101:1581-1596.

Burden, F. R., Mc Kelvie, I., Forstner U., and Guenther, A., 2002. Environmental Monitoring Handbook, Mc Grawhill Handbooks 3.1-3.21.

Craun, G.F. and Calderon, R.L. 2006. Observational epidemiologic studies of endemic waterborne risks: cohort, case control, time series and ecologic studies, J. of Water and Health, 4(2):89-99.

Dahl, C., Soggard, A.J., Tell, G.S., 2015. Population data on calcium in drinking water and hip fracture: An association may depend on other minerals in water. A NOREPOS study. Bone 81:292-299.

De, A. K. 2003. Environmental Chemistry, 5th Ed. New Age International, New Delhi. pp 242-244.

Environment Protection Agency. 2009. EPA Drinking Water Advice Note. USA.

Gulson, B.L., Sheehan, A., Giblin A.M., Chiaradia, M. and Conradt, B. 1997. The efficiency of removal of lead and other elements from domestic waters using a bench-top water filter system, Sci.Total Environ. 196: 205-216.

Ikem, A., Odueyungbo, S., Eqiebor, N.O., Nyavor, K. 2002. Chemical quality of bottled waters from three cities in Eastern Alabama. Sci. Total Environ. 285: 165-175.

Koseki, M., Fujiki, S., tanaka, Y., Naguchi, H. and Nishikawa, T. 2005. Effect of water hardness on taste of alkaline electrolysed water. Journal of Food Science. 704:S249-S253.

Marcussen, H., Bredia. W.L P., Stolzenbach. S., Brush W. 2013. Sensory properties of Danish municipal drinking water as a function of chemical composition, Food Research International. 54: 389-396.

Ozturk, N. and Yilmaz, Y.Z. 2000. Trace elements and radioactivity levels in drinking water near Tuncbilek coal-fired power plant in Kutahya, Turkey, Water Res. 34:704-708.

Risbero, H.L., Doria, M.F., Andersson, Y., Medema, G., Osborn, K., Schlosser O. and Hunter, P.R. 2007. Fault tree analysis of the causes of waterborne outbreaks, J. of Water and Health. 5(1): 01-18.

Sawyer, C.N., Mc Carthy, P.L. and Parkin, G.F. 1994. Chemistry for Environmental Engineering 4th Edition New York-McGraw Hill International edition. 365 – 577.

Sillanpaa, M., Hulkkonen R. M. and Manderscheid, A. 2004. Drinking water quality in the alpine pastures of eastern Tibetan Plateau, Rangifer 15:47-52.

Virkutyte, J. and Sillanpaa, M. 2006. Chemical evaluation of potable water in Eastern Qinhai Province, China: Human Health Aspects, Environment International 32: 80-86.

WHO. 2011a. Guidelines for drinking-water quality, fourth ed., World Health Organization, Geneva, Switzerland

WHO. 2011b. Hardness in drinking water- background document for development of WHO guidelines for drinking water quality. Geneva, Switzerland.