A. Introduction

The inspiration for the research occurred to me as I was cycling around Powai Lake on my way home. While cycling, I noticed people immersing the remains of flowers, coconut, & a variety of other items that I couldn't even identify. There have been numerous religious ceremonies in the past where people immersed idols of God with various metal jewelries & colorful flowers, which could damage the aquatic flora & life. I also learned about how this toxic element causes water pollution & how quickly all pure & drinking water on Earth will become polluted if things continue at this rate. These lakes also provide water to Mumbai, which can be a problem in the long run because increased pollution in the lakes' explicit areas, affects the fishing economy as well as the food web in the lake. Also, change in the volume of oxygen in the environment would also influence the biodiversity. So, I decided to conduct this experiment on water samples collected from Powai Lake[1], Vihar Lake[2], & Tulsi Lake[3] to see how the water samples have been influenced by the human influence we have on them & how it has changed their oxygen conveyance limit. Hence, I have selected my Research Question '**Determine the dissolved oxygen content of water bodies of Mumbai because of normal human activities using Modified Winkler Method.**'.

B. Background Information

a. Dissolved Oxygen & Biochemical Oxygen Demand

The amount of oxygen dissolved in water is referred to as dissolved oxygen(DO) (EPA). It refers to free & non-compound oxygen in water or other liquids that participates in a variety of biochemical & physiological functions. Oxygen in water is present in both the free, dissolved form & as a bound form such as oxygen contained in a compound like sulphate & nitrate. Without dissolved oxygen the water go septic & result can be unsightly & foul-smelling. The amount of dissolved oxygen in water is an essential indicator of water quality & a factor in water purification. The dissolved oxygen concentration can reflect the environment's self-regulation; a high dissolved oxygen content, which promotes the decomposition of various pollutants in water, implies that the water can be cleansed swiftly. A low dissolved oxygen content, on the other hand, causes contaminants in water to degrade slowly. Dissolved Oxygen is sometimes confused with Biochemical Oxygen Demand. Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen (DO) required (i.e. demanded) by aerobic biological

[1] Latitude & Longitude - 19.127580270325737, 72.90487704528644
[2] Latitude & Longitude - 19.155022183109985, 72.90743281207504
[3] Latitude & Longitude - 19.19149471371686, 72.91808337204078

organisms to break down organic material present in a particular water sample at a specific temperature & time period. (Contributors)When we see the *Table 1*, we can make out how levels of oxygen change in Dissolved Oxygen go from a bigger number to a small number the higher number means there is more free non-compounded oxygen & vice versa. For Biochemical Oxygen Demand it is opposite of Dissolved Oxygen.

Quality	**Dissolved Oxygen / ppm**	**Dissolved Oxygen Condition**	**Biochemical Oxygen Demand / mgL^{-1}**	**Biochemical Oxygen Demand Condition**
Very Good	> 9.00	Supports abundant fish population	< 2	Very less organic matter in the water
Good	7.00 – 9.00	Supports growth/ activity	2 - 3	Clean
Fair	5.00 – 7.00	Supports Spawning	3 - 5	Moderate Clean
Poor	3.00 – 5.00	12 – 24hrs range of tolerance/ stressful condition	5 - 6	Partially polluted, contains organic matter
Very Poor	< 3.00	Too low for fish population	> 6	Very polluted contains lot of organic matter

Table 1 – Dissolved Oxygen Levels & Biochemical Oxygen Demand Levels

b. Modified - Winkler Method

Redox titrations are used to ascertain a substance's unknown concentration in solution. To determine dissolved oxygen levels in a water solution, Winkler's method use redox titration. The process is based on the oxidizing capabilities of potassium or sodium iodide by dissolved oxygen or the proclivity of free oxygen to bind to specific ions. The azide modification is used to eliminate the interference of sulphate & nitrates found physiologically in water bodies, which can occasionally cause undesirable inaccuracies in measuring dissolved oxygen.

The dissolved molecular oxygen in the water sample is not capable of reacting with potassium iodide hence we use Manganese hydroxide which acts an oxygen carrier & brings about the reaction between dissolved oxygen & potassium iodide. This procedure is ineffective for oxidation of sulfite, thiosulfate, polythionate, or the organic matter in wastewater.

Manganous sulphate + Oxygen + Alkali–iodide reagent → Manganic hydroxide

In the first reaction the $2Mn^{2+}$ which is added to the H_2O sample in the form of manganese sulphate in the presence of oxygen is oxidized to Mn4+ which precipitates as a brown color $2MnO_2$ (s) + $2H_2O$ (l).

$$2Mn^{2+}{}_{(aq)} + O_{2(g)} + 4OH^{-}{}_{(aq)} \rightarrow 2MnO_{2\,(s)} + 2H_2O_{\,(l)}$$

$$Manganous\ sulphate + Oxygen + Alkali\text{-}iodide\ reagent \rightarrow Manganic\ hydroxide$$

In the second reaction it is dissolved by the addition of concentrated sulfuric acid to again form manganese sulphate under the influence of this low pH condition the manganese hydroxide oxidizes the iodide ions to free iodine.

$$MnO_{2(s)} + 2I^{-}{}_{(aq)} + 4H^{+} \rightarrow Mn^{2+}{}_{(aq)} + I^{2}{}_{(aq)} + 2H_2O_{(l)}$$

$$Manganic\ hydroxide + Iodide\ (from\ KI) + Conc.Sulphuric\ acid$$
$$\rightarrow Manganous\ Sulphate + Free\ Iodine + Water$$

In the third reaction which takes place during the titration of the free iodine with sodium thiosulphate the thiosulphate ions reduce the free iodine to iodide ions the amount of iodine present at this stage is directly related to the amount of oxygen present in the water sample. One mole of oxygen reacts with four moles of thiosulphate ions as can be seen in the overall reaction equations. The titration is complete when all the free iodine has been converted to iodide ions. The end point of the titration is determined using a starch indicator which from deep blue to colorless.

$$I_{2(aq)} + 2S_2O_3^{2-}{}_{(aq)} \rightarrow S_4O_6^{2-}{}_{(aq)} + 2I^{-}{}_{(aq)}$$

$$Free\ Iodine + Sodium\ Thiosulphate \rightarrow Sodium\ Tetrathionate + Sodium\ Iodide$$

C. Experiment

a. Variables

Independent Variable		
Type of water source	The independent variable is the three lakes from where I collected the water sample. They are Powai Lake, Vihar Lake & Tulsi Lake. The fourth sample of water was the tap water, which was selected as a base value.	
Dependent Variable		
Dissolved Oxygen	This dependent variable is calculated using the Modified Winkle Method. In this variable we will calculate the amount of oxygen dissolved in all four samples selected.	
Control Variable		
Amount of Manganous Sulphate Reagent	Used 1ml of Manganous Sulphate solution in all 100ml water sample.	Prepared when 24g of Manganese Sulphate tetrahydrate is added to 25ml of distilled water & made the total volume to 50ml.
Amount of Alkaline Iodide Azide Reagent	Used 1ml of Alkaline Iodide Azide solution in all 100ml water sample.	Prepared with 25g of Sodium Hydroxide & 6.25g of Sodium Iodide which is added to 15ml of distilled water. Added 0.5g of Sodium Azide & made the total volume to 50ml.
Amount of Starch Indicator Reagent	Added 1g of soluble starch in 2ml water & then add it to 100ml of boiling water & mix. The concentration is 0.5%.	
Amount of Sodium Thiosulphate Solution Reagent	Weight 0.20g of Sodium Thiosulphate & dissolved it in 100ml distilled water.	

Amount of Potassium Permanganate Reagent	Used 1ml of Potassium Permanganate solution in all 100ml water sample.	Prepared using 0.0632g of potassium permanganate in 10ml of distilled water.
Amount of Potassium Oxalate Solution Reagent	Used 0.5ml of Potassium Oxalate solution in all 100ml water sample.	Prepared using 0.02g of potassium oxalate in 10ml of distilled water.
Concentration of Sulphuric Acid	The concentration used was 96% & 17 Normal.	
Temperature of Room	This experiment was performed in a closed lab will all the windows & doors closed in an air-conditioned room at 22°C.	With a change in temperature, there is a change in the amount of dissolved oxygen. Therefore, temperature had to be kept constant.
Pressure of the Room	This experiment was performed in a closed lab will all the windows & doors closed in an air-conditioned room at 101kPa.	With a change in pressure, there is a change in the amount of dissolved oxygen. Therefore, pressure had to be kept constant.
Volume of water sample used	100.0ml of water was measured using a measuring cylinder & used	Different volume of water used can affected the dissolved oxygen.
Time of the Experiment	All the trials were conducted on the same day within of 7hrs of time.	As different day would have different surrounding temperature & cause change in dissolved oxygen

Table 2 – Independent, Dependent & Control Variable

b. Apparatus

Apparatus Name	Quantity	Size
Beaker	2 4 3	10 ml 100 ml 250 ml
Stirring Rod	5	
Funnel	5	
Dropper	2	
Volumetric Flasks	3 2	100 ml 1000 ml
Volumetric Pipettes	4 1 2	1 ml 5 ml 10 ml
Conical Flask	3 1	250 ml 1000 ml
Measuring Cylinder	1 1	100 ml 500 ml
Burette	1 1	25 ml 50 ml
Burette Stand	2	
BOD Bottles	2	300 ml
Pipette Dispenser	2	
Weighing Scale	1	
Spatulas	1	
Gloves, Goggles & Lab Coat	1	

Table 3 - Apparatus

c. Procedure

1. Collection of Water Sample

i. Take a BOD bottle with intact stopper.
ii. Immerse it to the desired depth in the water source.
iii. Remove the stopper of the BOD bottle and let the water seep into bottle.
iv. Put on the stopper again on the top of the bottle once it is filled.
v. Make sure no air bubbles are trapped in the BOD bottle.
vi. Repeated the step with other source of water.

2. Oxygen Fixation

i. Remove the stopper from the bottle.
ii. Add 0.84ml of concentrated sulphuric acid to the sample.
iii. Immediately add 1ml of potassium permanganate using a second pipette.
iv. Mix well by inverting the bottle several times & leave aside for at least 20mins.
v. The typical violet color of permanganate should persist for at least 20mins. If not, add a small quantity of permanganate solution. Mix well by inversion.
vi. Repeat the addition of permanganate until the color persists for at least 20mins.
vii. Now add 0.5ml of potassium oxalate solution & mix well by inversion several times. Set aside undisturbed for about 5mins.
viii. If the color of the permanganate persists, after addition of oxalate solution, add another 0.5ml of oxalate solution & mix well.
ix. When the permanganate color has disappeared completely proceed to the next part of oxygen fixation.
x. Add 1ml of manganous sulphate solution to the water sample using 1ml pipette.
xi. Add 1ml of alkaline iodide azide reagent to the sample using another pipette.
xii. Make sure that the pipette tip is immersed well below the water surface in the bottle when adding the reagents.
xiii. Now carefully add the stopper not introducing any air bubbles.
xiv. Observation – Brownish precipitate.

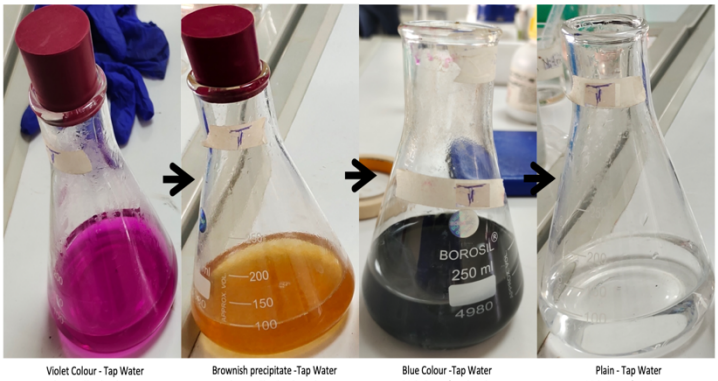


Figure 1 Change in colour

xv. Pour the excess water sample which was displaced from the bottle during the addition of the reagents into a waste beaker.

xvi. Then thoroughly mix the content of the bottle by inverting it several down.

xvii. Allow the precipitate to settle down.

xviii. Using a 1ml pipette carefully add 1ml of concentrated sulfuric acid by allowing it to flow down along the neck of the bottle.

xix. Make sure that the pipette tip is immersed well below the water surface in the bottle when adding the reagents.

xx. Place the stopper & pour the excess water sample which was displaced from the bottle during the addition of the reagents into a waste beaker.

xxi. Then thoroughly mix the content of the bottle by inverting it several down.

xxii. Using a 100ml measuring cylinder introduce it into a 250ml or 500ml conical flask.

3. Main Procedure

i. Fill burette up to the zero mark with standard sodium thiosulphate solution using a funnel.

ii. Now titrate the sample using the standard thiosulphate solution in the burette dropwise.

iii. Do so until the brown color of the sample in the flask becomes pale yellow or straw yellow.

iv. The add 4 drops of starch indicator solution to the sample. The sample turns becomes blue.

v. Immediately continue the titration until the first disappearance of the blue color on the addition of the single drop of the thiosulphate to the sample.

vi. Repeat the titration about two more times using fresh 100ml sample in fresh conical flask to obtain accurate mean titrate value.

D. Data

a. Raw Data

Burette Reading/ mL ± 0.1 mL	Water Source	Trial 1			Trial 2			Trial 3			Average Trial			Sodium Thiosulphate Used
		Initial	Final	Change	Initial	Final	Change	Initial	Final	Change	Initial	Final	Change	
	Tap Water	0.0	9.4	9.4	0.0	9.3	9.4	0.0	9.1	9.1	0.0	9.3	9.3	9.3
	Tulsi Lake	0.0	7.4	7.4	0.0	7.6	7.6	0.0	7.7	7.7	0.0	7.6	7.6	7.6
	Powai Lake	0.0	6.9	6.9	0.0	7.3	7.3	0.0	7.1	7.1	0.0	7.1	7.1	7.1
	Vihar Lake	0.0	8.3	8.3	0.0	8.4	8.4	0.0	8.6	8.6	0.0	8.4	8.4	8.4

Table 4 – Raw Data

The data in *Table 4* show how much sodium thiosulphate was used to titrate 100ml of water from various sources. The table is organized into six primary columns & five rows.

Row 1 contains the Trail number, such as Trial 1, Trial 2, Trial 3, Average Trial, & Sodium Thiosulphate used. The sub row under Trial 1 is the initial burette reading, final burette reading and change in burette reading. The initial burette reading is set to 0.0 ± 0.1 mL, the same is for Trial 2, Trial 3, & Average Trial. The formula used to calculate the Initial Average Trial value is $Initial\ AT = \frac{[Initial\ Trial\ 1]+[Initial\ Trial\ 2]+[Initial\ Trial\ 3]}{3}$. The formula used to calculate the Final Average Trial value is $Final\ AT = \frac{[Final\ Trial\ 1]+[Final\ Trial\ 2]+[Final\ Trial\ 3]}{3}$. The Sodium Thiosulphate used is calculated using the formula $STU = Final\ Average\ Trial - Initial\ Average\ Trial$. The numbers in the table are in milliliters & were measured with a burette with an uncertainty of ±0.1ml. Row 2 shows data for all trials as well as the average trial for the water sample collected from Tap Water. Row 3 provides the data for all the trials as well as the average trial for the Tulsi Lake water sample. Row 4 shows data for all trials as well as the average trial for the water sample collected from Powai Lake. Row 5 shows data for all trials as well as the average trial for the water sample collected from Vihar Lake.

b. Processed Data Calculation

i. First step is to calculate the moles of Sodium Thiosulphate for which the formula used is $\text{mol} = \frac{\text{mass}}{\text{molar mass}}$ hence when we substitute the value $\text{mol} = \frac{0.2\text{g}}{[(22.99\times2)+(32.07\times2)+(16\times3)}$ for which we got the value of $\text{mol} = 1.26 \times 10^{-3} mol$.

ii. Second step is to calculate the concentration of Sodium Thiosulphate for which the formula used is $\text{conc.} = \frac{\text{moles}}{\text{volume of solution (dm}^3\text{)}}$ hence when we substitute the value $\text{conc.} = \frac{1.26\times10^{-3}\text{mol}}{0.1\ \text{dm}^3}$ for which we got the value of $\text{conc.} = 0.0126\ \frac{\text{mol}}{\text{dm}^3}$.

iii. Now we know both the mol & conc. of Sodium Thiosulphate hence we will start with calculating the amount Thiosulphate. The formula used is $\text{mol} = \text{conc.} \times \text{Volume}$. When we subsite the value $\text{mol} = 0.0126 \times \frac{9.6}{1000}\text{dm}^3$. The value we got is $\text{mol} = 1.1844 \times 10^{-4} mol$.

iv. From the reacting ratio in third reaction[4], $2S_2O_3^{2-} : I_2 = 2 : 1$. The value we will get for I_2 got is $\text{mol} = \frac{1.1844\times10^{-4}}{2} = 5.922 \times 10^{-5} mol$.

v. From the reacting ratio in second reaction[5], $MnO_2 : I_2 = 1 : 1$. The value we will get for MnO_2 got is $\text{mol} = 5.922 \times 10^{-5} mol$.

[4] Pg.3 → $I_{2(aq)} + 2S_2O_3^{2-}{}_{(aq)} \rightarrow S_4O_6^{2-}{}_{(aq)} + 2I^-{}_{(aq)}$

[5] Pg.3 → $MnO_{2(s)} + 2I^-{}_{(aq)} + 4H^+ \rightarrow Mn^{2+}{}_{(aq)} + I^2{}_{(aq)} + 2H_2O_{(l)}$

vi. From the reacting ratio in first reaction[6], $2MnO_2 : O_2 = 2 : 1$. The value we will get for O_2 got is mol $= \frac{5.922\times10^{-5}}{2} = 2.961 \times 10^{-5} mol.$

vii. So, when we directly go from $S_2O_3^{2-} : O_2 = 4:1$.

viii. Now we need to express the amount of O_2 as $\frac{g}{cm^3}$. Hence, we will use the equation mass = mol $\times$ molar mass so if we substitute the value mass $= 2.961 \times 10^{-5}$mol $\times$ 32 g/mol so we will get the mass $= 9.4752 \times 10^{-4}$g.

ix. To find the dissolved oxygen we need to divide the mass of oxygen with the sample of water used DO $= \frac{9.4752\times10^{-4}\ g}{100\ cm^3}$ so the DO $= 9.4752 \times 10^{-6} \frac{g}{cm^3}$. Hence when we convert $1\frac{g}{cm^3} =$ 1000000 *Parts per Million*. The value get from calculation is DO $= 9.5$ppm

x. Uncertainty of dissolve oxygen is ±0.2 ppm which the relative uncertainty of the burette used for titration which is ±0.1cm^3 & the relative uncertainty of measuring cylinder used to measure the water sample which is ±0.1ml.

c. Processed Data

Dissolved Oxygen ± 0.2 ppm	Water Source	Trial 1	Trial 2	Trial 3	Average Trial
	Tap Water	9.5	9.4	9.2	9.3
	Tulsi Lake	7.5	7.7	7.8	7.6
	Powai Lake	7.0	7.4	7.2	7.2
	Vihar Lake	8.4	8.5	8.7	8.5

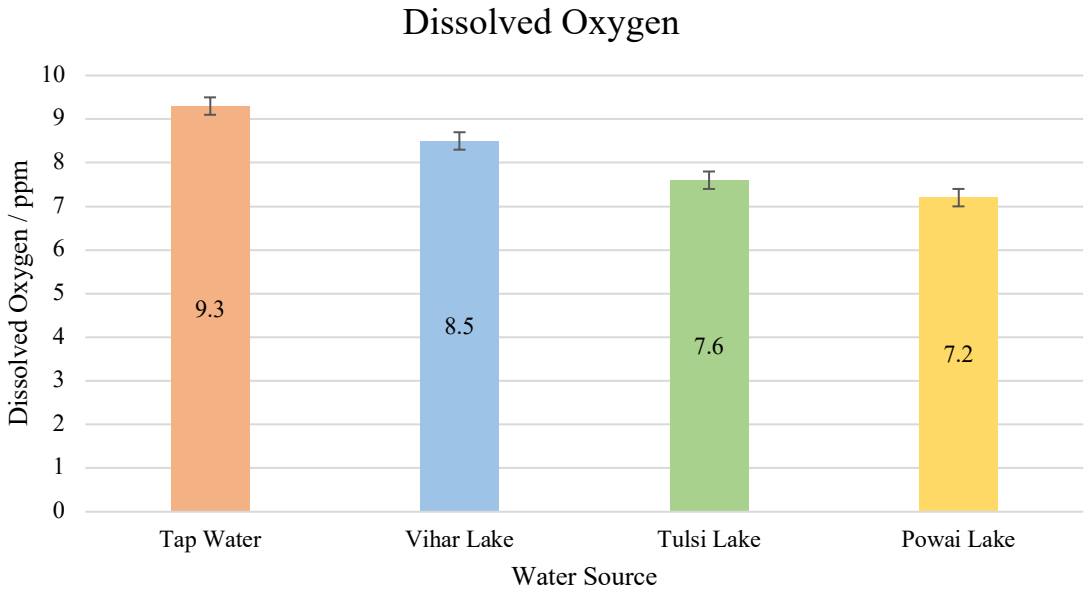
Table 5 – Processed Data

The data in *Table 5* show how much dissolved oxygen is present in different source of water. The table is organized into five primary columns & five rows. Row 1 contains the Trail number, such as Trial 1, Trial 2, Trial 3, & Average Trial. The data in the table is calculated the same way it is done for the Trial 1 of Tap Water under the heading Processed Data Calculation.

Row 2 has the data for Tap Water, Row 3 as the data for Tulsi Lake, Row 4 as the data for Powai Lake, Row 5 as the data for Vihar Lake.

[6] Pg.3 → $2Mn^{2+}{}_{(aq)} + O_{2(g)} + 4OH^-{}_{(aq)} \rightarrow 2MnO_{2\,(s)} + 2H_2O_{\,(l)}$

d. Processed Data Graph



Graph 1 Processed Data Graph

We are comparing the dissolved oxygen content of different sources of water hence the graph is a bar graph. The graph shows that the level of dissolved oxygen is higher in tap water. Because there are few organisms in tap water, the amount of oxygen necessary for them to respire is low & the water is purified & made safe to drink, & so the BOD of this water is less than $3mgL^{-1}$. The water sample from Vihar Lake has the second highest concentration of dissolved oxygen. The Vihar lake covers an area of 7 km^2. As a result, surface area is a key element influencing the dissolved oxygen level of water. Also, the lake has been a restricted area since 1993, therefore most other human activities that affects the lake is limited, so the lake is pouring, & the city obtains most of its water from Vihar Lake. The Tulsi Lake water sample has the third highest dissolved oxygen level. Tulsi Lake covers an area of $1.35km^2$. Because surface area is essential, we can notice a 0.9ppm drop in the quantity of oxygen available in the lake when compared to Vihar lake. Furthermore, because the lake is a confined area, there are fewer human activities that can impact the water quality, & it is the city of Mumbai's second largest lake after the Vihar Lake. The Powai Lake water sample has the fourth highest dissolved oxygen level. Powai Lake covers an area of $2.10km^2$. As we all know, surface area is important, but in the case of Powai Lake, it has a larger surface area, but due to its proximity to a human metropolitan area, there are many activities that take place in this lake, such as Ganesh Visarjan[7], global warming, agriculture, & the disposal of local waste. This demonstrates that, although having a bigger surface area, human activities have a significant

[7] Ganesh Visarjan is a Indian festival observed & celebrated by Jains & Hindus annually.

influence in water contamination, & as a result, the Powai Lake is no longer appropriate for human consumption.

E. Conclusion

The experiment's principal goal was to determine how human activities have affected waterbodies. We can clearly observe from the data above that Powai, which is adjacent to human habitat, is more affected, despite having a surface size of 2.10km^2. Lakes such as Tulsi & Vihar are protected from human interference & have a high dissolved oxygen level. When compared to Tulsi Lake, Vihar Lake has a bigger surface area & thus a higher concentration of dissolved oxygen. The conclusions reached prior to doing the experiment were very similar to the data received after the experiment. The result reached was that tap water would have the maximum oxygen level, followed by Vihar Lake, & there was considerable ambiguity about the oxygen content of Tulsi Lake & Powai Lake. However, after carrying out the experiment & research, all is now evident. Some of the ethical issues faced by this experiment include the usage of around 1.2 liters of water to conduct all the trials; after the trials, the water was discarded, but this water could have been utilized in a location where it is essential by the people who live there. The chemicals utilized in the experiment while manufacturing leave a carbon footprint, which contributes to global warming & has contributed to a decline in the dissolved oxygen level of aquatic bodies. The modified Winkler Method was employed in this experiment, which ensures that nitrates & sulphate do not interfere with the system & provide an accurate readout of the amount of dissolved oxygen, this is the strength of the experiment There is a lot of potential for this experiment technique to be used in the future, such as by persons working in the aquatic market to help them maintain the amount of oxygen required for the fish to live & grow healthily. Biologists can use the technique to forecast the future oxygen levels in bodies of water. The constraint was that when water was taken from a body of water, it was not possible to fix the oxygen at that location; there was a time delay between collecting the water & fixing the oxygen. Water was collected from the lake's bank, where there was a lot of biological material (algae, mud, papers) present, which entered the bottle with the water sample; it should have been collected from the center of the water body for precise measurements, but lakes were restricted, so only allowed to collect from the bank. By the fact that the water was not filtered before being put into the flask; if the water was exposed to air, the oxygen level may fluctuate, the particles in the water were sediment & decant, but some may still be transferred to the flask this resulted in random error. The concentration or molarity of the solution, as well as the chemicals utilized in the reactions, could induce systematic errors, because the reagents & solutions were only prepared once & utilized in all the trials.

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