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Evaluating Microbial &Chemical Quality of Delhi-NCR Drinking Water, Enhancing its Standard & Spreading Mass Awareness

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ABSTRACT

Pure and safe drinking water is indeed the "elixir of life". In this simple yet very topical and relevant study, carrying a huge impact on a large section of society, drinking water samples from Municipal water supplies across 11 select localities of Delhi-NCR were aseptically collected. Four domestic water purifying technologies were chosen from the market. Studies on chemical and microbiological parameters for water potability were done on water samples, one untreated (control) and four treated samples (using 4 selected technologies). Based on the results obtained, questionnaires for water evaluation were developed. Survey was carried out in various localities for assessment of the quality of their drinking water, spreading mass awareness about the importance of safe drinking water, and recommending the use of an economical, easy to use "COLI-CHECK" kit for assessing their drinking water supply. This study has proved to be very relevant and useful, since it not only evaluates the current situation of water potability in Delhi-NCR, but also provides an opportunity to disseminate this information among the general public.

Keywords :COLI-CHECK kit, coliforms, membrane filtration, potable/ drinking water, reverse osmosis, tap attachment filter.

Abbreviations:L: Liter; mL: Milliliter; SPC: Standard Plate Count; MPN: Most probable number; EMB: Eosin Methylene Blue; NA: Nutrient Agar; MH Agar: Mueller-Hinton Agar; TNTC: Too Numerous To Count; TLTC: Too Less To Count; NTU:Nephelometric Turbidity Unit; JTU: Jackson Turbidity Unit; TDS: Total Dissolved Solids

INTRODUCTION

It is of paramount importance to ensure 'potability' of our drinking water to maintain sound health and longevity. What's even more important is the need to generate/enhance this awareness among general public. Whereas chronic health risk emerges through a gradual chemical buildup in our body through our daily drinking water intake, the poor microbiological quality of our water culminates in more immediate but acute health problems such as diarrhea, dysentery & food poisoning that have a microbial origin (15).

WHO defines safe drinking water as that "which does not pose any significant risk to health over one's lifetime of consumption, including certain special and sensitive stages of life". Contaminated water may endanger our health and impair our life quality. Water that is free from disease causing microorganisms and harmful chemicals is termed 'potable water', and may be safely consumed without the risk of immediate or long term harm. Conversely, non-potable water is the one which is contaminated with either domestic or industrial wastes. Due to human negligence, inadequate treatment of domestic sewage, agricultural runoff, discharge of industrial effluents without proper treatment into the large water bodies, *etc.*, the overall quality of our drinking water runs the risk of getting adversely affected. Consuming such polluted water has proved to be one of the major threats to human health (5,9).

The contaminants of water are known to be essentially site specific. For example, at the site of mining, heavy metals are usually present, whereas the toilet waste is expected to be loaded with coliform bacteria. Defects in drinking water may be broadly classified into two categories:-

a) Physical and Chemical Contamination: Physical parameters include easily perceivable aspects such as turbidity, color, odor, taste *etc.*, pertaining to the appearance of the water. These are the factors by which people commonly assess the potability of water and make a decision if is fit or unfit for drinking. Although pure water is colorless, but when it contains certain pollutants its color, odour, and/or taste may undergo changes. Salty water is felt to be unable to quench our thirst most of the times.Water clarity, expressed in terms of turbidity, is also considered very important as it reduces the transmission of light into water, rendering it unacceptable for drinking purpose. Turbidity increases as a result of suspended solids in water, and is measured in NTU (Nephelometric Turbidity Units) or JTU (Jackson Turbidity Units).

There are also a plethora of chemicals that may occur in our drinking water. Water is usually tested for its pH (that might quickly get affected due to presence of certain chemicals) as well as for the presence of various organic and inorganic components. Chemical constituents have a number of serious consequences that cause a sharp decline in the potability of water, such as Total Dissolved Solids (TDS) leading to gastro-intestinal irritability; hardness (presence of calcium and magnesium ions) imparting a salty taste; presence of iron contributing a reddish color and off taste; chloride leading to carcinogenicity; fluoride culminating in fluorosis, whilst nitrates resulting in dangerous modifications in the hemoglobin, commonly referred to 'blue baby syndrome'. Most of these chemicals accumulate in our body over time, and go on to produce hazardous symptomatic effects after such long durations, that it becomes increasingly difficult to even attribute the same to the aforementioned water defects. Heavy metals like mercury, arsenic, lead, copper, chromium *etc.* and pesticides are highly toxic to all living beings.

b) Microbial Contamination: The microbiological aspect of water contamination mainly signifies the presence of live bacteria in it. These may include the pathogenic ones too,

predominantly those originating from fecal matter. For example, dreaded diseases like gastroenteritis, typhoid and cholera are known to be caused by water-borne pathogens *Escherichia coli*, *Salmonella typhi* and*Vibrio cholera* respectively. These, when discharged through household toilet sewage, may gain entrance into any water body that ultimately serves as a source of drinking water. Hence, the incidence of waterborne microbial diseases can increase due to human negligence (8).

Water purification is the transition of dirty and harmful (contaminated) water into clean drinking water. The purpose of purifying water is to get rid of contaminants that can be detrimental to our health. Water purification generally means freeing water from any kind of impurity it contains, such as contaminants or microorganisms. Water purification, or drinking water treatment, is the process of removing contaminants from surface water or groundwater to make it safe and potable for human consumption. There are various methods of water purification and filtration, some more effective at removing certain types of contaminants than others. There are contaminants in every water supply, hence, the methods of household water purification/ filtration methods required depend on: (1) the state of the local water supply; (2) the cost and performance of the filtration/ purification unit and (3) their health-benefits. Moreover, the water treatment methods used by common man also depend on their social as well as economic status.

The simplest water purifying methods include boiling and use of alum/ chlorine tablets. However, on resorting to these, the water quality becomes acceptable but not very palatable owing to their undesirable side effects. A tap attachment water purifying device is an easy, convenient and a very economical method of purification, which works on the principle of resin expansion. Although not energy dependent, it nevertheless requires a running water supply to operate. Based on low cost ingredients, they have a replaceable filter based product, which delivers safe drinking water. It can purify up to 7500Lof water at a rate flow of 2 L/min. It eliminates (doesn't kill, but traps within its pores, and also by virtue of ionic interactions) all the disease causing bacteria and also rids water from foul smell, if any.

A candle filter, which is based upon utilization of activated carbon to purify drinking water, is another inexpensive, effective and popular method used by general public. It offers the advantages of removing not only the dissolved substances, but also the residual tastes and odours from water. The activated carbon absorbs mostly all the contaminants from water leading to potable/ safe drinking water. However, to maintain its merit and efficacy, its cartridge must be replaced routinely.

Membrane filtration/ Ultrafiltration is yet another water purification option that relies on using a thin membrane with differential permeability, which is decided based upon size of molecule/microorganisms, allowing the removal of most of the major contaminants including a plethora of bacteria. This technology is a more effective means of water purification as it not only removes more impurities than simple filtration but does so faster and more selectively. However, it is less economical due to the need to replace the expensive membrane periodically.

Reverse osmosis is a very sophisticated but high cost technology of water purification based on the exploitation of concentration difference. Pressure is applied across a semi-permeable membrane, driving pure water across while leaving the concentrate behind. This technology removes significantly higher numbers of chemical and microbiological contaminants. However, it has certain drawbacks such as wastage of most of the water (~87%).To maintain uniform flow, high pressures are needed, so is electricity-dependent. The main disadvantage is removal of even those ions necessary for our body in minute quantities, and also that its membrane rapidly loses efficacy and needs to be replaced regularly, adding to its maintenance cost.

Delhi, the capital of our country India, is situated at the bank of the Yamuna river, between the latitudes 280 12' -280 53' N and the longitudes 760 50'- 770 23'. It is one of the most important business centers of the country and at the same time highly populated (Gupta & Gupta, 1999). In the past few years, drinking water problems have created havoc in this city. Many questions have been aroused regarding the quality of the water supplied by the Municipality (Delhi Jal Board). The present study was thus planned with the principal aim of determining the extent of microbial and chemical contamination in drinking water samples collected from various selected sites of Delhi-NCR.

In this project, eleven drinking water samples were collected from across the city as well as its surrounding areas. Different parameters were examined using Indian Standards (IS 10500, 2004) to find their suitability for drinking purpose. During this examination, mainly the physico-chemical and microbial parameters were taken into consideration. Since Delhi is fast becoming a world class city, it is important to monitor the toxicity of its drinking water regularly so as to match the standards laid by the Bureau of Indian Standards (BIS) and World Health Organization (WHO) for the drinking water quality. Mainly, the potability of the collected water samples was assessed and the presence of indicator organisms and chemical constituents were detected. Our finding may have a significant impact on the society due to its role in spreading mass awareness regarding importance of potable drinking water, and at the same time, to effectively compare various techniques available in the market for water purification, empowering people to decide their method of choice for water purification.

METHODOLOGY

Sample Collection: Drinking water samples from residential units were aseptically collected, from eleven selected localities across Delhi-NCR [North Delhi, South Delhi, East Delhi, West Delhi, Central New Delhi, Alipur, Narela, Noida, Faridabad, Ghaziabad and Gurgaon]; in sterile plastic Jerry Cans (10 L capacity) using standard methodology. All of these were then transported carefully to the laboratory and processed by four purification techniques: Tap Attachment, Candle Filter, Membrane filtration/Ultrafiltration and Reverse Osmosis (hereafter designated T1, T2, T3 and T4 respectively) {commercially available popular brands were selected and standardized}. The unprocessed samples served as the controls.All samples were processed and tested within 24 hours for microbiological parameters to prevent any false results arising from secondary microbial growth.

Chemical parameters: The values of pH, alkalinity, electrical conductivity, total hardness, turbidity and total dissolved solids were evaluated for the collected and processed samples using standard protocols (Standard Analytical Procedures for Water Analysis, 1999; Perlman, 2014). Their calcium content was determined using standard EDTA titrimetric methods according to APHA (1998) (1). All the instruments (Conductivity/TDS meter, pH meter, nephelometer) were calibrated prior to use. All chemicals and standards used during preparation and analysis were of analytical grade.

Microbiological parameters: Both processed and unprocessed (control) samples were tested for fecal coliforms, fecal streptococci and total coliforms by carrying out their MPN (Most Probable Number)/ Presumptive Test, Presence-Absence Test, Standard Plate Count and Membrane filtration and incubation on suitable media (LactoseFermentation Broth, Coliform PA broth, Nutrient Agar medium, Muller-Hinton Agar, Eosin Methylene Blue Agar, Endo Agar and Azide dextrose Agar) (3,4). Subsequently, confirmed and completed tests were also performed for water samples testing positive for the MPN test. A commercially available home water testing kit for detection of coliforms in potable water (COLI-CHECK, manufactured by Titan Biotech Ltd., Rajasthan, India) was also used to evaluate water potability, in comparison to the complicated and labor-intensive laboratory methods.

Deionized water and sterile, double distilled water were used to carry out chemical and microbiological work respectively. All tests and assays were performed in triplicates.
Spreading awareness: Evaluation instruments (questionnaires) were developed with the targetof educating and enlightening general public about the need and the importance of safe, potable water for drinking purpose, and also spreading awareness about the various commercially available options to further enhance its safety for consumption.

RESULTS

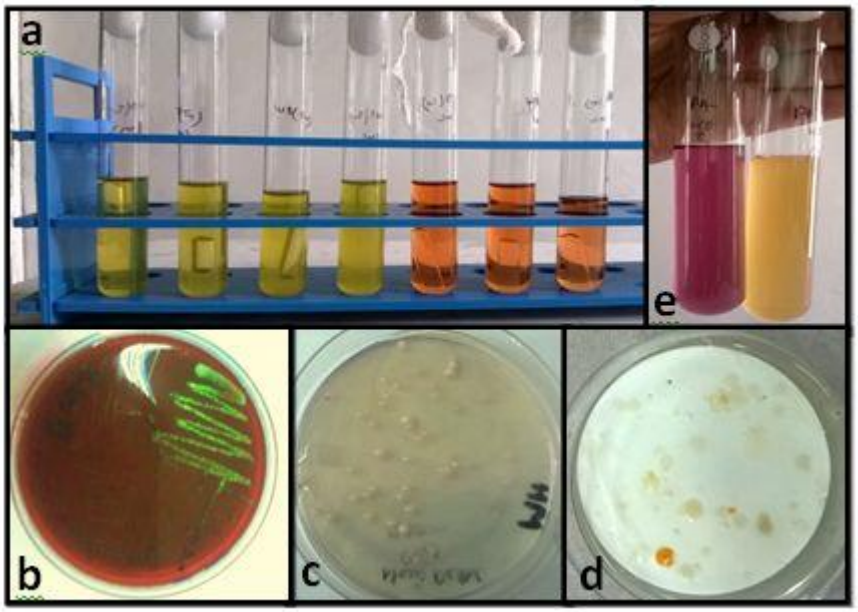

Figure I: (a) MPN tubes (Presumptive Test); (b) EMB Plate showing Green Sheen Colonies of *E. coli* (Confirmed Test); (c) Standard plate count (SPC) on MH agar; (d) Bacterial Colonies after membrane filtration; (e) Presence- Absence (PA) test.

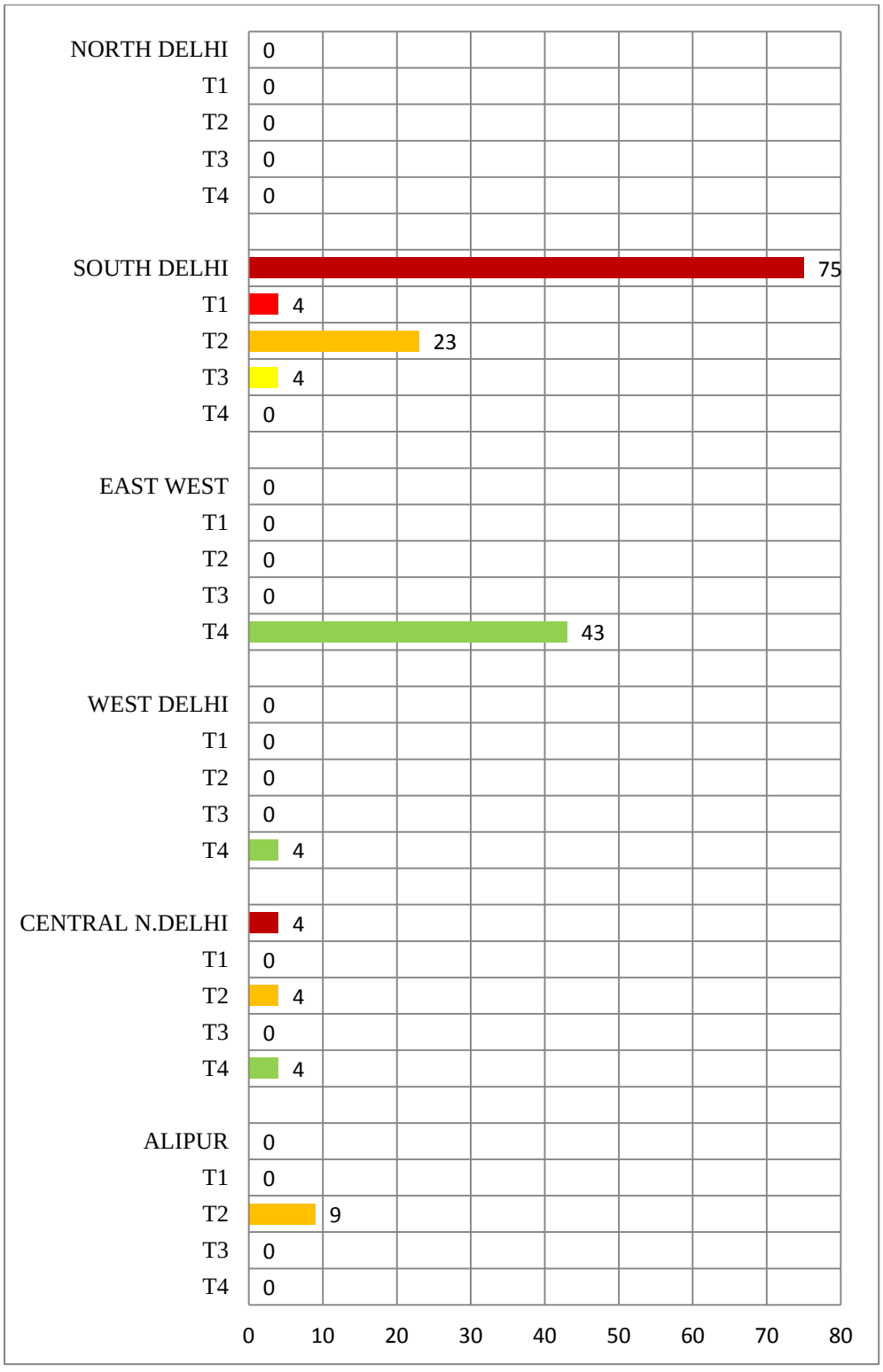

Figure IIa: MPN values of untreated and treated water samples collected from North Delhi, South Delhi, East Delhi, West Delhi, Central New Delhi and Alipur.

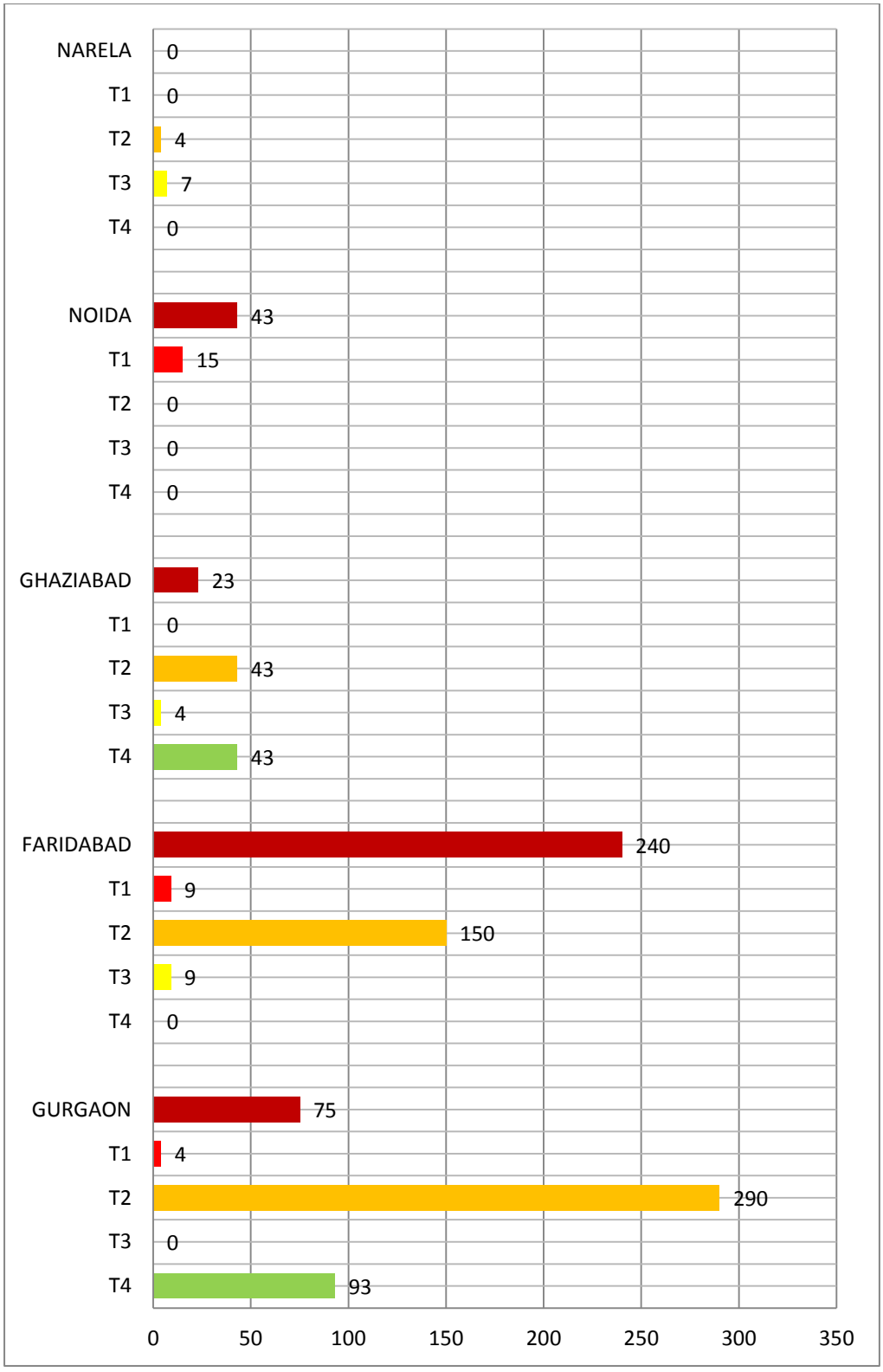

Figure IIb: MPN values of untreated and treated water samples collected from Narela, Noida, Ghaziabad, Faridabad and Gurgaon.

Figure III : COLI-CHECK kit; (a) Positive result (Non-potable water); (b) Negative result (Potable water).

Table I : Effect of various water purifying technologies on pH and Alkalinity of drinking water samples

REGION/ WATER SAMPLES	pH					Alkalinity (mg/l)				
	C	**T1**	**T2**	**T3**	**T4**	**C**	**T1**	**T2**	**T3**	**T4**
North Delhi	7.49	6.61	7.21	7.09	7.04	466.56	333.25	333.25	333.25	266.6
South Delhi	8.23	7.24	7.51	7.47	7.07	1199.7	999.75	999.75	866.45	133.34
East Delhi	7.25	7.21	7.21	7.21	7.04	199.95	199.95	199.95	199.95	66.65
West Delhi	8.32	6.55	7.02	6.95	7.05	333.25	199.95	333.25	266.6	66.65
Central New Delhi	7.56	7.45	7.6	7.6	7.3	333.25	199.95	266.6	266.6	133.3
Alipur	7.23	7.26	7.25	7.29	7.1	533.2	533.2	533.2	466.55	66.65
Narela	7.74	6.2	6.72	6.63	7.07	533.2	533.2	533.2	533.2	66.65
Noida	7.47	6.52	6.45	6.59	7.19	533.2	599.85	599.85	666.5	66.65
Ghaziabad	8.95	8.75	8.84	8.73	7.28	466.55	466.55	599.85	399.9	133.3
Faridabad	8.73	8.55	8.94	8.94	7.02	266.6	333.25	666.5	333.25	133.3
Gurgaon	8.72	8.48	8.6	8.63	7.14	599.85	533.2	533.55	533.2	66.6

C: Control water sample; T1: Tap attachment treated sample; T2: Candle filter treated sample; T3: Membrane Filter treated sample and T4 : Reverse Osmosis treated sample.

Table II : Effect of various water purifying technologies on Conductivity and TDS of drinking water samples.

	Conductivity (μmhos/cm)					TDS mg/l				
REGION/ WATER SAI	**C**	**T1**	**T2**	**T3**	**T4**	**C**	**T1**	**T2**	**T3**	**T4**
North Delhi	1.475	1.475	1.475	1.475	0.704	0.975	0.975	0.974	0.958	0.973
South Delhi	1.697	1.758	1.58	1.735	0.243	1.122	1.16	1.043	1.142	0.99
East Delhi	1.27	1.2	1.26	1.265	1.13	0.84	0.815	0.818	0.819	0.815
West Delhi	0.854	0.82	0.81	0.802	0.297	0.558	0.54	0.537	0.53	0.52
Central New Delhi	1.366	0.56	0.585	0.532	0.505	0.97	0.372	0.385	0.355	0.35
Alipur	1.328	1.625	1.562	1.618	0.249	1.033	1.078	1.037	1.055	1.012
Narela	1.367	1.805	1.758	1.778	0.109	1.225	1.192	1.16	1.18	0.685
Noida	0.648	0.928	0.854	0.868	0.071	0.65	0.619	0.566	0.577	0.038
Ghaziabad	3.01	3.08	3.01	3.0	0.728	2.3	2.4	2.3	2.2	0.45
Faridabad	1.376	1.795	1.758	1.778	0.109	0.77	0.862	0.81	0.062	0.064
Gurgaon	1.455	1.325	1.635	1.56	0.14	0.896	1.08	1.03	1.048	0.093

C: Control water sample; T1: Tap attachment treated sample; T2: Candle filter treated sample; T3: Membrane Filter treated sample and T4 : Reverse Osmosis treated sample.

Table III : Total hardness and Turbidity of water samples before and after treatment with various technologies.

SAMPLES	Total Hardness (mg/l)					Turbidity (NTU)				
REGION/ WATER SAMPLES	**C**	**T1**	**T2**	**T3**	**T4**	**C**	**T1**	**T2**	**T3**	**T4**
North Delhi	167.484	167.484	137.928	177.336	118.224	1.5	0.2	0.2	0.2	0.2
South Delhi	325.116	305.412	305.412	315.264	29.556	0.9	0.5	0.1	0.3	0.3
East Delhi	108.372	98.52	98.52	118.224	19.704	0.8	1.0	0.9	0.9	0.7
West Delhi	157.632	157.632	137.928	108.372	88.668	1.7	1.7	1.5	1.8	0.8
Central New Delhi	128.076	128.076	118.224	118.224	19.704	2.4	1.4	2.4	2.4	2.0
Alipur	423.636	394.04	394.08	394.08	49.26	3.4	3.0	3.0	3.3	0.4
Narela	423.636	423.636	285.708	285.708	39.408	3.4	2.5	1.9	2.9	2.4
Noida	334.968	325.116	285.708	325.116	39.408	1.5	1.0	1.0	0.6	0.3
Ghaziabad	226.596	137.928	206.892	147.78	108.372	2.8	2.6	2.4	2.4	2.4
Faridabad	305.412	226.596	167.484	108.372	78.816	3.0	2.1	2.5	2.4	2.0
Gurgaon	285.708	285.708	226.596	285.708	80.66	3.1	2.9	3.0	2.9	2.9

C: Control water sample; T1: Tap attachment treated sample; T2: Candle filter treated sample; T3: Membrane Filter treated sample and T4 : Reverse Osmosis treated sample.

Table IV : Bacterial count by Membrane filtration of Delhi-NCR water samples.

Culture Medium used Regions	Nutrient Agar	Muller Hinton Agar	EMB agar
North Delhi	-	-	-
South Delhi	TNTC	102	-
East Delhi	-	TLTC	-
West Delhi	-	-	-
Central New Delhi	TNTC	TNTC	TNTC
Alipur	TLTC	TLTC	-
Narela	TLTC	TLTC	TLTC
Noida	TLTC	TLTC	TLTC
Ghaziabad	TNTC	TNTC	TNTC
Faridabad	TNTC	TNTC	TNTC
Gurgaon	TNTC	TNTC	37

C: Control water sample; T1: Tap attachment treated sample; T2: Candle filter treated sample; T3: Membrane Filter treated sample and T4 : Reverse Osmosis treated sample.

Table V : Standard Plate Count (SPC) of all water samples on various culture media.

Region	Culture Media	Control	T1	T2	T3	T4
North Delhi	NA	TLTC	TLTC	TLTC	-	TLTC
	MH	-	-	-	-	-
	ENDO	-	-	-	-	-
	EMB	-	-	-	-	-
	AZIDE	-	-	-	-	-
South Delhi	NA	TNTC	-	TNTC	TLTC	TLTC
	MH	TNTC	-	62	-	243
	ENDO	-	-	94	-	-
	EMB	-	-	-	-	-
	AZIDE	-	-	-	-	-
East Delhi	NA	-	-	TLTC	-	TLTC
	MH	-	-	-	-	TLTC
	ENDO	-	-	-	-	TLTC
	EMB	-	-	-	-	TLTC
	AZIDE	-	-	-	-	-
West Delhi	NA	74	TLTC	TLTC	TLTC	TNTC
	MH	-	TLTC	-	-	TLTC
	ENDO	-	-	-	-	TLTC
	EMB	-	-	-	-	-
	AZIDE	-	-	-	-	-
Central New Delhi	NA	TNTC	144	TNTC	TNTC	146
	MH	-	TLTC	-	55	48
	ENDO	-	-	-	TLTC	-

	EMB	TNTC	-	TNTC	TLTC	54
	AZIDE	-	-	TLTC	-	-
Alipur	NA	TLTC	-	TLTC	TLTC	TLTC
	MH	-	TLTC	TLTC	TLTC	-
	ENDO	-	TLTC	-	-	-
	EMB	-	-	-	-	-
	AZIDE	-	-	TLTC	-	TLTC
Narela	NA	-	TLTC	TNTC	-	TLTC
	MH	-	TLTC	35	-	-
	ENDO	-	-	-	-	-
	EMB	-	TLTC	TLTC	-	-
	AZIDE	-	-	-	-	-
Noida	NA	TLTC	TLTC	TLTC	-	-
	MH	-	TLTC	TLTC	-	TLTC
	ENDO	TLTC	TLTC	TLTC	-	-
	EMB	-	-	-	-	-
	AZIDE	TLTC	TLTC	-	-	-
Ghaziabad	NA	42	TNTC	TNTC	TLTC	142
	MH	32	TNTC	TNTC	TLTC	30
	ENDO	36	-	TNTC	50	TLTC
	EMB	TLTC	TNTC	TNTC	TLTC	102
	AZIDE	-	-	TLTC	-	-
Faridabad	NA	TNTC	32	TNTC	-	TNTC
	MH	113	TLTC	TNTC	-	35
	ENDO	53	-	-	-	-
	EMB	42	TLTC	TNTC	-	TNTC

	AZIDE	-	-	80	-	-
Gurgaon	NA	TNTC	TNTC	TNTC	TNTC	TNTC
	MH	84	123	TNTC	TLTC	TNTC
	ENDO	-	-	TNTC	31	-
	EMB	TNTC	TNTC	TNTC	TNTC	-
	AZIDE	-	-	TLTC	-	-

C: Control water sample; T1: Tap attachment treated sample; T2: Candle filter treated sample; T3: Membrane Filter treated sample and T4 : Reverse Osmosis treated sample.

Table VI : Observations of the Presence-Absence (PA) Test of Coliforms in drinking water purified using various technologies.

REGION/ WATER SAMPLES	CONTROL	T1	T2	T3	T4
North Delhi	-	-	-	-	-
South Delhi	-	-	-	-	
East Delhi	-	-	-	-	+
West Delhi	+	-	+	-	-
Central New Delhi	-	-	+	-	-
Alipur	-	-	-	-	-
Narela	-	-	-	-	-
Noida	+	+	-	-	-
Ghaziabad	-	-	-	-	+
Faridabad	+	-	+	-	-
Gurgaon	+	-	+	-	-

C: Control water sample; T1: Tap attachment treated sample; T2: Candle filter treated sample; T3: Membrane Filter treated sample and T4 : Reverse Osmosis treated sample.

Table VII :Quick determination of potability of water samples using COLI-CHECK kit

Region	Result
North Delhi	-
South Delhi	+
East Delhi	-
West Delhi	-
Central New Delhi	-
Alipur	-
Narela	-
Noida	+
Ghaziabad	+
Faridabad	+
Gurgaon	+

The observations of the chemical and microbial parameters of the various water samples collected from Delhi-NCR were as follows:

Chemical parameters:

The observations of all drinking water samples collected from eleven distinct regions of Delhi-NCR with respect to the most important chemical parameters are presented in Tables I to III. Most of the chemical parameters either fell within the standard prescribed values or using the select water purification technologies, were successfully brought within permissible limits.

Microbiological parameters:

The microbial tests performed for the various water samples are depicted in Figure I . A bar-chart representation of the presumptive test results,*i.e.*,MPN values obtained from all eleven drinking water samples collected from Delhi-NCR regions is given in Figures IIa &IIb. Each one of them contain one control water sample and four samples of the same water passed through the four technologies. Broadly speaking, the tap water samples from North Delhi, East Delhi, West Delhi, Alipur, Narela, and Central New Delhi were rated to be much better than the others with respect to their microbial quality, as was inferred from the bar charts.

Awareness program/ Survey:

The efforts of our team trying to spread mass awareness among general public proved to be very fruitful and satisfying. Questionnaires about the necessity of clean drinking water for a healthy life got people really interested and receptive to the information shared by the students, though a portion of the assesses were found to be already educated on the topic.

DISCUSSION

The three distinct objectives of this project were to analyze the drinking water being supplied in the dwelling units of Delhi-NCR, to assess various water purifying technologies available in the market to enhance its potable quality, and last but most significant, to spread awareness among common masses about the need and importance of safe drinking water. Our project commenced with aseptic collection of water samples from different regions of Delhi-NCR, followed by immediate execution of their chemical and microbial analyses by standard protocols.

Chemical analyses : Most important chemical parameters, such as pH, alkalinity, TDS (Total Dissolved Solids), conductivity, total hardness and turbidity values of all drinking water samples collected from Delhi-NCR regions are presented in Tables I to III. All the sets comprisea single control (untreated water sample) and four samples of the same water passedthrough different water purifying technologies (T1 – T4). The pH values of South Delhi and West Delhi control water were found to fall well within the WHO limits (6.5-8.5), but are somewhat alkaline in nature. Control water of Ghaziabad, Gurgaon and Faridabad were found to be highly alkaline and exceeded the permissible pH limits. The untreated water from North Delhi, East Delhi, Alipur, West Delhi, Narela, and Central New Delhi were rated to be much better than the others with respect to their pH and alkalinity, as is clearly visible in Table I. Alkalinity of any fluid is closely related to its pH value, which in turn is a measure of free hydrogen ions in it (13). As the alkalinity of any water sample decreases,its pH value approaches neutrality (pH 7), which is desirable. However, beyond a limit, the same feature renders the water acidic. This makes the water non-potable and unacceptable. The present study verified in general that as the drinking water sample is passed through progressively more efficient and costly water purifying technologies, its qualityindeed improved, and reachedalmost neutrality in the end (Table I).

Total Dissolved Solids (TDS) is a measure of the combined content of both organic and inorganic substances dissolved in water. Besides impartingan undesirable salty taste to the water, a high concentration of TDS also affects plumbing appliances (5).Evaluation of Total Dissolved Solids of water samples collected from different regions of Delhi-NCRispresented in Table II. The TDS content of the drinking water samples collected from various sites was found to range between 345 mg/L to 2400 mg/L. It was heartening to discover that all water samples showed TDS values falling within Indian Standard of Drinking Water Specification,*i.e.*, 500 mg/L to 2000mg/L,with an exception of Ghaziabad drinking water supply (2400mg/L).

The electrical conductivity of water relates to the total concentration of dissolved ions (EPA, 2012; Perlman, 2014).Conductivity of most of the water samples collected from different regions was found to be out of limit (maximum allowed limit is 1055mhos/cm). However,conductivity was found to lie within the permissible limits for water samples of East Delhi, West Delhi and Noida (Table II). The conductivity of Ghaziabad water was recorded to be the highest, almost 2.5 times of the permissible limit. This may be attributed to the high TDS value of this water. Hardness of water is caused by the presence of multivalent metallic cations in it (11; 14), and is largely due to the presence of calcium and magnesium ions. Hardness is conventionally reported in terms of presence of calcium carbonate in the water. Its presence adversely affects the capacity of this water sample to react with soap. In other words, if the water is ‘hard’, it requires considerably more soap to produce the same quantity of lather, as it would have produced as ‘soft’ water. It is influenced by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations.The total hardness of water samples lay within the range 108 mg/L and 423 mg/L, but the picture got substantially better following treatment through different water purifying technologies (Table III). One of the good points observed was that the hardness values of all water samples collected across Delhi-NCR were not seen to be crossing the WHO prescribed limit of 500

mg/L. Although hard water is generally not recommended for drinking and washing purposes, a noteworthy fact remains that slightly hard water may be acceptable and superior to its soft counterpart. Absolutely soft water is tasteless, corrosive and is known to readily dissolve metals. Moderately hard water is preferred to soft water for irrigation purposes too. Based on the WHO limits, the alkalinity and hardness of the water samples from Delhi-NCR may be concluded to be safe and acceptable. The turbidity of all the water samples analyses ranged between 0.8 – 3.4 NTU (Table III), this was within the WHO limit of 0 – 5 NTU.

Microbial analyses: The major goal was maintained on detection of total coliforms, fecal coliforms and fecal streptococci while planning the microbial analyses of the drinking water samples. Coliforms qualify as good indicator microorganisms in assessing potability of water because they are the most common microbes found in water samples, are easy to detect, non-pathogenic and possess life spans similar to those of the pathogenic ones in the collected water samples. All drinking water being supplied in Delhi-NCR households is essentially derived from treated sewage and treated river water. Since both of these sources are likely to be heavily contaminated with fecal matter, chances of finding coliforms in these are very high and easy if the water is not treated adequately. Therefore, our work was majorly focused on detecting their presence in drinking water. Coliforms by nature are Gram negative fermentative microorganisms, which grow by fermenting carbon sources, producing acid and gas.

Coliform contamination in drinking water supply may easily be executed using a three step procedure comprising presumptive test (MPN test), confirmed test and completed test. However, only if the presumptive test gives positive result, the other two tests were required to be carried out. MPN tests were considered positive for the presence of coliforms if the lactose fermentation broth in the MPN test tubes undergoes a color change from orange to yellow, and simultaneously produces gas, a part of which gets trapped in the inverted Durham's tubes placed within the lactose fermentation broth tubes (Figure I a). These two features are strongly indicative of the characteristic fermentative metabolism of coliforms. From the Standard MPN table, the MPN index number was calculated for all the water samples, from which the lower and upper number limits of live bacterial cells (coliforms) in 100 mL of the given sample were estimated. In the confirmed test, a loopful from the positive tube of lactose fermentation broth, when streaked on EMB media, gave a characteristic result. On EMB agar, Gram negative lactose fermenting microorganisms grow by fermenting lactose and release of acids, which imparts a pink color to the colonies. EMB agar is also an indicator media specifically for *E. coli* (most common coliform in water), which produces colonies with metallic green sheen due to a large amount of acid production (Figure I b).

The last component termed completed test is carried out by inoculating these bacteria again in a fresh MPN tube and streaking them on nutrient agar medium. After 24-48 hours, the MPN tube was observed for a positive color changeas well as gas production. Also, the bacterial culture was tested for their Gram character. Gram negative rod shaped cells, coupled with a color change from red to orange along with gas production in MPN tubes, verifies the presence of coliforms.

From our results of the presumptive test, it was inferred that out of 11 water sample tested, six (belonging to North Delhi, East Delhi, West Delhi, Central New Delhi, Alipur, and Narela) were found to be free of coliforms [Figures IIa and IIb]. Consequently, they were interpreted to be of excellent microbiological quality. They were rated fit for drinking as their MPN indices were found to be within the permissible range. The MPN value of the North Delhi tap water was observed to be zero, indicating it to be most satisfactory in potability (Figure IIa). Its quality was further enhanced with respect to its chemical quality by using a candle filter and a membrane filter. Likewise, the results of microbiological analyses of water

samples from East Delhi, West Delhi and Alipur were also very encouraging and it could be inferred that the drinking water provided in Delhi households is of acceptable quality (Figures II a and II b).

However, in this study, the tap water supplies of South Delhi, Noida and Ghaziabad appeared to be of poor quality (Figures II a and II b). The untreated water from of these areas seemed to be substantially contaminated with coliforms, rendering them unsuitable for drinking purpose. The MPN indices of South Delhi and Noida were found to be quite high. But a decrease in the coliform numbers occurred by using any of the water purifying methods, the least decrease with T1 and most with T4. The Tap attachment did decrease the number of coliforms present in the water to a limited extent. Passing the water through a fine quality candle filter does improve the water, but is not adequate to turn it into completely safe drinking water. Reverse osmosis seems to be the method that is found to be most suitable to meet the goal. Ghaziabad water, though not found to be fit for drinking as such, could be easily turned potable by simply using a tap attachment, an economical and portable device (Figure II b).

Very importantly, the water samples from Faridabad and Gurgaon were found to be unfittest to drink as their MPN index was quite high, *i.e.*, 240 and 150 respectively (FigureII b). Tap attachment, candle filter and membrane filtration techniques were indeed found to be reducing their MPN index, but not adequately. It was only Reverse Osmosis that could turn these water samples to safe drinking water, as indicated by the satisfactory MPN values.

The membrane filtration technique (Figure I d) was used to detect any bacteria missed in small water samples used while performing MPN, thus, water samples were concentrated by passing a larger volume of water through membrane filters and incubating on suitable media. The results of membrane filtration mirrored that of MPN, so wherever bacteria were detected in the presumptive test, they were also detected on filters (Table IV). This proves the efficacy of the presumptive test itself in properly assessing the quality of drinking water samples.Similar results were seen for SPC (FigureIc, Table V), where water samples were diluted, rather than concentrated, to determine the number of bacteria based on colonies obtained.

The Presence-Absence test (Figure Ie) is a qualitative rather than a quantitative method to detect the presence or absence of coliforms in the water samples tested, just based on color change of the indicator dye in the culture medium. Hence, wherever coliforms were present, color of the lactose fermentation broth changed from orange to yellow upon incubation due to acid production as they grew and multiplied in the broth. Again the PA results were similar to that of MPN (Table VI), confirming our inference that presumptive test is the easiest and most reliable.

It was interesting that a commercially available, easy to use and economical “COLI-CHECK” kit (FigureIII) gave results consistent to the PA test. It was capable of accommodating and analyzing larger volumes of water samples (Table VII). Hence, during the course of this investigation, it was inferred that all tedious, labor-intensive, time-consuming laboratory based experiments carried out by trained hands could be substituted with a simple home kit for checking the microbiological quality of drinking water in every household even by the layman, if the accompanying simple instructions were carefully followed.

Survey: The results of the survey indicated mixed results. Some of the Delhites were very well-informed about potable water and the dependence of sound health on the same, whereas a lot many of them needed to be made aware of the issue. People living in the outskirts of Delhi were particularly enthusiastic and wished to know more about the nature of problems associated with contaminated drinking water, and the methods of satisfactory purification of the same. By and large, general public appeared to be curious and concerned about the equipment cost as well as the running cost of all these techniques. When asked whether they

would like to get their drinking water tested, they seemed all enthusiastic and excited about it! Encouraged by their progressive motive of proactively avoiding water-borne diseases, their water was tested once by our team. Thereafter, they were suggested to go for an easily available, reliable and inexpensive water testing kit, in the eventuality of any indication of changes in their water supply. This was strongly recommended for use during the monsoons.

CONCLUSION

It was relieving and reassuring that the Municipality treated drinking water supply across Delhi-NCR was found to be of reasonably good quality, adequately treated and safe for consumption. Chemical parameters like pH, total hardness, conductivity, turbidity and TDS values of the MCD water supplies were found to be mostly within permissible limits. Based on microbiological tests like MPN, spread plating on special culture media, water testing kit *etc.*, the quality of drinking water supply in most localities within proper Delhi was found to be generally better than that in surrounding areas (NCR). As expected, Reverse Osmosis technology proved to be the best technology towards enhancing water potability, both chemically and microbiologically, as compared to other techniques. However, taking into consideration the ease of operation, cost/maintenance and portability of equipment, the use of at leastan inexpensive tap attachment may be recommended to the end users, particularly if they have not been using water purifiers till now due to financial constraintsand/or lack of awareness.

Recommendations: As the students proceeded to disseminate information among the general public and to request them to fill questionnaires towards assessing their drinking water quality, an immense need was felt by usto acquaint them with various water purifying options available in the market. On their demand, a 'do-it-yourself' home water testing kit, which happens to be both user-friendly and affordable, was recommended for useto analyze their drinking water quality, and consequently to decide on which water purification method would suit them the most. It was immensely gratifying to enhance general awareness among publicabout the direct and sure relationship between water impurities anddisease incidence, and accordingly to recommend appropriatemethods of prevention and rectification of this problem.

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