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Statistical Analysis of the Relationship between Faecal Coliform Levels and Dissolved Oxygen in Ganga River

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Abstract
This study explores the relationship between faecal coliform levels and dissolved oxygen concentrations in the Ganga River in India from 2018 to 2021. faecal coliform indicates microbial contamination resulting from the improper disposal of sewage, while dissolved oxygen is essential for sustaining aquatic life and maintaining ecosystem health. This study utilizes publicly available data from PIB Delhi and the Central Pollution Control Board (CPCB) to analyze temporal trends and correlations between the two variables. The hypothesis was that an increase in faecal coliform concentration would lead to a decrease in dissolved oxygen levels, and a decrease in faecal coliform levels would lead to an increase in dissolved oxygen levels in the Ganga River from 2018 to 2021. The methodology consisted of identifying a detailed material list and procedure, and discussing the valid risk factors and ethical/environmental considerations. The primary tool used for analyzing the data was statistical analysis, which revealed relevant patterns. The evaluation involved identifying the study's limitations and assessing the impact of seasonal and locational factors on the data. The results indicated an inverse correlation between faecal coliform levels and dissolved oxygen, showing higher contamination corresponding to reduced oxygen availability. The findings indicate an urgent need for a course of action to improve wastewater management and conservation initiatives, thereby mitigating pollution and restoring ecological balance in the Ganga River. The critical interaction between microbial contamination and water quality in this study provides valuable insights into environmental health and the sustainable management of freshwater resources in India.

Keywords: Faecal; Microbial; Coliform; Bacteria; Contamination; Pollution

Introduction
Water pollution comes in several forms, including surface water pollution, sewage pollution, chemical pollution, nutrient pollution, microbiological pollution, and others (International Labmate Limited, 2020). This lab report will focus on how faecal coliform levels (caused by sewage pollution) affect dissolved oxygen levels. Faecal coliform bacteria are microscopic organisms that inhabit the intestines of warm-blooded animals. Additionally, they are found in the waste products—feces—expelled by the digestive system. A high concentration of faecal coliform bacteria in a water sample indicates that the water has come into contact with faecal matter from some source via sewage pipes (H2O Research Center, 2020).

In an urban environment where ecological health is often overlooked, people often prioritize efficiency, human interest, and cost-benefit analysis, leading to self-interested pollution and environmental degradation. For example, several sewage systems connect to the Ganga River because it is convenient for people to dispose of waste there. It is an example of the anthropocentric world view, which is a people-centered worldview that insists nature exists not because it has any inherent value but rather so that humans can utilize all of its natural resources for their gain; the managers of sustainable global systems are people (Foundations of Environmental Systems and Societies, 2017).

Pollution in the Ganga River at several points poses a regional problem in India, as 80% of the river's flow originates in the Himalayas and flows south and east. It crosses northern India, finally emptying into the Bay of Bengal (National Geographic Society, n.d.).

High levels of faecal coliform indicate that pathogens or viruses contaminate the aquatic system, which can cause typhoid fever, viral and bacterial gastroenteritis, and hepatitis (H2O Research Center, 2020). However, high faecal coliform levels do not solely indicate the presence of pathogens that pose a risk to organisms' health; they also decrease dissolved oxygen levels. While water molecules contain oxygen atoms, aquatic life in natural waters does not require this oxygen. Water contains a tiny amount of dissolved oxygen, typically ranging from 0.1 to 10 molecules per million of water (Water Science School, 2018). The amount of oxygen in water is referred to as dissolved oxygen, or DO. The atmosphere and aquatic plants are the primary sources of DO in water. The system's oxygen supply runs out if the amount used exceeds the input amount. Hence, aquatic systems are stressed when DO levels drop too low since most aquatic animals need oxygen to survive (Defining Dissolved Oxygen, 2015). Aerobic (oxygen-requiring) organisms aid in the breakdown of organic matter (OM), such as faecal coliform, in water, which requires oxygen. The biochemical oxygen demand (BOD) is the quantity of oxygen needed to decompose organic matter in a given volume of water at a specific temperature and time. Low quantities of dissolved oxygen (DO) are the outcome of high BOD/CBOD levels in the water that has an excess of organic matter (OM) (Organic Matter Breakdown & Biochemical Oxygen Demand, 2015).

The primary factors contributing to the pollution of the Ganga River's water are the growing population density, causing the untreated sewage to be dumped into the river, industrial waste, agricultural runoff, animal carcasses, and the remains of partially or completely burned bodies from funeral pyres. The Ganges is currently ranked as the fifth-most-polluted river in the world (Britannica, 2021). The interest in conducting the lab report stemmed from India, where the importance of the Ganga River to the local economy and way of life was recognized. The concern about the impact of water pollution through outfall pipes motivated the exploration of the topic. If there is an increase in faecal coliform concentration will lead to a decrease in dissolved oxygen levels, and a decrease in faecal coliform levels will lead to an increase in dissolved oxygen levels in the Ganga River from 2018 to 2021.

Materials and methods

Materials

Computer
Access to Google Sheets
Levels of dissolved oxygen and faecal coliform from 2018 to 2021 from pib.gov.in (CPCB)

Procedure

1. Obtain levels of dissolved oxygen and faecal coliform from 2018 to 2021 from pib.gov.in (CPCB) and add the data to Google Sheets.
2. Find the mean of faecal coliform and dissolved oxygen levels for the years 2018, 2019, 2020, and 2021 to find an average across all locations provided in the data. Find the average by typing in Google Sheets, for example, =AVERAGE(D5:D97) below each column of data to find the mean for each year of both faecal coliform and dissolved oxygen.
3. Place the averages in a table with the x-axis as year and the y-axis as faecal coliform.
4. Create a line chart of the averages of faecal coliform against the years to analyze a trend in the levels of DO as time passes.
5. Place the averages in a table with x-axis as year and y-axis as DO.
6. Create a line chart of the averages of dissolved oxygen against the years to analyze a trend in the levels of DO as time passes.
7. Compare the line structures (highs and lows) of faecal coliform and dissolved oxygen as time progressed to deduce if the two variables increased or decreased together or fluctuated inversely.
8. Place the averages of the faecel coliform (x-axis) and dissolved oxygens (y-axis) on a table.
9. Create a scatter chart of the averages of the faecel coliform (x-axis) and dissolved oxygen.
10. Generate a line of best fit and the coefficient of determination (R^2) to see if there is a strong linear correlation between the faecel coliform and dissolved oxygen levels.

Safety and Ethical Concerns

Safety Concerns

Working with water, which is often heavily contaminated with waste and pollution, poses significant health risks, including illness and infections. Protective gear, including gloves, goggles, and masks, should be worn to prevent waterborne diseases.
Conducting fieldwork near a river creates the risk of slipping, falls, and potential encounters with wildlife. Wearing a helmet when collecting data from heights, wearing boots that prevent slipping, and taking precautions will limit the risks.

Ethical Concerns

Maintain respect for local communities and their use of the river. Ensure that collecting samples does not interfere with their livelihoods or cultural practices.

If data is mishandled and accuracy is forgone, causing misinterpretation, the safety and well-being of the community are at risk. Hence, seriousness and consideration are to be put in prominence.

The collection of data should not cause any harm to the environment. All waste should be collected and properly disposed of, not released into the river or the environment.

Variables

Independent Variable: Faecal Coliform

Dependent Variable: Dissolved Oxygen

Control Variable	How/was it controlled?	Why was it controlled?
The location where the sample is taken throughout the years	By only using the published data and considering the sampling locations provided in that data.	If a sample was taken from a contrasting site not on the list, the consistency of the data would be called into question. Changing the locations for each year would yield inconsistent results, as the different locations along the Ganga have distinct water quality.
River	Only considering faecal coliform and DO levels of the Ganga River.	The data source provided faecal coliform and DO levels of both Ganga and Yamna rivers. By being consistent and using data only from the Ganga river, a concise, relevant conclusion can be reached.
Type of pollutant (Faecal Coliform)	By only using the data considering the faecal coliform and not changing the pollutant.	By considering only faecal coliform consistently, the focus of the investigation is maintained; hence, only one pollutant will be observed in the lab. Changing the pollutant would compromise the validity of the investigation in finding a relationship between the IV and DV.

Type of Data: Secondary Data collected by the Central Pollution Control Board (CPCB) of India.

Results

Table 1. Dissolved Oxygen vs Faecal Coliform of River Ganga from 2018-2021

State	Parameters								
	Station Name	Dissolved Oxygen (mg/l)				Faecal coliform (MPN/100 ml)			
		2018	2019	2020	2021	2018	2019	2020	2021
Uttarakhand	BHAGIRATHI AT GANGOTRI	8.8	10.3	9.8	-	7	7	2	-
	MANDAKINI B/C ALAKNANDA, RUDRAPRAYAG	9.2	9.5	9.8	10.4	450	1.9	1.8	1.8
	ALAKNANDA B/C MANDAKINI, RUDRA PRAYAG	9.2	9.7	9.4	10.2	2300	1.9	1.8	1.8
	ALKANANDA A/C MANDAKINI, RUDRAPRAYAG	9.2	9.7	10.1	10.4	780	1.9	1.8	1.8
	BHAGIRATHI B/C ALAKNANDA,	9.2	9.7	10	9.9	36	1.9	1.8	1.8

	DEVPRAYAG								
	ALAKNANDA B/C BHAGIRATHI, DEVPRAYAG	9.2	9.5	10	9.7	780	1.9	1.8	1.8
	ALAKNANDA A/C BHAGIRATHI, DEVPRAYAG	9.4	9.7	10.6	10	490	1.9	1.8	1.8
	U/S RISHIKESH	9.8	10.1	10.6	10.3	-	17	12	14
	A/C SONG NEAR SATYANARAYAN TEMPLE, D/S RAIWALA	8.8	9.1	9	9.9	-	110	50	64
	RISHIKESH D/S	9.6	9.7	9.8	9.8	-	30	22	13.5
	HAR-KI- PAURI GHAT	8.8	9.7	9.8	9.5	-	30	32	41.5
	HARIDWAR D/S	9.1	9	9.2	8.9	-	140	60	79
	ROORKEE D/S	9.2	9.3	9.4	9.7	-	70	46	63
Uttar Pradesh	MADHYA GANGA BARRAGE (BIJNOR)	8.8	8.3	8.8	9.4	-	-	-	790
	GARHMUKTESHWAR	7.79	8.7	9.1	10.2	330	505	350	350
	BRIJGHAT GHARMUKTESHWAR	8.03	8.4	9.3	10.7	210	240	210	170
	U/S ANOOPSHAHAR	7.4	8.3	8.5	8.1	270	230	780	920
	ANOOPSHAHAR D/S	8.95	8.3	8.6	8.3	235	220	1100	1100
	NARORA (BULANDSAHAR)	7.45	8	8.6	8.3	270	540	1100	1100
	KACHHLA GHAT (ALIGARH)	7.4	10.1	10.3	9.6	220	220	220	260
	FARRUKHABAD	8.5	8.5	8.8	11	1700	1350	1000	1100
	U/S KANNAUJ (RAJGHAT)	8.15	8.3	8.5	10.5	2200	2100	1700	1400
	KANNAUJ D/S	8.75	8.1	8.2	9.8	2750	2650	2250	1600
	BITHOOR (KANPUR)	8.2	7.5	8.5	11.2	2500	2150	1800	1400
	U/S KANPUR (RANIGHAT)	7.1	7.5	8.4	10.8	2950	2600	2600	2800
	BATHING GHAT (BHARAOGHAT)	7.7	7.6	8.2	9.7	2700	2200	2200	2100
	SHUKLAGANJ D/S	6.9	7.6	8	10.6	3250	3650	3300	2700
	BATHING GHAT (GOLA GHAT)	6.7	7.3	7.6	10.4	3400	3700	8100	10000
	KANPUR D/S (JAJMAU PUMPING STATION)	5.75	6.8	7.4	10.1	30000	22000	22000	15000
	BATHING GHAT (JAJMAU BRIDGE)	6.4	7.3	7.5	10.3	7000	6400	17000	14000
	DALMAU (RAI BAREILLY)	10	7.9	9.3	10.45	4700	2850	1400	1350
	KALA KANKAR (RAI BAREILLY)	9.9	8	9.7	10.5	4900	2750	1300	1300
	PRAYAGRAJ (RASOOLABAD)	9.1	8.2	8.4	8.45	11000	7850	1100	1150
	KADAGHAT (PRAYAGRAJ)	8.8	8	8.5	7.8	17000	11000	1300	810
	PRAYAGRAJ D/S (SANGAM)	9	8.1	7.9	7.4	11000	10150	1100	1200
	A/C TAMSA RIVER (SIRSA)	9.2	7.8	8.7	8.4	6800	7000	1300	810
	U/S, VINDHYACHAL (MIRZAPUR)	8.8	8.2	8.5	8.8	800	800	1200	800
	D/S, MIRZAPUR	7.7	7.6	7.5	7.6	2200	8500	11000	12000

	CHUNAR	8.4	7.9	8.2	8.4	8000	7000	6000	8000
	U/S VARANASI (ASSIGHAT)	7.8	8.2	8.7	8.7	1300	800	1100	800
	VARANASI D/S (MALVIYA BRIDGE)	6.4	7.2	7.4	7.9	32000	19500	13000	11000
	A/C GOMTI RIVER (BHUSAULA)	7.55	8.1	8.4	8.4	17000	8000	8000	7000
	TARIGHAT (GHAZIPUR)	6.9	7.4	7.6	7.6	23000	13000	13000	13000
Bihar	BUXAR	8.2	8.3	9.1	9.75	3100	7450	22000	12450
	U/S JAIL GHAT, BUXAR (A/C THORA RIVER)	7.9	7.6	8.2	9.1	3100	4000	31500	63500
	BUXAR, RAMREKHAGHAT	8	7.6	8.5	8.45	4000	4000	35000	107000
	BUXAR D/S, NEAR GANGA BRIDGE	7.8	7.7	8.2	7.7	4000	6450	44500	35000
	ARRAH CHAPRA ROAD BRIDGE (U/S, DORIGANJ)	8.1	7.9	8.6	9.3	2100	2100	13000	8200
	C/F SONE DORIGANJ, CHAPRA	8.1	8.2	7.2	9.3	3300	3300	57000	7900
	MAA AMBIKA ASTHAN, DORIGANJ D/S (SARAN)	7.9	8.5	8	9	7900	9950	22000	11000
	DANAPUR, NEAR PIPAPUL	8.1	8.3	8.3	9.5	3300	3300	2600	1040
	KHURJI, U/S PATNA	7.95	8.1	7.8	9.45	3100	3600	22000	26000
	DARBHANGA GHAT (PATNA)	7.6	8.1	7.2	7.7	6100	11000	60000	160000
	GULBI GHAT (PATNA)	7.8	7.3	7.1	7.65	6100	4500	107000	160000
	PATNA D/S (GANGA BRIDGE)	7.77	7.4	7.5	8.2	7000	7900	31500	92000
	MALSALAMI (PATNA)	8	8.2	8.8	9.05	3100	3300	11000	54000
	GANGA AT KACHCHI-DARGAH-BIDUPUR ROAD BRIDGE, PATNA	-	8.5	7.8	9.3	-	3600	17000	35000
	TRIVENI GHAT	7.65	7.6	7.3	8.05	6550	11000	7500	28500
	FATUHA	7.3	6.7	6.3	6.15	2850	3300	17500	92000
	BAKHYIYARPUR-TAJPUR BRIDGE ON GANGA, ATHMAGOLA, PATNA	-	7	7.9	9.2	-	5950	35000	24500
	BARH	7.6	7.6	7.1	9.4	3100	4900	17000	23000
	NAWADAGHAT D/S	7.8	7.5	7.5	9.55	3100	3600	13000	19950
	U/S BARAHPUR BINDTOLI	7.8	7.8	8.1	9.45	4000	5950	19500	26000
	U/S MOKAMA	7.8	8.1	7.7	9.6	4000	3100	35000	31500
	MOKAMA D/S	7.7	7	6.9	9	11000	12500	11000	3050
	BARAHIA	7.85	8.5	7.8	9.05	4000	7000	7900	10450
	U/S MUNGER	8.2	7.5	7.8	9.5	6100	7000	14000	24000
	MUNGER	7.9	7.2	7.6	9.2	13000	12000	35000	44500
	U/S SULTANGANJ	7.8	7.8	7.8	9.45	11000	7000	41000	63500
	WATER INTAKE POINT,	-	7	7.3	7.95	-	5900	160000	35000

	BHAGALPUR								
	SULTANGANJ (BHAGALPUR)	7.5	7.3	8.1	8.85	17000	6100	73000	35000
	CHAMPANAGAR	8.3	7.3	6.5	9	9000	3950	22000	4800
	BHAGALPUR	8.3	8.2	7.1	9	7000	4500	17000	22000
	U/S BHAGALPUR	7.5	7.1	6.8	6.8	7000	7000	160000	54000
	KAHALGAON	8	8	9.2	9.5	7000	6100	24000	58000
	KAHALGAON D/S, NEAR CREMATION GHAT	7.5	7.4	9	9.25	6100	11000	17000	13150
Jharkhand	U/S NEARA LCT GHAT	8.5	8.2	8.6	7.55	-	-	-	-
	NEAR JANTA GHAT D/S	7.8	8.2	8.4	7.55	-	-	-	-
	RAJMAHAL	8.1	8.4	8.4	7.7	-	-	-	-
	SANGI DALAN	8.2	8.3	8.6	7.5	-	-	-	-
West Bengal	BEHARAMPORE	6.75	6.8	6.9	-	30000	80000	64500	-
	KHAGRA, BEHARAMPORE	5.7	7	7.6	-	70000	110000	49000	-
	GORABAZAR, BEHRAMPORE	7.7	6.6	7.4	-	60000	75000	25000	-
	NABADIP, GHOSHPARA NEAR MONIPURGHAT	7.15	6.8	6.8	-	65000	50000	35500	-
	TRIBENI, NEAR BURNING GHAT	6.2	6.4	6.9	-	71500	50000	17000	-
	SHITALATALA, PALTA	6.25	6.4	5.7	-	130000	110000	94000	-
	PALTA	6.35	5.8	6.1	-	50000	130000	29500	-
	SERAMPORE	6	6.3	5.8	-	95000	50000	24500	-
	DAKSHINESHWAR	5.4	5.8	6.4	7	300000	130000	80000	79000
	SHIVPUR (HOWRAH)	6.2	5.3	5.2	7	160000	80000	70000	49000
	GARDEN REACH	5.1	5.5	5.5	7.1	240000	80000	70000	33000
	ULUBERIA	5.55	5.5	5.7	7.6	23000	22000	20000	17000
	DIAMOND HARBOUR	6.35	6.2	6.3	6.7	17000	1300	7450	6800

By using the data from Table 1, Tables 1 and 2 were created which condensed the information and made it specific to answering the research question. Faecal coliform values were averaged from all locations for each year and placed in a table (x-axis is year and y-axis is faecal coliform). Similarly, the dissolved oxygen levels were averaged from all locations for each year and placed in a table (x-axis is year and y-axis is dissolved oxygen).

Year	Faecal Coliform (MPN/100 ml)
2018	21,443.39
2019	15,011.03
2020	21,769.26
2021	21088.57

Table 2. Total average Faecal Coliform from 2018-2021

Year	Dissolved Oxygen (mg/l)
2018	7.87
2019	9.67
2020	8.08
2021	8.99

Table 3. Total average dissolved oxygen from 2018-2021

Type of Data

Quantitative Data, data collected and represented through numerical measurements and values. The 2 graphs in Fig. 1 and Fig. 2 are inverse of one another, demonstrating a negative correlation; an increase in faecal coliform levels causes a decrease in dissolved oxygen levels. When there was a peak in dissolved oxygen levels in 2019, as shown in Fig. 2, it can be inferred from Fig. 1 that this was due to low faecal coliform levels in 2019.

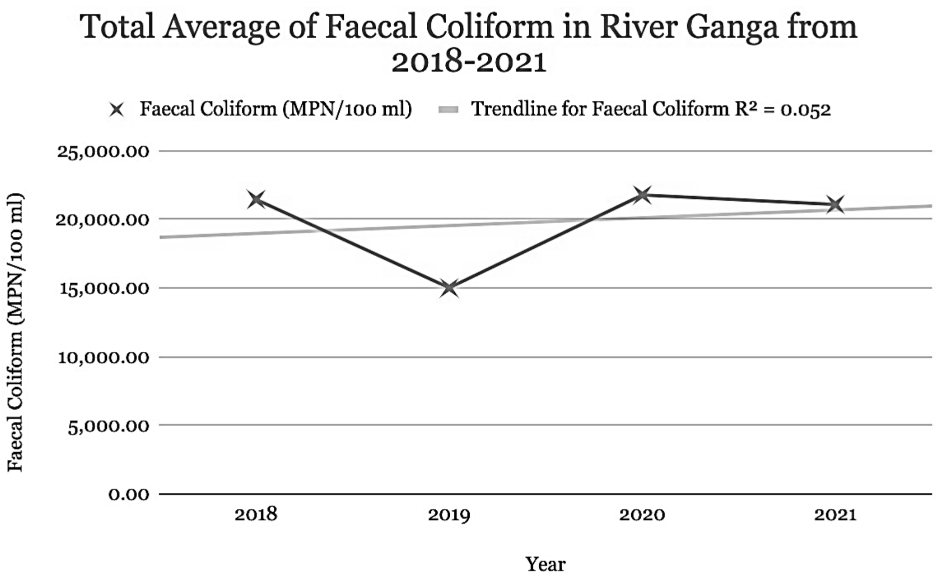

Fig. 1. Graph of the Total Average of Faecal Coliform in River Ganga from 2018-2021 (Graphed from data collected from PIB Delhi, & Central Pollution Control Board)

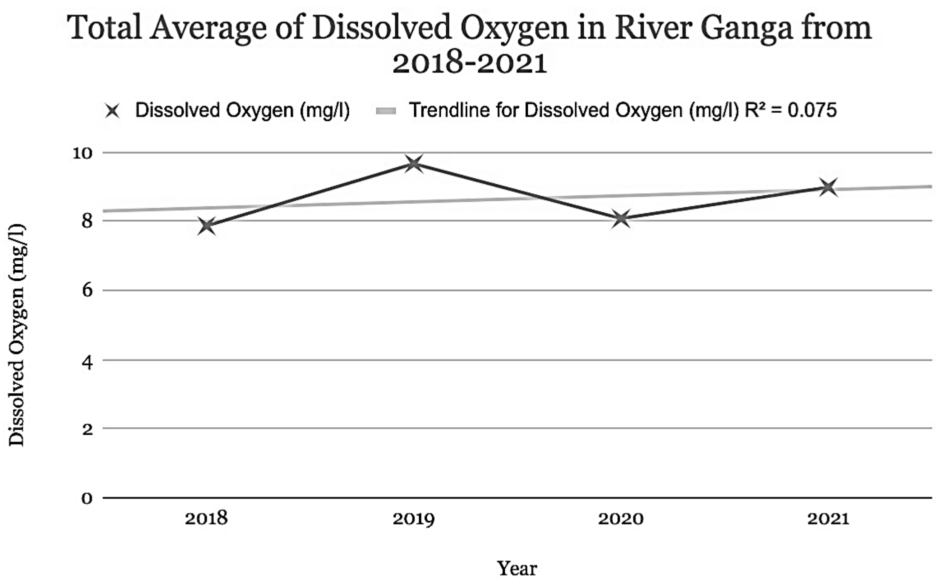

Fig. 2. Graph of the Total Average of Dissolved Oxygen in River Ganga from 2018-2021 (Graphed from data collected from PIB Delhi, & Central Pollution Control Board)

The general trend is that as faecal coliform levels increased, dissolved oxygen levels decreased. However, there was an anomaly in the last row, where the dissolved oxygen level increased instead of decreasing as predicted.

Faecal Coliform (MPN/100 ml)	Dissolved Oxygen (mg/l)
15,011.03	9.67
21088.57	8.99
21,443.39	7.87
21,769.26	8.08

Table 4. Average Faecal Coliform vs Average Dissolved Oxygen in River Ganga in Ascending Order of Faecal Coliform

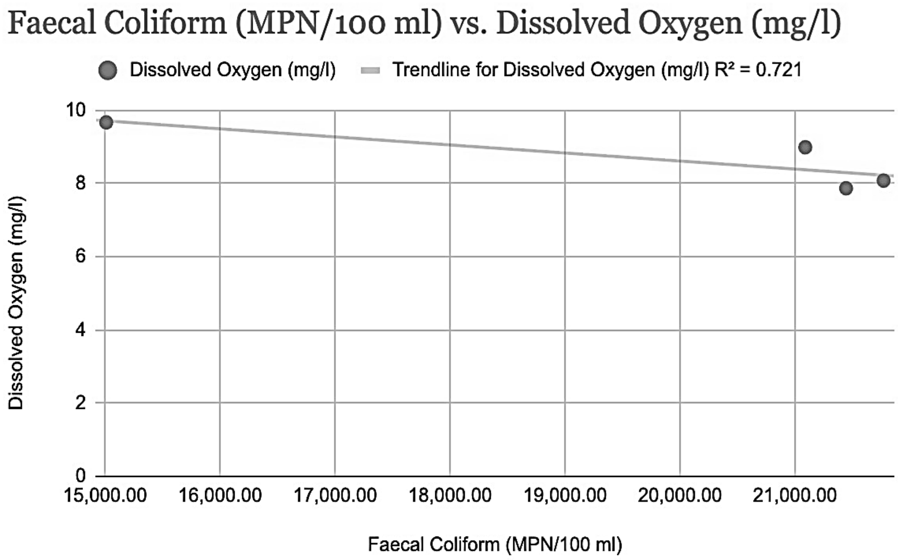

Fig. 3. Graph of the Average Faecal Coliform vs Average Dissolved Oxygen in River Ganga (Graphed from data collected from PIB Delhi, & Central Pollution Control Board)

In Fig. 3, when faecal coliform levels are graphed against dissolved oxygen, a downward slope is observed, indicating that as faecal coliform levels increase, dissolved oxygen levels decrease. All the data above conclude that when faecal coliform levels are high, dissolved oxygen levels are low. Throughout the years 2018 to 2021, the trend was not consistent, as in 2019, there was a drop in faecal coliform levels, followed by a rise and another small decline. Inversely, from 2018 to 2021, dissolved oxygen rose, then declined, and then rose again; this observation further supports the conclusion.

Discussion

The following conclusion was reached by observing that the dissolved oxygen and faecal coliform graphs were inverse of one another, for example, from 2018 to 2019, in Fig. 1 (faecal coliform), the trend is a downward slope, while in Fig. 2 (dissolved oxygen), the trend is an upward slope. The reason for this inverse relationship is that faecal coliform requires oxygen to be broken down, which decreases the dissolved oxygen levels in a water body. Hence, when faecal coliform levels were high, dissolved oxygen levels were low because oxygen was being used to break down a large amount of faecal coliform (there was a high biochemical oxygen demand). Likewise, when faecal coliform levels were low, dissolved oxygen levels were high because relatively little oxygen was being consumed to break down faecal coliform (low BOD). The graphs were created by taking the mean of all the sampling locations for each year. This made the data interpretation simpler and helped reach a more accurate conclusion. Moreover, when faecal coliform and dissolved oxygen levels were plotted against each other in Fig. 3, a downward trend was observed, suggesting that as faecal coliform levels increase, dissolved oxygen levels decrease.

An anomaly is observed in Table 4, where the final column shows that dissolved oxygen levels increase with an increase in faecal coliform levels. This difference may be due to natural variations in river conditions and to external environmental factors, such as water turbulence, seasonal flow variations, and localized oxygenation from aeration. In fast-flowing river systems like the Ganga, increased turbulence can increase the diffusion of oxygen into the water, leading to a temporary increase in the dissolved oxygen levels even in the presence of higher bacterial loads. Thus, it is likely that this anomaly is due to environmental and sampling variation and not a true positive association between the two variables. This explains the mid R^2 value of 0.849 in Fig. 4. It is important to note that although the relationship is evidently inverse and the R^2 value should be negative, Google Sheets calculates the square of the Pearson correlation coefficient, which is mathematically restricted to a range of 0 to 1. Moreover, by graphing the variables for 2018-2021 in Figs. 1 and 2, it can be concluded that time has no significant impact on water pollution in the Ganga River. There is no linear relationship, and the R^2 values of both graphs are between 0.05 and 0.075.

The results of this experiment were consistent with the findings of another experiment titled "Comparative Assessment of the Physico-Chemical and Bacteriological Qualities of Selected Streams in Louisiana", published in Int J Environ Res Public Health in 2005. One difference in the data of this lab with the lab conducted is that this lab compared faecal coliform bacterial colonies with biochemical oxygen demand, "BOD is a measure of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter" (Hill et al., 2005) . One of the selected streams in the experiment was Lake Claiborne, which had the lowest number of faecal coliform bacteria colonies, ranging from 100 to 200 CFUs/100mL. Consequently, it also had the lowest BOD at 3.96 mg/L (hence, the highest dissolved oxygen levels) and was ranked as good. Moreover, the Hill Farm Research Station Stream had a slightly greater number of colonies, with a mean of 249 CFU/100mL. This resulted in a BOD of 5.56mg/L, ranking it as fair (hence, slightly lower dissolved oxygen levels). On the other hand, Ray Pond had the highest bacterial colonies (482 CFU/100 mL) and BOD measurements (16/70 mg/L; hence, the lowest dissolved oxygen levels), giving it a ranking of poor (Hill et al., 2005).

When the levels of faecal coliform in the Ganga River are compared with those of the streams in Connecticut, USA, it is shown that Connecticut has a mean faecal coliform level of 293.6 CFU/100mL, while the Ganga River has an average faecal coliform level of 19,828.06 MPN/mL. Although the data from Connecticut water bodies dates back to 2005, and the data from the Ganga spans from 2018 to 2021, the difference remains immense and noteworthy. It is also vital to consider that the faecal coliform measurements used in the two comparison studies above use different microbiological methods of Colony Forming Units (CFU/100mL), representing the number of viable bacterial colonies capable of growing on agar plates. In contrast, the Ganga River data were in Most Probable Number (MPN/100mL), a statistical estimation method based on bacterial growth observed in dilution tubes. Although both methods are not directly interchangeable due to methodological differences, both are internationally accepted indicators of faecal contamination and water quality (Eurofins US, n.d.). Hence, the comparison made is to be interpreted qualitatively to demonstrate broader contrasts in contamination levels between the studied water bodies rather than as a precise quantitative equivalence.

Evaluation

Error/Limitation	Impact on the Lab	How to Fix it
Time Range of Data	The data collected was only considered for 4 years, and a long-term analysis was unable to be produced. This limitation weakens the validity of the conclusion, as a short time span is considered.	Finding and incorporating data from more years, both before 2018 and after 2021. A larger time range of data will help solidify the relationship between the two variables.
Reliance on Google Sheets for calculating the Mean	Systematic error remains a limitation because only the Google Sheets average function was used to compute the mean.	This error can be addressed next time by using multiple algorithms to calculate the mean.
Gaps in Data	There were several data gaps for certain sampling locations and years. This could explain the anomaly observed in Figure 7, where the final column shows that dissolved oxygen levels increased with an increase in faecal coliform levels.	This can be improved by reaching out to the institution that collected the data and expanding the study to a larger group, which will help collect more samples.

A major concept of this investigation is that the data are not original, but rather secondary; hence, several assumptions are made in the procedure and data collection, as well as potential limitations. Although the data is sourced from a government site, it does not dispel doubts about biases and inaccuracies. This can be addressed by combining data from multiple sources and calculating the mean across them to create a final dataset.

Another limitation is that this experiment examines a short-term temporal relationship between the two variables, as only data from 2018-2021 is analyzed, and a broader conclusion on whether the Ganga River is becoming more or less polluted over a longer time range cannot be made. This can be improved for future research by experimenting with a larger time range, for example, 10 years. The specificity of the exact years decreases the reproducibility of the investigation; however, the trend analyzed is consistent across all areas.
A strength of the method is its large sample size, as it collects samples across a wide range of locations along the Ganga River, encompassing all states and several cities of India through which the river passes. Instead of taking a sample from a single point along the Ganga and conducting an analysis, a more holistic and informed approach is to consider the entire river. Another strength of this application is that by studying the results of this investigation and comparing them with the community biomass or biodiversity of the Ganga, changes in aquatic life can be deduced with confirmation. For further investigation, the impact of faecal coliform levels on methane concentrations can be explored.

Conclusion

In conclusion, the data of this investigation supports the initial hypothesis that if there is an increase in faecal coliform concentration, it will lead to a decrease in dissolved oxygen levels; and a decrease in faecal coliform levels will lead to an increase in dissolved oxygen levels in the Ganga River as per data from 2018 to 2021. Additionally, the data indicated that there was no linear increase or decrease in faecal coliforms or dissolved oxygen over these years. This helps to obtain a bigger picture that the problem of high faecal coliform levels causing lower dissolved oxygen is not being completely addressed, or that the precautions and measures being taken are not effective.

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