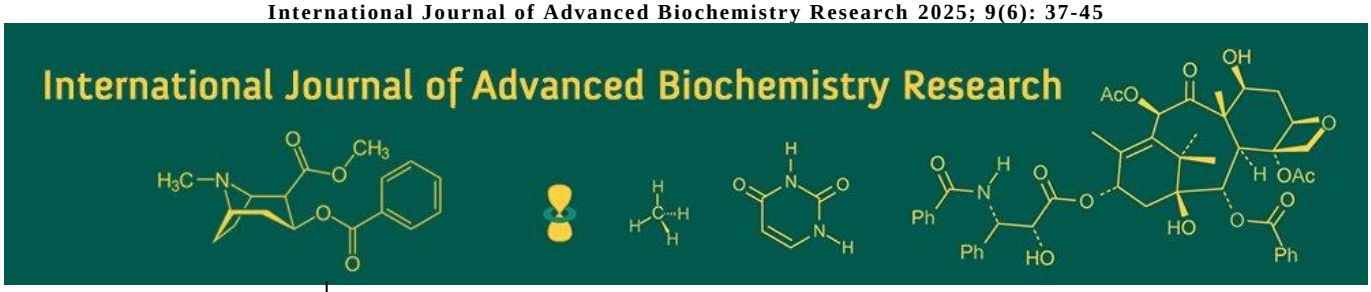

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Assessing the impact of water quality on gastrointestinal health: A cross-sectional, retrospective and statistical analysis in undergraduate students using GSRS and ANOVA

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Abstract
Background: Access to potable and safe drinking water is a key determinant of human health. This investigation explores the association between water quality metrics and the incidence of gastrointestinal (GI) symptoms among undergraduate (UG) students in Dehradun, Uttarakhand. In light of growing concerns about water contamination and its potential effect on GI health. This study aims to access both water quality data and subjective heath reports using validated tools.
Methods: In a cross-sectional retrospective study involving 60 undergraduate participants, the GSRS and WCHQ were utilized to investigate GI health and water consumption behaviours. Water samples from typical sources were analysed in accordance with WHO and IS10500:2012 standards. Descriptive statistics and one-way ANOVA were applied to assess the correlations between perceptions of water quality, usage, and the intensity of GI symptoms.
Results: The analysis of variance (ANOVA) indicated a significant difference ($F = 32.54$, $p<0.0000001$), suggesting a strong relationship between water consumption behaviours and GI health.
Conclusion: The research emphasizes the influence of water quality, particularly non-biological factors, on gastrointestinal health. To minimize health risks and ensure safe and clean water consumption in institutional environments, it is recommended to conduct regular monitoring, increase student awareness as well as develop potable water treatment strategies.

Keywords: Gastrointestinal symptoms, GIT disorders, GSRS, ANOVA, gastrointestinal health, water consumption habits, undergraduate students

1. Introduction
Water is one of the major elements crucial for life on this planet. A human body is made up of about 70% of water, making it one of the main components that builds the body. Other than being essential for life, water and its quality impacts human health at various levels. Good water quality directly links with proper physiological functions of the body including improved metabolism helping in proper digestion, better gut health, healthy skin whereas bad water quality may lead to various problems. Availability of clean and safe drinking water is a basic step to sustain optimal health by prevention of waterborne illnesses. Despite significant progress in public health systems and water treatment technologies, concerns regarding water quality and its negative effects continue to persist in various social settings where large numbers of students depend on different water supplies like undergraduate students, due to their specific living conditions and consumption habits face various challenges related to water quality that may affect their gastrointestinal health directly sabotaging their academic success, quality of life and overall health [1].
Problems like belching, bloating, nausea, emesis, constipation, diarrhoea, irregular bowel movement are the major gastrointestinal disturbances or symptoms which mostly occur due to disoriented irregular water consumption or drinking contaminated water which is unfit for drinking. Researches have shown that drinking microorganism contaminated water from untreated sources may influence the risk of acute gastrointestinal illness (AGII). During an investigation on water quality based on cohort's study, it was found out that about 20% of sampled rural households had microbial contamination in their drinking water that surpassed the thresholds of current safety levels of bacterial indicator [2].

The reason for the decreasing quality of water is primarily due to certain human activities and also the rise in industrialization, urbanization, population growth, and climatic changes play a synergistic role in lowering the drinkable water quality. Dumping wastes from industries involving manufacturing sector, textile sector, pharmaceutical sector, automobile sector also releasing hazardous effluents, pollutants, toxins and faecal matter into water bodies which serve as an open source for water distribution system across localities escalate the propagation of water borne illnesses in a population.

An extensive analysis utilizing data from the 2016 China Genuine Progress Indicator Survey indicated that switching to safer and treated water sources from untreated contaminated ones, improved the health rating of individuals by 7.9%, 10.4%, and 12.9% respectively whereas exposure to water pollution diminished their health status by 2.4% and also elevated their negative health ratings by 2.1% [3].

These results emphasize the potential role of water quality in shaping perceived health status and actual physiological health and wellbeing.

1.1 Estimation of Water Quality: Parameters, Key Approaches and WQI.

The approach of analyzing quality of water using specific criteria, such as its suitability for diverse purposes and its intended uses is generally collectively termed as estimation of water quality. The World Health Organization (WHO) establishes internationally acknowledged guidelines to ensure that drinking water remains safe for human use. It involves methodological evaluation of physical, chemical and biological parameters that often assist in calculation the water quality index (WQI), which serves as a comprehensive indicator of water safety and sustainability [4, 5, 6, 7].

Assessment of water quality is the most vital step as it ensures public health protection, sustainability of natural water resources and also supports balanced ecosystems.

1.1.1 Physical Parameters: Physical attributes predominately affect the visual appeal and consumer acceptability of water. Key indicators majorly include:

- **Color and Odor:** Indicates the presence of pollutants or organic matter or metals including toxic and lethal substances like arsenic, mercury, lead etc.
- **Turbidity:** Measure of haziness or cloudiness caused by suspended particles, reduces light penetration and clarity of water; high turbidity can shield microorganisms from disinfection.
- **Temperature:** Influences chemical reactions and microbial growth, though no specific limit is set by WHO.
- **Conductivity**: Measures the ability of water to conduct electricity, indicating the presence of dissolved ions.
- **Total Dissolved Solids (TDS):** Reflects the concentration of dissolved substances that may affect taste and can cause GIT disturbances.

1.1.2 Chemical Parameters: Presence of chemical substances in drinking water can lead to both short and long term health issues. Consumption of such kind of water over a long time period can result into severe illnesses, so in order to avoid specific health threats WHO has set certain guidelines or indicator values, they are:

- **pH:** pH range provides the measure of acidity or alkalinity of water. The pH of neutral water is given as 7. It also effects the solubility of different minerals and chemical reactions occurring in water. pH levels are also a direct measure of effectiveness of water treatment processes.
- **Hardness:** Presence of calcium and magnesium ions in water is measured by hardness. Higher concentration of Mg^{2+} and Ca^{2+} in drinking water can affect the taste, but over lifetime can lead to problems like constipation, hair loss as well as gallstones.
- **Dissolved Oxygen:** DO denotes the measure of dissolved oxygen in water. Low levels of DO happen because of organic pollution, algal blooms, or eutrophication making water unfit for drinking.
- **Heavy Metals:** Waste discharge from industries like pharmaceuticals, textile, fertilizers, pesticides, insecticides and mining activities can accumulate toxic metals into water bodies which often surpass the treatment process. Heavy metals include arsenic, mercury, lead and cadmium.
- **Chlorine and Chloramines:** Chlorine is usually used for disinfection during water treatment but monitoring their levels is crucial as they directly affect the taste and odor as well as lead to adverse health risks.

1.1.3 Biological Parameters: The utmost important factor during assessment of water quality is its microbiological aspect. According to WHO, no detectable thermo tolerant coliform or *Escherichia coli* should be present in 100 ml of water.

The comprehensive assessment of water quality relies on these three fundamental group of parameters physical parameter ensure the acceptability of water, chemical parameter helps in prevention of acute and chronic toxicity, and biological parameter offers role of protection from any infectious illness [5, 6, 7, 8, 9].

Table 1: WHO Guidelines for drinking water [5, 6, 8, 9]

Parameter	Type	Who Guideline/Value	Health Significance
Turbidity	Physical	≤ 5 Ntu	Aesthetic, Microbial Protection
Color	Physical	Acceptable to Consumers	Aesthetic
TDS	Physical	≤ 600 Mg/L (Up To 1000)	Taste, Acceptability
pH	Chemical	6.5-8.5	Corrosion, Disinfection
Arsenic	Chemical	0.01 mg/L	Carcinogenic
Fluoride	Chemical	1.5 mg/L	Dental/Skeletal Health
Nitrate	Chemical	50 mg/L	Methomoglobinemia
Lead	Chemical	0.01 mg/L	Neurotoxicity
Iron	Chemical	0.3 mg/L	Aesthetic, Staining
Sulfate	Chemical	400 mg/L	Laxative Effect
E. coli	Biological	0 CFU/100 ml	Acute Infection Risk
Coliforms	Biological	0 CFU/100 ml	Acute Infection Risk

1.2 Water Quality Index (WQI)

WQI is a highly recommended and used method that integrates various physical, chemical and biological water quality parameters into one sole index number, thereby providing a comprehensive view of water quality [4, 7] It serves as a transparent and brief illustration of overall water quality, allowing for easy comparisons between different sites and periods, which aids in informed decision making and effective communication regarding water resource management and the protection of public health [10, 11].

Typically, WQI is measured on a scale from 0 denoting poor quality to 100 representing excellent quality, incorporating categories like good, fair and poor. The selection of parameters for calculation of WQI must be based on local health risks and prioritized accordingly [10].

1.3 Survey: Region and Questionnaire

A survey was distributed through Google Forms to collect data regarding GI symptoms and water consumption habits among individuals. The survey was majorly divided into 6 parts:

1. Confidentiality and participation agreement
2. Subject profile form (demographic data like age, gender, residence etc.)
3. GSRS (Gastrointestinal Symptoms Rating Scale)
4. Water Consumption Habits Questionnaire
5. GI Health and Water Consumption
6. Additional Insights

1.3.1 Region

The conducted study aims to present a survey that focuses on assessment of water quality across different regions of Dehradun, a city situated in foothills of the Himalayas.

Dehradun has a unique terrain that features diverse topography with presence of hills, plains and rivers valleys that additionally influences the distribution as well as quality of water from various water sources in the region.

The region has coupled with increasing urbanization and elevated population growth which has significantly raised concerns about quality and safety of drinking water. Furthermore, the study also aims to highlight regional variations in water quality and provide insight into the impact of geographic, environmental and population-based factors on potable water resources in Dehradun [12].

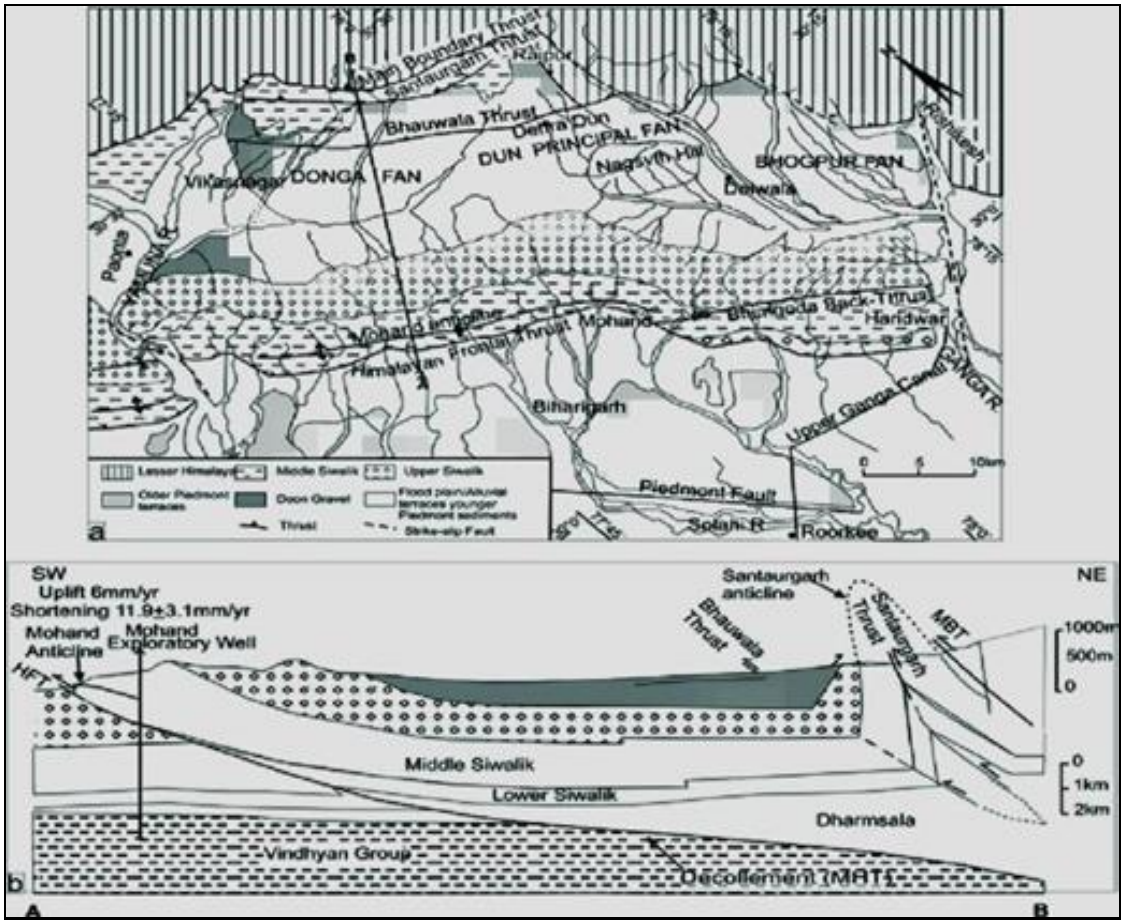

Fig 1: Terrain of Dehradun [13].

1.3.2 Questionnaire

The survey was conducted using Gastrointestinal Symptoms Rating Scale (GSRS) and water consumption habits questionnaire, distributed through Google Forms.

1.3.2.1 Gastrointestinal Symptoms Rating Scale (GSRS)

GSRS is a self-administered, validated and reliable disease-specific tool to assess a whole category of GI symptoms, their severity and frequency through 15 items, each addressing a specific symptom experienced over past week [14, 15].

Participants rate each item on a 7-point Likert scale, where 1 signifies “no discomfort at all” and 7 indicates “very severe discomfort”.

GSRS is mainly organize into five symptom domains:

1. Reflux (eg., heartburn, acid regulation)
2. Abdominal pain (eg., upper abdominal pain, nausea)
3. Indigestion (eg., bloating, belching)

4. Diarrhoea (eg., loose stools, urgent need for defecation)
5. Constipation (eg., hard stools, incomplete evacuation)

All the scores for each domain are calculated as mean of relevant items and a total GSRS score is calculated, higher score means higher severity.
The GSRS has illustrated good reliability and validity across diverse populations and is widely used in clinical studies and research studies to monitor GI symptoms and assess efficient treatment outcomes [14, 16].

1.3.2.2 Water Consumption Habits Questionnaire
To investigate water consumption habits among individuals, a self-administered questionnaire comprising 15 carefully designed question was developed. The main objective of the questionnaire was to gather comprehensive data on individual's drinking water preferences, consumption routines, sources and awareness about water quality and health impacts.
The questionnaire focused on daily drinking water intake, asking participants to estimate the average amount of water they consume per day and number of times they drink water throughout the day. Several questions addressed the source of drinking water (tap water, bottled water, boiled water, RO/purified water), including whether participants regularly test their water, use purification methods or have experienced health problems related to water consumption.
Additional questions regarding occurrence of any GI symptoms, its impact on daily life and how it is affecting the quality of life were also included [17].

2. Materials and Methods
2.1 Study Design and Participants
This cross-sectional study was conducted among undergraduate students to evaluate relationship between water quality and gastrointestinal symptoms. The study employed the Gastrointestinal Symptom Rating Scale (GSRS) questionnaire, which was distributed through Google Forms, and also involved the collection and analysis of water samples from various sources frequently used by the participants.

2.2 Sampling Strategy
A tiered sampling strategy was employed by selecting random locations where colleges are situated. The students were invited through mails and social media outlets. The inclusion criteria specified that participants must be undergraduate and provide voluntary consent. The exclusion criterion was limited to presence of any congenital or chronic gastrointestinal diseases.
The determination of sample size was based on prevalence estimate of GIT symptoms in analogous populations, with a goal of achieving minimum 50 responses to ensure adequate statistical power.

2.3 Data Collection: GSRS Questionnaire
For the evaluation of GI symptoms, use of validated and precise tools that can effectively capture complex nature of digestive issues, is necessary. The GSRS is a reliable validated instrument that contains 15 items aimed to measure five gastrointestinal symptoms including reflux, abdominal pain, indigestion, diarrhea, and constipation. Each item is rated on a seven-point Likert-type scale, where 1 signifies no discomfort and 7 denotes very severe discomfort. The GSRS has exhibited satisfactory reliability and validity across diverse population and languages, with constant reliability coefficients (Cronbach's alpha) ranging from 0.43 to 0.87 and test-retest ones between 0.36-0.75 [15, 18].
Additionally, GSRS has proven highly reliable and efficient in distinguishing between patients based on frequency and severity of their symptoms, thus helping in differentiating healthy participants from those experiencing GIT issues.
The questionnaire was adapted for online distribution using Google Forms. Participants received information regarding the study's objectives and were assured of their confidentiality and were required to give electronic consent before participating. Furthermore, demographic information (age, gender, year of study, residential status) and self-reported primary sources of drinking water were also collected.

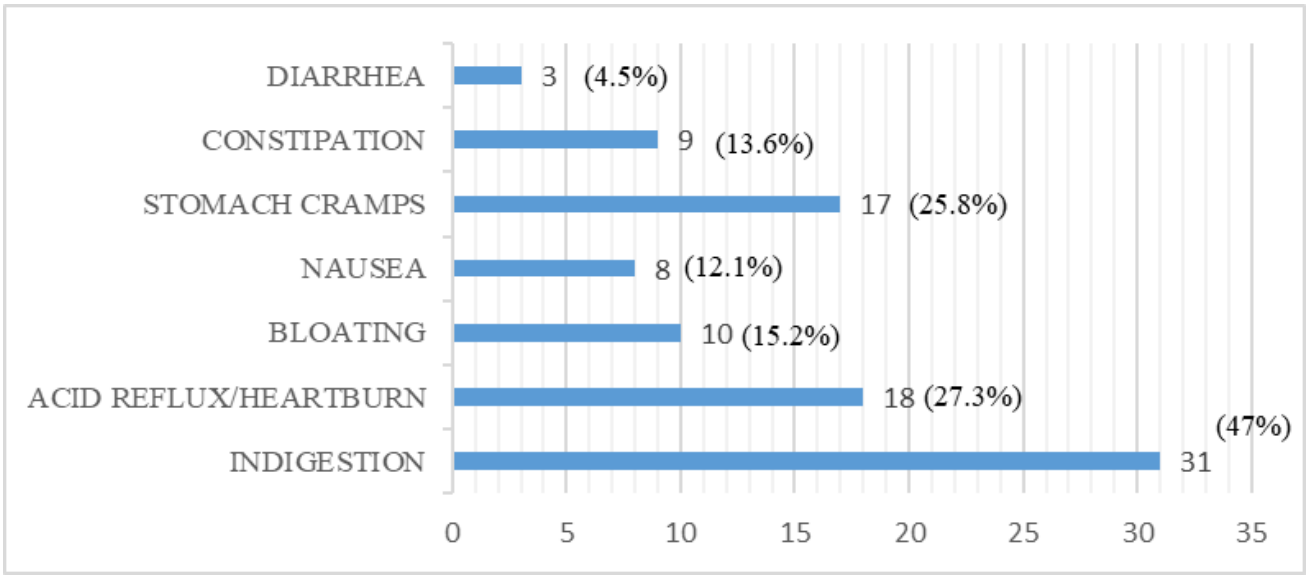

Fig 3: Graphical Representation of GI Symptoms Occurring in UG Students, collected using GSRS.

2.4 Water Sampling and Testing

Samples were gathered from the key sources indicated by students, including municipal tap water, filtered water, RO sources and bottled water. The method of grab sampling was used which involves collection of single samples from each source at predetermined times, in accordance with standard procedures to avoid any contamination risks [19].

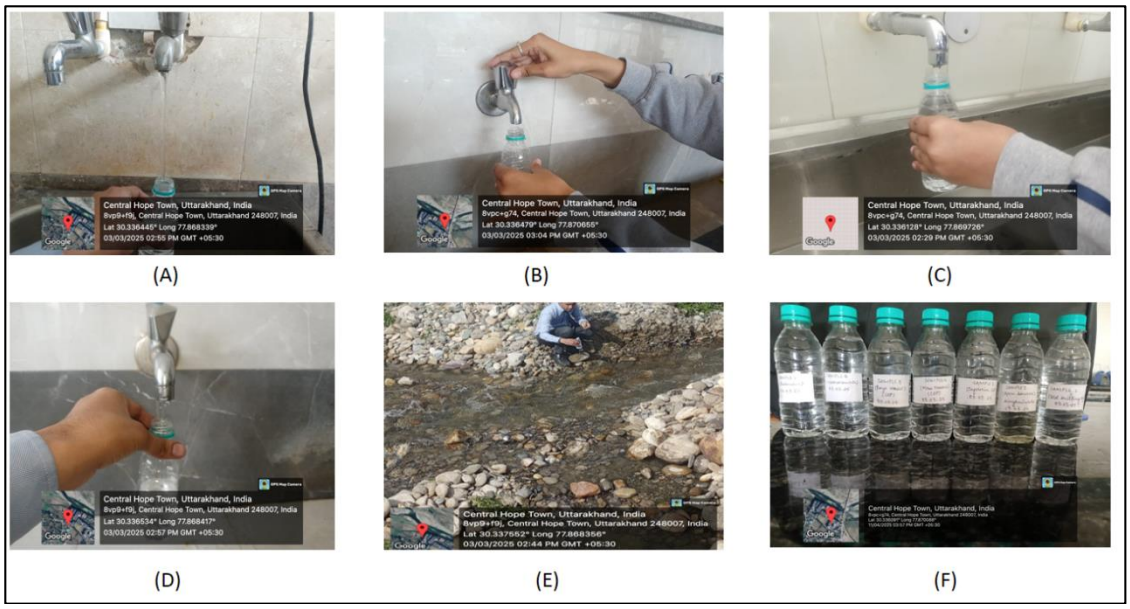

Fig 4: Sampling of various water samples from different sources. (A) Mothorowala, (B) Cafeteria Cop, (C) Old Building Cop, (D) Mess Cop, (E) Open Source Singhniwala, and (F) All Samples. (Pictures Were Taken Using Geo-Tag Camera).

The criteria for choosing sampling sites were accessibility, representativeness and their proximity to student hostels and housing accommodations. Each sample was collected in sterile, inert and transparent containers and was transported under cooled conditions to laboratory for analysis [9, 19].

2.5 Water Quality Analysis

In accordance with WHO guidelines, collected samples underwent analysis for critical physical, chemical and biological parameters. The physical parameters assessed over turbidity, color, and total dissolved solids (TDS). The chemical parameters include pH, nitrate, fluoride, chloride, sulfate and heavy metals like lead and arsenic. Biological quality was evaluated by testing for total coliforms and *E. coli* using membrane filtration methods. All analyses were conducted following standardized protocols recommended by the Central Pollution Control Board and WHO [8, 9].

Certain basic laboratory tests that could be conducted in a college laboratory like hardness test, total dissolved solids (TDS), pH measurement and certain specific limit tests were performed and obtained results were validated by comparing them to results deduced by Uttarakhand Jal Sansthan (water testing laboratory) after conducting tests of all major key indicators of water quality of potable water within permissible range given by WHOand CPCB [5, 6, 8].

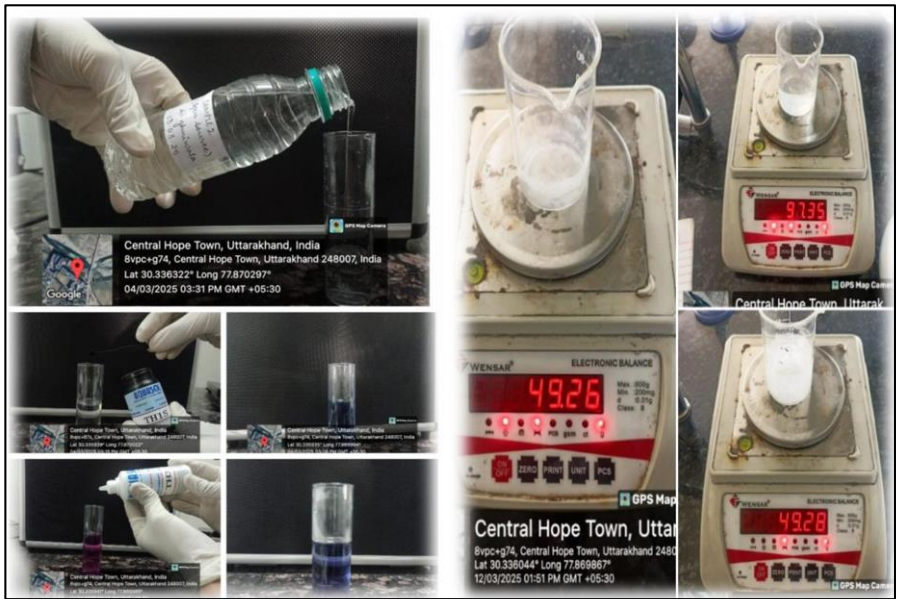

Fig 5: (A) Hardness Test and (B) Total Dissolved Solids (TDS)

2.6 Data Analysis
Scores on GSRS were computed for every participant, and the result regarding water quality were compared to the WHO guidelines benchmarks [5, 6]. Descriptive statistical methods were employed to encapsulated demographic characteristics, water sources and the occurrence of symptoms. The relationship between water quality indicators, water consumption habits and GSRS scores were analyzed using relevant statistical techniques like one factor ANOVA test, with a significance set at $p = 0.05$ [20, 21].
A one-way analysis of variance (ANOVA), performed using Microsoft Excel to analyse the mean difference between two variables: Total GSRS scores and the scores obtained from the Water Consumption Habits questionnaire. This statistical evaluation sought to establish whether variations in gastrointestinal, significantly correlated with diverse water consumption practices, thus facilitating the exploration of potential association between water quality and gastrointestinal health outcomes [22, 23].

2.7 Ethical consideration
Participation was voluntary and data integrity as well as confidentiality was strictly maintained. A confidentiality as well as participation agreement was made at very beginning of survey.

2.8 Documentation
After all the data was collected and analyzed statistically, a result was obtained, thereafter all the findings were drafted accordingly to prepare a survey paper and thesis report.

3. Observations, Scoring and Calculations
The survey was distributed among 100 undergraduate students in different regions of Dehradun, out of which 92 students accepted the form, 67 students filled and submitted the form while 25 didn't responded and 8 students denied being a part of the study and rejected the form. Female student submission made the response of 9% while male student population had contribution of 91%.
Foremost a mandatory consent section was asked to be filled, whether the individuals want to be involved in the study or not, and a confidentiality statement was made altogether. The demographic data was collected regarding age, gender, residential accommodation, social habits etc. The gastrointestinal symptoms rating scale (GSRS) scores were calculated based on its scoring where " no discomfort at all" was designated as "1" and "very severe discomfort" was marked as "7".
Similarly, water consumption habits questionnaire (WCHQ) scores were also calculated by marking "1" for "NO" and "2" for "Yes". GIT issues were given scores based on their severity, that is, "1" for "minor discomfort", "2" for "heartburn", "3" for "indigestion", "4" for "constipation" and "5" for "diarrhea".
Total scores were calculated for both questionnaire for each participant and one-way analysis of variance (ANOVA) was performed using Microsoft EXCEL.

4. Results and Discussions
4.1 Interpretation of Water Testing Results
The testing of physical, chemical and biological parameters of drinking water from various sources (TABLE 2) revealed key deviations from WHO and IS 10500:2012 acceptable limits [24]. Particularly:

1. Total Dissolved Solids (TDS) value exceeded the acceptable range (500 mg/L) in some samples, particularly from Mothorowala (450mg/L) and Boys Hostel (330 mg/L), which can affect taste, GI absorption and fluid retention.
2. Total Hardness levels were also high in multiple sources, including Mothorowala (422mg/L) and Cafeteria (268 mg/L).Elevated harness may contribute to symptoms like constipation or GI discomfort due to high calcium and magnesium content.
3. Magnesium levels in water from Mothorowala (64.64 mg/L) and Singhniwala (36.45 mg/L) were close to or slightly above the acceptable limits, potentially causing laxative effects or digestive irregularities.
4. pH levels remained within recommended range (6.5-8.5), but localized variations might still affect the solubility of metals and microbial activity.

Encouragingly, biological contaminants (*E. coli* and total coliforms) were absent across all samples, indicating low immediate microbial risk.

Table 2: Test Results of Physical, Chemical and Biological Parameters of Drinking Water from Different Sources

S.N	Parameters	Water Testing Result							As per IS 10500:2012	
		OLD Building COP	Open Source Singhniwala	Cafeteria COP	Mess Hostel COP	Boys Hostel	Mothorowala	Balawala	Acceptable Limit	Permissible Limit
1.	pH at 25 °C	7.21	7.68	7.52	7.18	7.26	7.50	7.02	6.5-8.5	No Relaxation
2.	Total Dissolved Solids (TDS), mg/l	200	322	320	56	50	450	330	500	2000
3.	Turbidity, NTU	0.96	0.91	0.86	0.82	0.86	0.96	0.99	1	5
4.	Total Hardness as $CaCO_3$, mg/l	116	254	268	38	36	422	312	200	600
5.	Total Alkalinity as $CaCO_3$, mg/l	52	200	216	24	24	240	140	200	600
6.	Colour, Hazen	Less than 01	Less than 01	Less than 01	Less than 01	Less than 01	Less than 01	Less than 01	5	15
7.	Calcium as Ca, mg/l	20	41.60	43.20	7.20	4.80	62.40	51.20	75	200
8.	Magnesium as Mg, mg/l	16.04	36.45	38.88	4.86	5.83	64.64	39.37	30	100
9.	Sulphate ($SO4^{2-}$), mg/l	20	24	30	18	16	15	16	200	400
10.	Nitrate ($NO3^{-}$), mg/l	2.2	1.8	2.6	3.2	1.8	2.2	1.6	45	No Relaxation
11.	Iron, mg/l, Max	0.10	0.12	0.13	0.08	0.12	0.14	0.16	1.0	No Relaxation
12.	Odour	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable	Agreeable
13.	Chloride (Cl^{-}), mg/l	12	26	23	9	8	28	20	250	1000
14.	Total Coliform, MPN/100 ml	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
15.	*E.* coli, MPN/100 ml	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent

These physio-chemical imbalances, while subtle, may have a cumulative impact on GI health, especially with chronic exposure. Importantly, many students reporting higher GSRS scores were found to consume water from elevated TDS and hardness, underscoring a likely environmental-health linkage.

4.1 Statistical analysis

This study aimed to compare means of two independent groups using a one-way Analysis of Variance (ANOVA). The statistical evaluation focused on determining whether the observed differences in group means were significant or likely to have occurred by chance.

The finding revealed a statistically significant difference between the groups, with implications for interpreting the effect size and consistency of responses in each group.

4.2 Descriptive Statistics

1. Column 1 (Total GSRS Score) has a lower mean (24.45) and a higher variance (152.35), depicting variability in the data.
2. Column 2 (Total WCHQ Score) has a higher mean (34.42) and a lower variance (30.79), indicating more consistent data with better performance or outcomes.

Table 3: One-way ANOVA Results (conducted using MS Excel)

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Column 1	60	1467	24.45	152.3534		
Column 2	60	2065	34.41667	30.78955		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2980.033	1	2980.033	32.54325	$8.8*10^{-8}$	3.921478
Within Groups	10805.43	118	91.57147			
Total	13785.47	119				

4.3 ANOVA Results and Interpretation

1. The F-statistic = 32.54, which is much greater than the critical value (F-crit) = 3.921, suggesting that the variability between-group is significantly larger than variability within-group.
2. The p-value = $8.8*10^{-8}$, is far below the conventional alpha level (0.05), strongly suggesting that the observed differences in group means are statistically significant.

Therefore, we reject the null hypothesis that there is no difference between the group means [22, 25].

5. Discussion

The findings suggest a substantial disparity between the two groups, signifying that the independent variable, as represents by the grouping factor, has a discernible effect on the dependent variable, that encompasses the calculated/measured outcomes. The higher average in column 2 (Total WCHQ Scores) reflects a favourable treatment effect, improved performance, or a greater score, depending on the specific context of the research.

Remarkably, Column 2 (Total WCHQ Score) presents a superior mean and a considerably lower variance, indicating a higher degree of data consistency. In contrast, Column 1 (Total GSRS Score) demonstrates elevated variability, suggesting that responses were more inconsistent in that scenario.

The difference in central tendency (mean) and dispersion (variance) provides additional evidence that the effect observed in Column 2 (Total WCHQ Score) is significant in both statistical and practical terms. The high F-ratio and low p-value reinforce the conclusion that the groups are derived from distinct populations.

5.1 Graphical Representation

To facilitate a better understanding and presentation of results, graphs with different plot types [bar charts with error bars (indicating standard deviation), box plot and violin plot] were developed. The charts significantly demonstrate:

1. Column 2 (Total WCHQ Score) has a greater mean and narrow error bars, which indicates a tighter clustering of data around the mean.
2. Column 1 (Total GSRS Score) signifies a lower mean with wider error bars, reflecting increase variability.

The non-overlapping nature of error bars reinforces the statistical finding that the difference between the groups is significant [22, 23, 26].

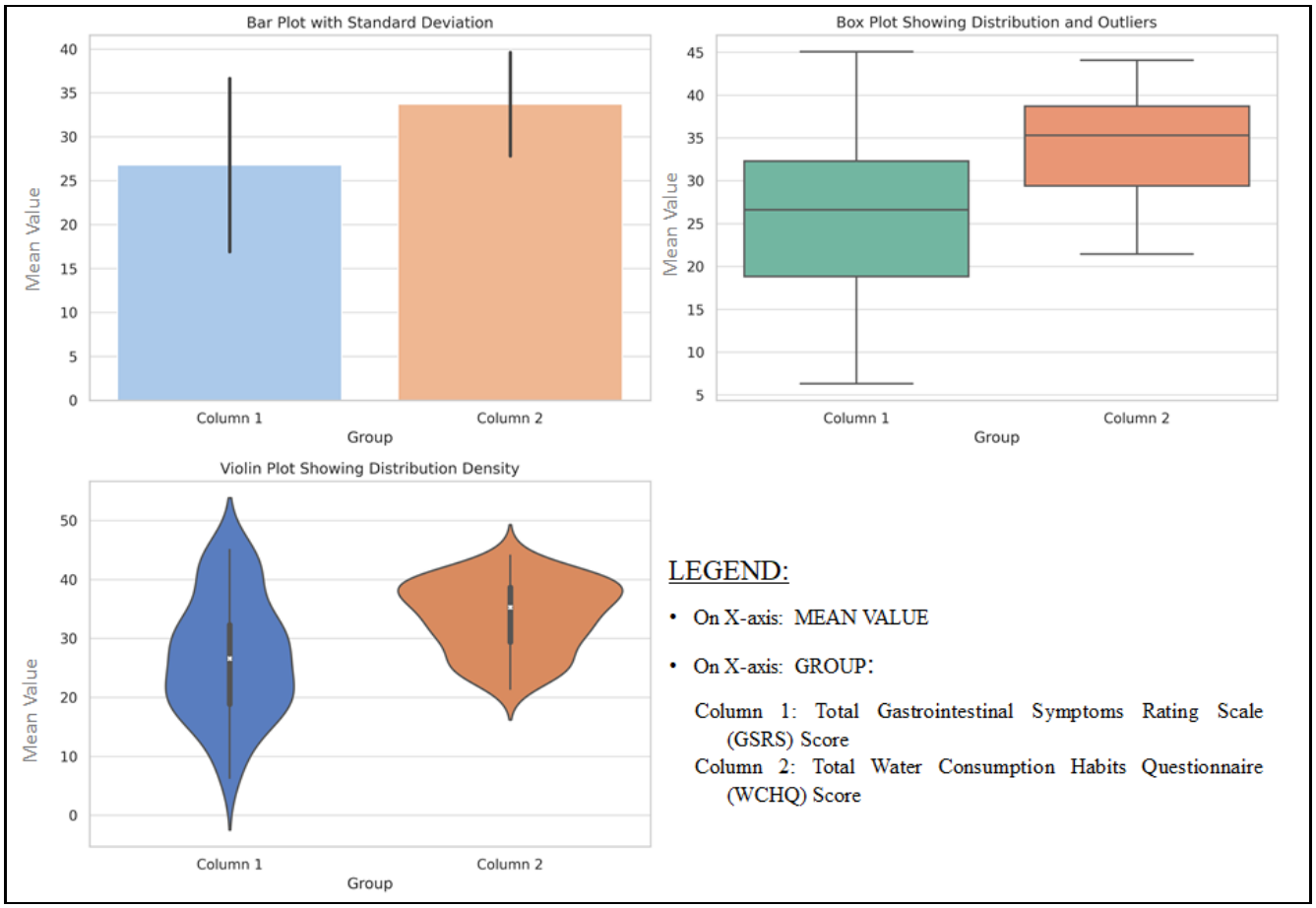

Fig 6: Graphical Representation of Results of ANOVA using Charts with Different Plots [22, 27]

5. Conclusions

The findings emphasize the need for:

1. Routine monitoring of drinking water sources around campuses and other residential areas.
2. Improved awareness among students about safe water practices.
3. Institutional interventions to ensure access to safe, clean and contaminant-free drinking water.

Thereafter, the results of the one-way ANOVA indicate a statistically significant difference in means between Column 1 (Total GSRS Score) and Column 2 (Total WCHQ Score) i.e, $p<0.0000001$. This implies that the variable separating the two groups has a meaningful and considerate influence on the outcomes.

Furthermore, the uniformity and reduced variability observed in Column 2 (Total WCHQ Score) indicate that it may represent a more dependable group or condition. Subsequent research should explore further variables or replicate the study to confirm these results, considering longitudinal or multivariate methodologies to gain more comprehensive insight. Given that here are merely two groups, a post hoc analysis is unnecessary: the significant F-test is adequate for this context.

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