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Water Potability and Public Health in Delhi: Assessment for Physicochemical and Microbiological Parameters of Drinking Water

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Abstract — The public health of a country is largely dependent on the quality of water supplied to and consumed by its citizens. Recent decline in the number of potable water sources, especially in developing countries like India, has raised several concerns and has put a spotlight on the policies and the enforcement of regulations concerning drinking water by the governments. The situation is further grim in urban poor neighbourhoods. Therefore, the aim of this study is to test drinking water samples, collected from different sources in a poor neighbourhood in North Delhi, with a view to assess its potability, with respect to physicochemical and microbiological parameters, in order to find out its effects on the health of the residents. An initial survey of the residents revealed that the consumption of Privately Accessed Public Water (PAPW) had resulted in illnesses, which had forced many residents to switch to unbranded bottled water (UBW) for drinking purposes. Therefore, our research design entailed the testing of water samples belonging to both these drinking sources - PAPW and UBW, which were aseptically collected considering all precautionary measures. The two samples were tested for organoleptic, chemical, radioactive, pesticide residual and microbiological parameters according to the IS 10500:2012 (Amendment No. 2, Sep 2018) standards. The pH value for the UBW sample, determined with the help of a pH meter,was 6.52, which indicated that the sample was acidic and on the borderline of the permissible range. The membrane filtration and MPN tests showed the presence of Escherichia Coli in the UBW sample making it unfit for drinking, as it causesdiarrhoea and kidney failure. Inductively Coupled Plasma Mass Spectrophotometry (ICP-MS) detected excessive Aluminium (Al) with a value of 0.393 mg/l, which causes skin rash and Alzheimer's disease amongst others. Surface-Enhanced Raman Spectroscopy (SERS) detected Polynuclear Aromatic Hydrocarbons (PAHs) in quantities exceeding the permissible limits (over 17 times) in the PAPW sample. Such chemicals at these unusually high levels are carcinogenic in nature and have severely detrimental effects on the human body. Hence, this study has conclusively proved that the collected water samples not only did not conform to the IS 10500:2012 (Amendment No. 2, Sep 2018) regulation but also contained faecal and toxic substances that are extremely harmful for the human body. Finally, the paper drew inferences for public health particularly for the urban poor with regard to the potability of water.

Keywords: Potable | Aseptically | Organoleptic | Inductively Coupled Plasma Mass Spectrophotometry | Surface-Enhanced Raman Spectroscopy | Membrane Filtration | Escherichia Coli | Polynuclear Aromatic Hydrocarbon | Faecal

Abbreviations: IS 10500: Indian Standard 10500 | MPN: Most Probable Number | PAPW: Privately Accessed Public Water | UBW: Unbranded Bottled Water | ICP-MS: Inductively Coupled Plasma Mass Spectrophotometry | SERS: Surface-Enhanced Raman Spectroscopy

1. INTRODUCTION

A demographic study of ancient civilizations accounts for the fact that human civilizations, for centuries, have settled at the banks of a river or lake for a constant source of water. Empirical and historical evidences show that any change in water conditions due to anthropogenic pressure has caused many settlements to vanish. 3% of the earth's water is classified as freshwater. 70% of the human body itself is made up of water, thus making water a vital element for the survival of living beings. Water is used in numerous daily taskslike washing, bathing and drinking. Human civilizations mainly derive water from 2 sources: groundwater and surface water.

'Urbanization and increasing anthropogenic activity have wedged the Earth's natural environment and negatively impacted human health.'[1] Due to poor sanitation or flexible regulations, water contamination causes millions of deaths around the world, which causes diarrhoea, dysentery, typhoid and cholera. As a result of the poor quality of drinking water, diarrhoea has become the fourth leading cause of death worldwide. According to a study conducted in 2015, Diarrhoea caused an estimated 1.3 million deaths with over 500,000 deaths of children under the age of 5.[2] Furthermore, antibiotic-resistant bacteria have worsened the problem and created widespread epidemics.Therefore, researchers from around the

[1] *Singh et al., "Physicochemical Parameters and Alarming Coliform Count of the Potable Water of Eastern Himalayan State Sikkim."*
[2] *Troeger et al., "Estimates of Global, Regional, and National Morbidity, Mortality, and Aetiologies of Diarrhoeal Diseases."*

globe are working on framing a systematic approach for the long-term conservation of drinking-water.[3]

According to Singh et al, there are three significant elements that affect the quality of drinking water: 'quality of raw water at the source, the purification process employed for water and the distribution system used for water.'[4] They argue that these three elements 'affect the physicochemical characteristics as well as the microbial composition of drinking water.' Therefore, in this research, all physicochemical and microbiological parameters were tested in samples taken from the terminal point of the distribution system.

On the basis of the tests (ICP-MS, membrane filtration, MPN and SERS) conducted for physicochemical and microbiological parameters according to the IS 10500:2012 Standards, I would like to argue that thedrinking water, of the urban poor community in Outram Lines, North Delhi, is non-potable as it contains faecal and toxic contaminants which are carcinogenic and pathogenic in nature.Therefore, it can be inferred that the consumption of PAPW is a serious health issue amongst the urban poor, requiring regulations and policies for routine monitoring.

This argument is progressed in four stages corresponding to the four main sections of this paper. In section one, the sampling site, as well as the standard procedures used for sample collection, are described, which validate sterile and aseptic water collection. In addition, the various parameters that the samples were tested for, and their correspondence to quality standards such as the IS 10500:2012, are discussed. The methodology followed to test for these parameters is also elaborated upon. In the second section, the certified findings and results of the tests are presented. Furthermore, the discrepancies in the data and the non-compliant parameters are clearlystated and displayed through statistical and graphical means. In the third section, the main analysis of the sources of such contaminants and their health implications is conducted and the interpretation of these findings is stated.The last section of the paper contains the inference drawn from the study and suggestions proposed to improve public health amongst the urban poor. These findings infer that non-potable water sources are present at most urban poor dwellings and hence this study is representative of the status of water amongst a majority of the urban poor in Delhi-NCR. Next, the study urges the implementation of policies and regulations to monitor potability of private household water in urban poor communities. Finally, the paper proposes that social intervention from civil society can act as an important corrective measure.

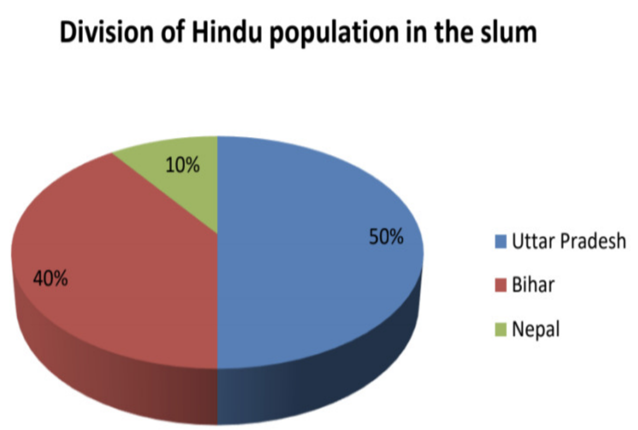
[3] *Chauhan, Badwal, and Badola, "Assessment of Potability of Spring Water and Its Health Implication in a Hilly Village of Uttarakhand, India."*
[4] *Singh et al., "Physicochemical Parameters and Alarming Coliform Count of the Potable Water of Eastern Himalayan State Sikkim."*

2. MATERIAL AND METHODS

In this section, the demographic details of the sample site are described, the parameters and standards used to assess water samples are discussed and the methods followed in the testing procedure are explained.

Sampling Site and Sample Collection

The site for sampling was chosen based on the criteria of an urban poor locality that derives its water from tap and bottled sources. The site is an urban poor community located in Outram Lines, Delhi, India. Present at a latitude and longitude of 28.7019° N and 77.2067° E respectively, the community of approximately 5000 people resides on a land of area 1 acre. Based on a baseline survey conducted in 2014, the population consists of a predominantly Hindu population with 50% of its inhabitants from Uttar Pradesh, 40% from Bihar and 10% from Nepal. The population comprises of daily wage labourers and people owning their own businesses (selling vegetables, ironing clothes), earning a monthly wage of Rs.5000 or lower (39% of residents) to Rs.5000-Rs.10000 (61% of residents).[5]



A trend observed in past research is that primarily Municipal or State water was tested in urban areas[6] and groundwater or natural water was tested in rural areas[7]. Keeping in line with this trend, PAPW and UBW samples were tested to assess the quality of drinking water in the urban poor sample site. Water samples were aseptically collected in sterile plastic Jerry cans (4L capacity) for chemical analysis and 1 L sterile glass bottles for microbiological analysis using standard prescribed methodology[8]. Before collection, the containers were sterilized using autoclave and washed with aqueous sodium thiosulphate

[5] *Baseline survey conducted for 5000 residents in January 2014.*
[6] *Archana et al., "Evaluating Microbial &Chemical Quality of Delhi-NCR Drinking Water, Enhancing Its Standard & Spreading Mass Awareness."*
[7] *Chauhan, Badwal, and Badola, "Assessment of Potability of Spring Water and Its Health Implication in a Hilly Village of Uttarakhand, India."*
[8] *"IS 3025-1 (1987): Methods of Sampling and Test (Physical and Chemical) for Water and Wastewater Part 1 - Sampling."*

solution [100 g/l (w/v)][9]. All samples were stored and carefully transported to the certified laboratory for analysis. The samples were tested before 24 hours for microbiological parameters to ensure an accurate representation of data and prevent false results due to secondary microbial growth.

Parameters and Standards

The quality of drinkable water is assessed by various public health organizations around the globe such as the World Health Organisation (WHO), International standards organisation (ISO) and American Public Health Association (APHA). Each of these organisations has their own standards, serving as global standards for water potability. However, different countries also have their own standards; in India, the central body responsible for creating standards for the country is the Bureau of Indian Standards (BIS) and the document that governs standards for drinking water quality is the Indian Standards (IS) 10500. With a view to secure both national and international credibility, this paper has adhered to the IS 10500:2012[10] Standard issued by the BIS for national compliance and the 'Guidelines for drinking-water quality'[11] issued by the WHO as an indicator of international compliance. The water samples were tested for all physical, chemical, pesticidal and microbiological parameters enlisted in the IS 10500:2012 Standard issued by the BIS.

Physicochemical parameters**:** The water samples were tested for pH, conductivity, TDS, DO, Alkalinity, Total hardness, sulphites, chlorides, nitrates, organic and inorganic elements and toxic substances according to standard procedures listed in the APHA 1998 and IS 10500:2012 Standards. Elemental detection was carried out by the ICP-MS (Inductive Coupled-Plasma Mass Spectroscopy) method. The alkalinity and hardness were measured using titration and ethylene diamine tetra acetic acid (EDTA) titration respectively. Calcium, nitrate and chloride were measured using flame photometry, spectrophotometry and Mohr's method respectively. Proper calibration of measurement tools was carried out to prevent false data. Deionized water was used for chemical analysis.

Microbiological parameters: The samples were tested for faecal contamination by carrying out tests to detect Escherichia coli (E. Coli) and Coliform count. Most probable numbers (MPN) and membrane filtration tests were followed to check for the presence of these pathogens. These tests were carried out following the guidelines proposed by the APHA (1998) and WHO (2008) to ensure the reliability of laboratory results. Sterile, double distilled water was used to carry out the microbiological analysis. All tests and assays were performed in triplicates.

Methods of Sample Testing

The IS 10500:2012 Standards enlists 66 parameters that together determine the quality of drinking water. However, this paper limits the description of the methodology to only those parameters whose quantities are outside the permissible limits.

For detection of E. Coli, the following steps are followed: (a) Chromogenic coliform agar is weighed and dissolved in screw cap bottles in distilled water. (b) The media is sterilized by heating to a boil on a hot plate (Autoclaving and overheating should not happen). (c) 12-15 ml of sterilized and liquid media is aseptically poured on sterile Petri dishes and the media is allowed to solidify in petri dishes. (d) 0.45-micron pre-sterilized membrane filter paper is placed on the holder and clamped. (e) 250 ml of the water sample is filtered through a membrane under vacuum. (f) The membrane is then transferred to the petri dish containing solidified media. (g) The Petri dishes are then incubated at 37-degreeCelsius for 24 hours. (h) Lastly, the dark blue to violet colonies are counted in the petri dish on filter paper. (i) For the confirmatory test, E. Coli shows positive on the Indole test by giving a red colour upon addition of Kovac's reagent afterthe culture is grown in sterile tryptophan for 24-48 hours.[12]

The pH of water is measured using a pH meter. The pH meter contains 2 glass electrodes: a reference and sensor electrode. The electrodes are in the form of glass tubes, containing a pH 7 buffer solution and a saturated potassium chloride solution (neutral). The sensor electrode bulb is made of a porous glass membrane coated with silica. Silver wires coated with silver chloride are immersed in the solutions. When the probe is placed in the water solution, hydrogen ions (H^+) replace the metal ions in the bulb (Ag^+, K^+). This creates a potential difference generating voltage. The voltage is measured by the meter and converted into the pH value using the reference electrode and the governing formula of the principle - $\mathbf{pH = -\log[H^+]}$

For detection of Aluminium, ICP-MS was carried out according to the IS 3025(P-65) 2014. The process entails the following four steps[13]: (a) The water samples pass through the sample introduction system where they are nebulised, creating an aerosol that is passed to the argon plasma. (b) The samples are atomised and ionised by the high-temperature plasma, generating cations and anions which are transferred into a set of electrostatic lenses called ion optics. (c) The ion beam is focused and guided by the ion optics into the quadrupole mass analyses. (d) The analyser separates the charged particles according to their mass-charge ratio (m/z). (e) Aluminium ions

[9] *Singh et al., "Physicochemical Parameters and Alarming Coliform Count of the Potable Water of Eastern Himalayan State Sikkim."*
[10] *"IS 10500 (2012): Drinking Water."*
[11] *World Health Organization, Guidelines for Drinking-Water Quality.*

[12] *This method was described by the head of microbiological analysis at the Bisleri testing plant, Delhi, India on 16.06.2020; "IS 1622 (1981): Methods of Sampling and Microbiological Examination of Water."*
[13] *The below four steps of ICP-MS have been borrowed from Wilschefski and Baxter, "Inductively Coupled Plasma Mass Spectrometry: Introduction to Analytical Aspects."*

with m/z value of 8.998 are identified and their quantity is measured at the detector.

For detection of Polynuclear Aromatic Hydrocarbons (PAHs), SERS was used according to the APHA 23rd Edn. 6640 document. Raman Spectroscopy is a spectroscopic technique used in condensed matter physics and chemistry to study vibrational, rotational, and other low-frequency modes in a system. It depends on the inelastic scattering, or Raman scattering of monochromatic light, usually from a laser in the visible, near-infrared or near-ultraviolet range of electromagnetic spectra[14]. Its biggest advantage is that it greatly enhances inelastic light scattering by molecules (by a factor of 10^8 or larger) when the molecules are adsorbed onto corrugated metal surfaces such as silver or gold nanoparticles[15].

3. FINDINGS AND RESULTS

The water samples were tested for 66 parameters including organoleptic, chemical, toxic, pesticidal, microbiological and physical substances. The 8.5 L samples were collected on 09.07.2020 and analysed within 24 hours. All tests were conducted and only those were quantified whose values exceeded the lower limit of quantification (LLOQ) were analysed. All values of pesticides were below the quantification limit. Most parameters for the samples complied with the IS 10500 standard with an exception of 4 parameters that were outside the permissible range according to WHO and IS standards.

Discrepancies and Non-Compliance

The four non-compliant parameters present in the water samples were pH, Aluminium (Al), Polynuclear Aromatic Hydrocarbons (PAHs) and Escherichia Coli. Aluminium and PAH were found in excess amounts in the PAPW sample and Escherichia Coli and pH were found in non-compliant values in the UBW sample. Aluminium is a common metallic element found in nature and present in a multitude of man-made objects. PAHs are organic and toxic compounds made of hydrogen and carbon and are aromatic in nature. Escherichia Coli is gram-negative coliform bacteria found in the lower intestine of mammals and are found in faecal remains. The pH value of a sample describes its acidity or basicity.

TABLE 1: Detected values of E. Coli in UBW sample

Test	Results	Acceptable limit	LLOQ	Permissible limit	Method
Escherichia Coli /100ml	Detected	Not detectable	-	-	IS 15185-2016

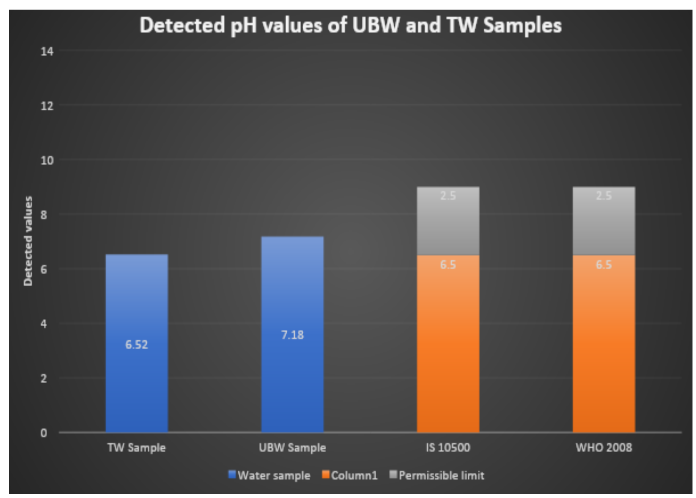
Escherichia Coli: E. Coli was detected in the UBW sample, following the method IS 15185-2016. Therefore, the above parameters according to the IS 10500 exceed the permissible limits and are non-compliant samples.

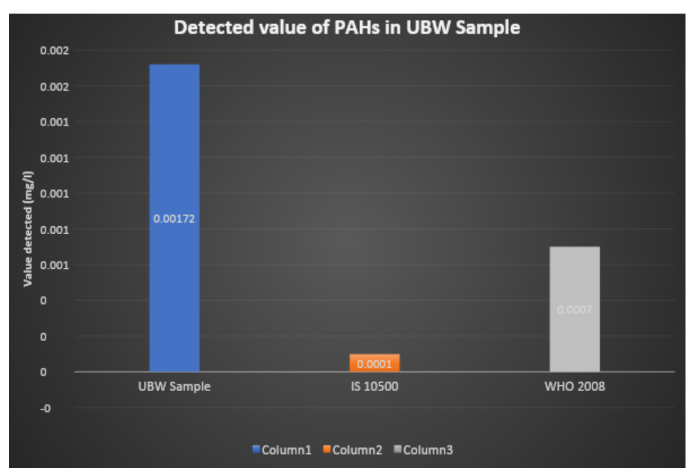
[14]Sur, *"Surface-Enhanced Raman Spectroscopy."*
[15] Langer et al., *"Present and Future of Surface-Enhanced Raman Scattering."*

pH Value: pH value for the UBW sample was detected as 6.52, which is on the borderline of the permissible limit of 6.5 to 8.5. The method carried out to detect pH was IS 3025(P-11) 1983.

TABLE 2 : Detected values of pH in UBW sample

Test	**Results**	**Acceptable limit**	**LLOQ**	**Permissible limit**	**Method**
pH Value	6.52	6.5-8.5	-	-	IS 3025(P-11)-1983

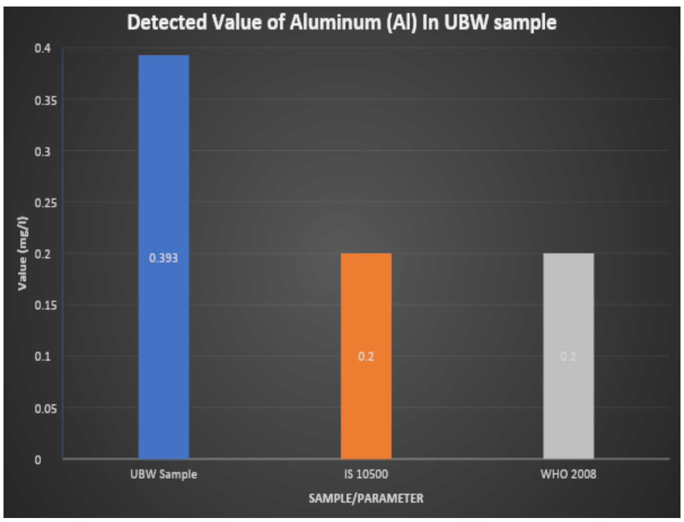




Aluminium (Al): Aluminium (Al) in the TW was detected as 0.393 mg/l, which is nearly twice the maximum permissible limit of 0.20 mg/l. The method followed to detect it was IS 3025(P-65)-1983 and had a LLOQ of 0.0020 mg/l.

TABLE 3: Detected values of Aluminium in PAPW sample

Test	Results (mg/l)	Acceptable limit	LLOQ	Permissible limit	Method
Aluminium (Al)	**0.393**	**0.03 Max**	**0.0020**	**0.20 Max**	**IS 3025(P-65)-1983**



Polynuclear Aromatic Hydrocarbons (PAH): PAH value for the TW sample was detected as 0.00172 mg/l, which exceeds the acceptable limit of 0.0001 mg/l by over 17 times. The LLOQ for detection of PAHs was 0.000050 mg/l. The method carried out to detect PAH was the APHA 23rd Edn. 6640.

TABLE 4 : Detected values of PAHs in PAPW sample

Test	Results (mg/l)	Acceptable limit	LLOQ	Permissible limit	Method
Polynuclear Aromatic Hydrocarbon (PAH)	0.00172	0.0001 Max	0.000050	-	APHA 23rd Edn. 6640

4. ANALYSIS AND INTERPRETATION

Based on the finding in the previous section, the non-compliant substances were individually assessed for their short-term and long-term effects on the human body as well as possible causes for this contamination.

Escherichia Coli (E. coli)

According to the previous section, Escherichia Coli was detected in the UBW sample. There are two main types of E. coli bacteria that contaminate food and water: Shiga toxin-producing E. coli (STEC) and enterotoxigenic E. coli (ETEC). Most strains of E. coli are harmless, but STEC can cause severe diseases. This bacterium is predominantly present in the lower intestines of warm-blooded animals. Presence of E. coli in water arises mainly from faecal contamination. Due to the location and geography of the community, two possible causes for this contamination can be inferred. Due to the absence of toilets, open defecation is a major problem in the community which could lead to contamination of the drinking water. The other possibility is that of the diffusion of sewage water with the drinking water source. This would cause faecal remains to mix with the drinking water and consequently be consumed by the residents. Regular consumption of such water has acute and chronic effects on the human body. The main symptoms for STEC (serotype O157:H7) are abdominal cramps and diarrhoea (sometimes bloody diarrhoea). Fever and vomiting can also be present. This disease generally has an incubation period of 8 days with a median of 3-4 days. This infection may also lead to haemolytic uraemic syndrome (HUS): A life-threatening disease that causes haemolytic anaemia, thrombocytopenia (low blood platelets) and acute renal failure. According to a study conducted by WHO, 'It is estimated that up to 10% of patients with STEC infection may develop HUS, with a case-fatality rate ranging from 3 to 5%. Overall, HUS is the most common cause of acute renal failure in young children. It can cause neurological complications (such as seizure, stroke and coma) in 25% of HUS patients and chronic renal sequelae, usually mild, in around 50% of survivors.[16]'. Long-term effects of E. coli include high blood pressure, kidney failure and heart problems.

pH Value

As prescribed by the IS 10500 standard and WHO guidelines, pH values between 6.5-8.5 are considered suitable for drinking water. The UBW sample upon testing showed a pH value of 6.52 which is so close to the borderline of the permissible limits that it can be considered harmful. The pH of water is a measure of the acid-base equilibrium that is controlled by the concentration of free hydrogen or hydroxide ions in the solution. Even though the pH value has no direct impact on consumers, it is extremely important in assessing the quality of water. While a pH value of 7 indicates neutrality of the sample, values above 7 show a basic nature and values below 7 show an acidic nature. Values of pH outside the permissible limits indicate non-potability of the water sample and have adverse

[16] *"E. Coli", World Health Organisation, accessed on 13.08.2020, https://www.who.int/news-room/fact-sheets/detail/e-coli*

effects on the health of living organisms. As the value of pH goes from 7 to 1 and from 7 to 14, the strength of the acidity/basicity of the sample increases respectively. Factors such as temperature and carbon dioxide (CO_2) concentration affect the pH value of a solution. pH values of water vary a lot from region to region as it depends on the composition of the source water and the materials used in the distribution systems. High pH values can occur from accidental spills, treatment breakdowns and insufficiently cured cement mortar pipe lines[17]. For every 0.1 decrease in value of pH that occurs, the acidity of water almost doubles. Water with a low pH (less than 6.5) is considered corrosive. Hence, the water can leach metal ions such as iron, manganese, lead and zinc from the piping fixtures and lead to high levels of toxic metals in the drinking water sample. There are severe acute diseases and symptoms caused by pH values outside the prescribed limits. Extreme pH values cause irritation to eyes, skin and mucous membranes. In sensitive individuals, gastrointestinal irritation can also occur. Lastly, pH can affect the degree of corrosion of metals and hinder disinfection efficiency, having an indirect effect on the health[18].

Aluminium (Al)

It was qualitatively assessed that 0.393 mg/l of aluminium was present in the TW sample. The permissible limit according to WHO and BIS is a maximum of 0.2 mg/l of aluminium. This means that the presence of aluminium in water below a concentration of 0.2 mg/l does not have any adverse effects on the human body and is safe for consumption. However, values above 0.2 mg/l have harmful effects on the human body at an exponential rate. Aluminium is one of the most abundant metallic elements found in nature, constituting 8% of the earth's crust. The major presence of aluminium in water comes from the usage of aluminium salts in water treatment as coagulants that reduce organic matter, turbidity, microorganism level and colour.[19]pH values of higher or lower than 5.5-6 pH directly affect the concentration of aluminium in water and its absorption.

Other factors that influence aluminium mobility and transportation are chemical speciation, hydrological flow path, composition of underlying geological materials and soil-water interactions. Acid mine drainage or acid rain also increase aluminium content in water.[20] Hence, contamination of surface water by acid rain or acid mine drainage and improper use of aluminium salts, like aluminium sulphate ($Al_2(SO4)_3$) and aluminium hydroxide ($Al(OH)_3$), in water treatment plants are the main causes for this contamination. While the benefits of aluminium in water treatment is acknowledged, over-dosage has serious effects on the human body. Neurotoxicity in the form of behavioural impairment has been observed in laboratory animals exposed to high amounts of aluminium from a contaminated water source[21]. According to another study, a population of 20,000 individuals in Camelford, England were exposed to high levels of aluminium from a water supply facility. Symptoms like nausea, diarrhoea, ulcers, skin rashes and vomiting were found. However, these symptoms were short-lived with no long-term effects[22]. Lastly, one long-term effect of the consumption of excess aluminium is a cause of Alzheimer's disease. There is a positive relationship between Alzheimer's disease (AD) and excess aluminium according to a study demonstrated by WHO. According to the report, 3 out of 6 (50%) studies in different countries reported a positive correlation between AD and aluminium and hence drew a conclusion of AD being a possible effect of the consumption of aluminium in excess amounts[23].

Polynuclear Aromatic Hydrocarbons (PAHs)

The results from the test showed the presence of 0.00172 mg/l of PAHs in the TW sample. To place this in context, the value determined was 17 times more than the permissible limits prescribed by the IS 10500 standard. IS 10500 prescribes a maximum value of 0.0001 mg/l of PAH in the water sample while the WHO prescribes a value of 0.0007 mg/l. Values above these parameters are considered toxic and harmful for the human body while values below this do not have any adverse effects. PAHs are organic compounds containing fused aromatic rings of carbon and hydrogen. They are always found in multiple forms in contaminated water with the most common PAHs being fluoranthene (FA). phenanthrene, pyrene (PY) and anthracene. Incomplete combustions of coal and crude oil, fires, incineration of waste, tobacco smoking and vehicle activity produce PAHs and therefore they are found in the environment as a result of anthropogenic activities. Thus, high concentrations of PAHs are observed mainly due to urban

[17] *World Health Organization & International Programme on Chemical Safety. (1996). Guidelines for drinking-water quality. Vol. 2, Health criteria and other supporting information, 2nd ed. World Health Organization*

[18] *World Health Organization & International Programme on Chemical Safety. (1996). Guidelines for drinking-water quality. Vol. 2, Health criteria and other supporting information, 2nd ed. World Health Organization*

[19] *Health Canada (1993) Guidelines for Canadian drinking water quality. Water treatment principles and applications: a manual for the production ofdrinking water. Ottawa, Ontario, Health Canada, Environmental Health Directorate. Printed anddistributed by Canadian Water and Wastewater Association, Ottawa, Ontario.*

[20] *ATSDR (1992) Toxicological profile for aluminium. Atlanta, GA, US Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry (TP-91/01).*

[21] *Commissaris RL et al. (1982) Behavioral changes in rats after chronic aluminium and parathyroid hormone administration. Neurobehavioral toxicology and teratology, 4:403-410.*

[22] *Clayton DB (1989) Water pollution at Lowermoore North Cornwall: Report of the Lowermoore incident health advisory committee. Truro, Cornwall District Health Authority, 22 pp.*

4. Colomina MT et al. (1992) Concurrent ingestion of lactate and aluminium can result in developmental toxicity in mice. Research communications in chemical pathology and pharmacology, 77:95-106.

[23] *WHO (1997) Aluminium. Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 194).*

runoff, atmospheric deposition and industrial point sources. Presence of PAHs in rainwater is observed as a result of the adsorption of compounds to particulate matter that is dispersed into water from wet deposition. However, the main source of PAH contamination in drinking water is the coating of the distribution pipes containing water. Coal tar is used for pipes to prevent corrosion. Leaching off the coating, the coal tar enters the drinking water, bringing with it 30 different types of PAHs. Thus, the main causes for the presence of PAHs in drinking-water are coal tar, industrial discharge in surface water and acid rain, all of which contain PAHs. According to a study conducted, coal tars have been identified as skin carcinogens[24]. Coal tar paints (CTP) have shown a positive result in a test conducted to determine the carcinogenicity of CTP in SENCAR mice[25]. Another study concluded that CTP are mutagenic (i.e. caused changes in the DNA of an organism) in nature[26]. Hence, PAHs (mainly FA) have carcinogenic and mutagenic effects on the human body in the long term. Furthermore, other long-term effects of PAHs include cataracts, kidney and liver damage, and jaundice[27].

5. INFERENCES FOR PUBLIC HEALTH |

This research gave us real-time insights on the potability of drinkable water amongst poor communities in an urban city such as Delhi. Primarily, the four sources of drinking water in Delhi are (a) water supplied by the Municipal Corporation of Delhi (MCD), (b) groundwater accessed through borewells or tube wells, (c) bottled water (both branded and unbranded), and (d) privately accessed public water (PAPW). This research experience, which yielded negative results with regard to the potability of water amongst the urban poor in Delhi, has enabled us to draw four key inferences for public health.

Water Non-Potability Amongst Urban Poor

'Informal City' is a widely used term to describe that section of an urban population that resides in slums, urban villages, resettlement colonies and unauthorized colonies.[28] These areas are characterized by sub-human conditions, lacking the most basic amenities present such as clean drinking water. In Delhi, as of 2019, 6.2% of the population reside in such areas and thus make up a substantial fragment of the population.[29] As of the year 2019, Delhi has a population of 29,399,000 (a growth of 3.10% from 2018).[30] Hence, roughly 1,785,390 people in Delhi reside in the informal city. Our research of the Outram Lines community revealed people dwelling here do not have access to potable drinking water, particularly provided by the government. From this, we can confidently infer that this is the same case with the rest of the urban poor community in Delhi which comprises 1.8 million of the Delhi population. This entire segment of the populationdoes not have access to Government certified potable water for drinking purposes. They are forced to privately access water, usually public water, through their own means.

Our preliminary research and baseline survey revealed that all water sources of the Outram Lines slum community are,thus,private. This water is made accessible with the help of private plumbers that lay down private lines from the public water sources to these communities. However, this procedure is conducted without following any regulations or policies and hence results in a poor quality of the distribution system. According to the thirteenth five-year plan released by the government of India for the years 2017-2022, there are no systems and regulations in place that monitor and control private water.[31] This creates multiple issues regarding the quality of drinking-water present in such areas in Delhi as well as in India as a whole. Hence, our preliminary research reveals that the people living in urban poor areas in Delhi, who are deprived of regulated potable water for drinking, suffer from serious health hazards due to private sourcing of drinking-water.

Regulation to Monitor Potability of Unbranded Bottled Water

There exists a rigid set of policies and regulations to monitor the quality of water distributed by bottled water companies. However, there exists a vast disparity in the enforcement of these policies and constant monitoring between branded and unbranded bottled water companies. Reputed companies such as Bisleri have a large consumer base and have a high price point of Rs.80 - Rs.90 for a 20L bottle. This premium pricing allows the companies to monitor their water to ensure that their water passes all quality checks. On a visit to the Bisleri testing plant, I was able to witness their procedures. The water is purified from multiple filters before it gets ready for bottling. The bottles pass through a disinfecting machine before water is

[24] *Wallcave L et al. (1971) Skin tumorigenesis in mice by petroleum asphalts and coal-tar pitches of known polynuclear aromatic hydrocarbon content. Toxicology and applied pharmacology, 18:41-52.*

[25] *Robinson M et al. (1984) Comparative carcinogenic and mutagenic activity of a coal tar and petroleum asphalt paints used in potable water supply systems. Journal of applied toxicology, 4:49-56.*

[26] *Robinson M et al. (1984) Comparative carcinogenic and mutagenic activity of a coal tar and petroleum asphalt paints used in potable water supply systems. Journal of applied toxicology, 4:49-56.*

[27] *"Polycyclic Aromatic Hydrocarbons (PAHs)", Illinois department of public health, accessed on 15.08.2020, http://www.idph.state.il.us/cancer/factsheets/polycyclicaromatichydrocarbons.htm*

[28] *"Profiling 'informal' City of Delhi."*

[29] *Ministry of Housing and Urban Affairs, Government of India, "Handbook of Urban Statistics 2019," (accessed on 18.08.2020).*

[30] *According to Government of India Census 2011, the population of Delhi was 17 million. (Office of the Registrar General & Census Commissioner, Ministry of Home Affairs, Government of India, "Census of India 2011"). Since then, there has not been any other census, however, the UN has estimated that the population of Delhi in 2019 is 29 million, and I am using this data as it is the latest.(https://population.un.org/wpp/)*

[31] *Ministry of Finance, Government of India, "XIIIth Five-year Plan (2017-2022)," (accessed on 17.08.2020).*

filled. Lastly, there are hourly, daily and monthly checks for different parameters in an in-house lab for quality monitoring.

On the other hand, our initial survey found that unbranded bottled water companies primarily catered to urban poor localities due to their low pricing of up to Rs.10 for a 20L bottle. This structure of low pricing itself gives an indication of the low quality of unbranded bottled water and the purification procedures they follow. This hunch was validated by the results of our qualitative water tests. The analysis revealed the presence of pathogens such as E. coli and a pH of 6.52 in the water sample.

This raises the question about how well are the implementation of the policies monitored particularly with regard to unbranded bottled water? Even though policies and regulations do exist for water bottling companies, our test results show that they are not being followed and that there is no system for monitoring and holding the unbranded bottling companies accountable for their actions. This raises a lot of questions: Can anyone sell water without conforming to set norms? Is there a fine imposed for selling non-potable water? This paper, therefore, draws an inference that although there are policies for monitoring quality of bottled water that are strictly followed by drinking water companies, the unbranded bottled water companies don't follow these regulations and are not held reliable for their actions. Further, this paper proposes that constant monitoring by an independent government entity for all unbranded bottled water companies should exist, which would ensure the quality of water is up to the mark and would hold the companies accountable for any non-compliance.

Regulation to Monitor Potability of Privately Accessed Public Water

As mentioned above, this study, accompanied by a survey of the water sources of the community, revealed that the urban poor community accessed water privately through private plumbers and a network of distributary water pipes. Thus, from this research, the chief inference drawn is that this system of procuring drinking water is the main cause for the contamination of the drinking water. Cheap and corroded materials of poor quality are used to construct this private distribution system. Hence water flowing through these pipes leeches toxic metals and chemicals harmful for the body which is then consumed by the residents of urban dwellings.

Although there are constant monitoring and quality checks in place to control the quality of State water, there exist no such policies controlling the quality of private drinking water (according to the thirteenth five-year plan issued by the government of India)[32] in urban poor communities. This essentially states that anyone with access to a plumber can tap into the public supply of water without fulfilling any governance or quality compliance, resulting in providing a drinking water source that is neither certified or tested for potability. The findings of aluminium and PAHs in the PAPW sample are most likely caused due to this 'private distribution system' for water. Thus, this study puts forth a question - if over a sizable segment of the population of Delhi resides in the 'informal city', then - even though they may not be authorized or regularized colonies–do these localities not deserve access to at least the most basic amenities like clean drinking water?

Social Intervention as a Corrective Measure

Governments of developing countries such as India have limited funds and resources that need to be allocated to various departments. This confines the reach of the government in providing even basic amenities. Unauthorized urban communities are last in the list of priorities when it comes to public services. A common explanation given is that the government's hands are tied because the colonies are unauthorized. Thus, millions of people living in these urban poor colonies are bereft of an adequate life and are deprived of basic resources such as health and education.

Therefore, in developing countries like India, how can these social needs be met? Historically, a large contribution has been made by civil society. This is where Non-Profit Organisations (NGOs) and civil bodies step in and complement the work of the State. Especially in developing countries like India, NGOs are able to play a critical role in serving the underprivileged communities, bringing aid and relief to the marginalised sections of society. With regard to the issue of the lack of clean drinkingwater and minimal awareness on such a topic, perhaps, a way forwardcould be through the interventions of NGOs and civil bodies who might facilitate the provision of basic amenities such as drinking water.

Thus, pertaining to this specific study, the research team exclusively worked with an established NGO in the community to investigate and conclusively find the pathogens and chemicals present in the drinking water and consequently to explore the possibilities to remedy the existing water contamination and provide clean potable water. Hence, the community has the required facilities to access clean drinking water based on a model focussing on the longevity of the intervention. In doing so, awareness has also been spread regarding the importance of clean drinking water.

6. CONCLUSION

This paper aimed to establish the health hazards of consuming privately accessed water (i.e. UBW and PAPW) as it contained faecal and toxic contaminants that are carcinogenic and pathogenic and hence can be classified as non-potable. To validate this claim, the methodology, standards and sampling followed in the study were clearly stated, the results of the tests

[32]Ministry of Finance, Government of India, "XIIIth Five-year Plan (2017-2022)," (accessed on 17.08.2020).

conducted were displayed both graphically and statistically and an analysis of the health hazards imposed by the non-compliant parameters was conducted and its interpretation was specified. The findings of this paper revealed that Escherichia Coli, Polynuclear Aromatic Hydrocarbons, Aluminium and pH value were present in the UBW and PAPW samples in quantities exceeding the permissible limits and hence had acute and chronic health effects on the consumers. Furthermore, this paper drew inferences for public health from the study by establishing the lack of regulations and routine monitoring for private water and validating the importance of social interventions as corrective measures.

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