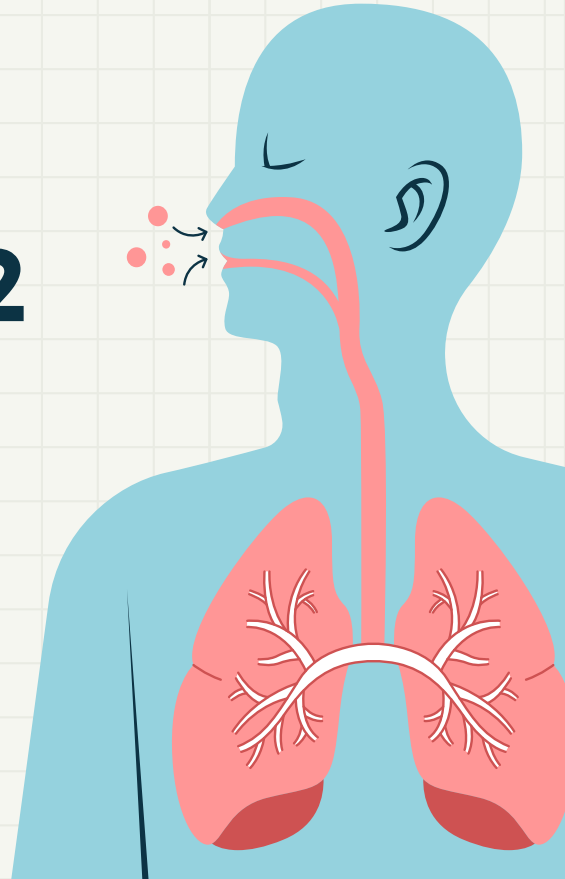
The Effects of Exercise on CO^2 Respiration.

Science Fair 24-25
Navneeth 8-5 & Shreyas 8-3
Fairview School



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The QUESTION...

...that's guiding our research and project.

The QUESTION

How does **exercise** affect the average **person's carbon dioxide output**?

?

II

The HYPOTHESIS...

...our prediction of the outcome of our experiment.

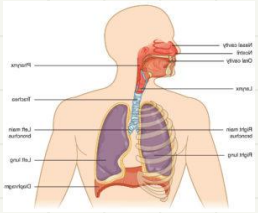
The HYPOTHESIS

If a person **exercises**, **then** their **CO^2** output will **increase, because** the **heart** has to pump excess amounts of **blood** that saturates **oxygen,** which spreads around the body **faster** than normal. This is due to the body needing **extra oxygen**, for the **muscles, ligaments** and other **body parts** to function under stress. The blood returns to the lungs in a **deoxygenated** state, with the blood containing **CO^2**, which, through respiration, exits the body.

Background RESEARCH...

...to understand our experiment.

Background RESEARCH



What is respiration?

- To put it simply, **respiration** is another term to describe **breathing**.
- In the process of respiration, we are moving **gases** in and out of our **lungs.**
- Specifically, respiration is inhaling **oxygen (O^2)** from the air around us, and thus expelling any unwanted **carbon dioxide (CO^2)** content from our lungs.

How do respiration and blood circulation relate?

- When a person **breathes** in, the oxygen in the air travels through the **larynx**, **trachea** and **bronchi** to the lungs.
- In order for the oxygen to reach organs, it travels via the **bloodstream**.
- The lungs and heart work together to exchange oxygen and carbon dioxide in the lungs from the blood. This process is called **gas exchange**.
- After **deoxygenated blood** exits the heart through the **pulmonary artery**, it travels to the **lungs** to get **oxygen**.

Background RESEARCH

How do respiration and blood circulation relate?

- After **oxygen** is replenished, it **saturates** the blood, and the blood enters the heart through the **pulmonary vein**.
- **Blood oxygen saturation** is measured as **SP02%**, with a level of 95-100% being ideal. This can indicate **breathing rate** as well.
- The **oxygenated blood** then travels away from the heart through the **arteries**, and returns to the heart in a **deoxygenated** state through the **veins**.
- The process then **repeats**. If breathing rate is **higher**, the process happens faster in order to provide ample **oxygen** amounts to all **parts of the body**.
- Information like **SP02%**, **breaths per minute**, and **heart rate** can determine if a person is breathing and if their body's functioning **correctly**.

Background RESEARCH

What does pH mean?

- The term **pH** is a term used in chemistry which stands for "The **potential of hydrogen**".
- In more chemistry aligned terms, it is primarily determined by the amount of hydrogen **ions** in a substance, alongside **various other factors**.
- **pH = -log[H+]** is the formula used to determine pH. It is the **negative logarithm** of the concentration of hydrogen ions in a substance (Base 10).
- It's a **numerical** way of measuring how **basic/alkaline** or **acidic** a substance is.
- In this experiment, we used a **colorimetric** pH test which changed in colour depending on how **acidic** or **basic** the solution was.

Background RESEARCH

What does pH mean?

- Generally, the **more acidic** a solution, the **lower the number** associated with it, and the more **basic**, the **higher number** associated with it. A pH level of **7** is considered **neutral** and is associated with **distilled** water.
- Therefore the more **alkaline** water is, the **lower** amount of **hydrogen** is in it, the **higher boiling** point it has (due to lesser particle density meaning less kinetic energy and more time needed for heat to spread out) and the **higher the pH level** is.
- As we're measuring **carbon dioxide** output in this experiment, we're going to be checking how **acidic** the water is after **respiration**, due to carbon dioxide being an **acidic gas**.

IV

The MATERIALS...

...we needed to complete our experiment.

Our MATERIALS

To build the respirators

- 2 plastic water bottles
- Tap water (167 ml per bottle)
- Scissors
- Aerator Setup
- Safety Valve

To do the experiment

- Bromothymol blue solution (5ml in total per respirator)
- Lab partner- to record info
- Stopwatch
- PH strips
- Watches with heart rate monitoring (different watches with each person.)

V

The VARIABLES...

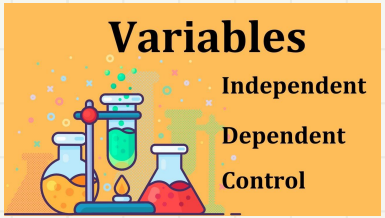
...that shape our experiment.

The VARIABLES

Manipulated (Independent) Variable: Whether the tested person(s) **exercises** or not prior to breathing into the respirator.

Responding (Dependent) Variable: Amount of **carbon dioxide** (CO^2) output by the tested person before and after they exercise. We also analyze the possible **implications** of lower **breathing** and **heart rates**, as well as factors that can cause this.

Controlled (5): Same location, Same person (for each set of trials), Same amount of time **breathing** into the respirator for each trial (15 seconds), Same amount of time **exercising** ahead of respiration (1 minute per trial), Same type of **pH strips** used throughout.



VI

The PROCEDURE...

...we will use in our experiment.

The PROCEDURE (First Experiment)

1. Create our respirator (link used in bibliography for ideas, actual respirator in images)
2. Place 5 ml of the bromothymol blue solution into 167 ml of tap water.
3. The first tested person will breathe into the respirator without having done exercise, and their lab partner will check the color of the water 60 seconds after the tested person finishes breathing, and after 60 seconds they will check the PH levels of the water using PH strips.
4. Then, the lab partner will aerate the water using the oxygen aerator setup, sending it back to its original state
5. Repeat steps 3–4 three times, and record the results of each trial
6. After trial #3, make the tested person complete any form of aerobic exercise(push ups, jumping jacks, etc) for 1 minute
7. Then, repeat steps 3-4 again, ensuring that the tested person completes exercise ahead of breathing into the respirator, while still recording the results of each trial.
    - We will also be checking the person's heart rate before and after they exercise to see how heart rate affects their carbon dioxide output.
8. Using the PH levels from the 3 trials the tested person did without exercising, and the 3 they did after exercising, we will determine the difference in CO_2 output.

The PROCEDURE (Second Experiment)

To understand the true effect of CO_2 what we measured in the experiment was modified to identify the time it takes to change the water colour between resting and exercise trials, per the procedure below:

1. Place 5 ml of the bromothymol blue solution into 167 ml of tap water, and 5ml in the 167 ml of distilled water.
2. The first tested person will breathe into the respirator with the tap water in it without having done exercise, and their lab partner will wait until they change its colour from teal to green. Then, they'll track how long the person had to breathe in the respirator to do this.
3. Then, the tested person will breathe into the respirator with the distilled water in it, and their lab partner will wait until they change the water colour from pale to golden yellow. Then, they'll track how long it took for them to do this
4. After they breathed into both respirators, the lab partner will aerate both respirators, back to their original states.
5. Repeat steps 3-5 two more times to end up with 3 trials in total.
6. Then, complete steps 3-5 three more times, this time ensuring that the tested person exercises for 1 minute before breathing into the respirator this time.
7. Now, compare your results from the trials with and without exercise. The shorter it took to change the colour of the water, the more CO2 was outputted by the person.

VII

The DATA and OBSERVATIONS...

...from our experiment.

The DATA

Bromothymol blue (raw solution) initial pH level

pH = 7-ish. The pH strips we used only gave **approximations** for each level so we were unable to find out the exact decimal point pH level. The pH strips **dried out** quickly so later on they gave the illusion that the level was 6. Due to the strips **not** giving a **precise** and **decimal-point** result, we only have an approximate reading.

We discovered that bromothymol works **best** in fluids with 6.0 to 7.6 pH, and it's commonly used in fluids with a pH level of **approximately** 7. The colour also changes depending on that pH level. Bromothymol blue turns **yellow** in solutions with pH < 6.5, **green/teal** between 6.5 - 7.2 and **blue** at pH > 7.2.

The DATA

Navneeth (resting)

Trial #	Duration of Respiration	Heart Rate immediately after resting period (bpm)	Water colour 1 minute after respiration	pH level 1 minute after respiration
1	15 sec	98	teal	6
2	15 sec	88	light greenish teal	8
3	15 sec	83	green	7

The DATA

Shreyas (resting)

Trial #	Duration of Respiration	Heart Rate immediately after resting period (bpm)	Water colour 1 minute after respiration	pH level 1 minute after respiration
1	15 sec	78	dark teal	7
2	15 sec	67	dark teal	7
3	15 sec	66	dark greenish teal	7

The DATA

Navneeth (exercise)

Trial #	Type of exercise completed	Duration of Respiration	Heart Rate immediately after resting period (bpm)	Water colour 1 minute after respiration	pH level 1 minute after respiration
1	Jumping Jacks	15 seconds	131	green	7
2	Jumping Jacks	15 seconds	136	green	7
3	Jumping Jacks	15 seconds	161	green	7

The DATA

Shreyas (exercise)

Trial #	Type of exercise completed	Duration of Respiration	Heart Rate immediately after resting period (bpm)	Water colour 1 minute after respiration	pH level 1 minute after respiration
1	Jumping Jacks	15 seconds	130	teal	7
2	Jumping Jacks	15 seconds	136	teal	7
3	Jumping Jacks	15 seconds	135	green	7

The OBSERVATIONS

pH Averages

Navneeth (without exercise) - 7.3
Shreyas (without exercise) - 7
Navneeth (with exercise) - 7
Shreyas (with exercise) - 7

We noticed that **overall** the pH level is near 7, which likely means one of two things:

- Bromothymol doesn't have it's own pH, adapting to the fluid (We later realized this was true),
- OR the bromothymol's pH level is 7, and that level isn't affected by CO^2 (we later realized this is false)

We only have the bromothymol-water solution provided to us by Mr. DeGelder, a science teacher at our school, so therefore we're unable to test the pH of the bromothymol itself, due to it being a powder. As we'll mention in a bit, the pH of the raw solution we got could be slightly inaccurate.

The OBSERVATIONS

We noticed that after the person had exercised, their heart rate **skyrocketed** from the 80s and 90s to the 130s and 150s. Also, we noticed that the water colour changed quite **significantly** after the person exercised, turning into a **lighter** shade, meaning that **more** oxygen was inhaled, and **more** CO^2 was exhaled. Evidence of this is the fact that during the trials **without** exercise, generally the colour was **darker and more blue-ish**, but **after** exercise, the colour was more **lighter and greenish.** Generally, the **lighter** the colour of water, the **more** $\mathbf{CO^2}$ is being utilised, and while the pH didn't change much, we realized that bromothymol **doesn't have its own** pH, instead remaining the same as the fluid it resides in. We also realized that CO^2 **doesn't affect** pH levels **significantly** from what we tested, even in **combination** with bromothymol. Thus, the colour of the water proved to be a more **deciding factor** in our experiment, to aid us in **supporting** our hypothesis.

The OBSERVATIONS

After our first experiment, we realized a lot of things could be **changed** to **improve** our experiment, such as measuring how **long** it takes to change the water to a certain **colour**, while also testing whether **distilled** or **tap** water would be more **accurate**.

We filled one respirator with **tap** water and the other with **distilled** water. For the tap water respirator, we noticed the starting colour was **teal**, and the distilled water respirator starting colour was **yellow**, as opposed to the deep **blue** of the first experiment we conducted. We'll explain some of our **theories** for why this could be later.

We conducted **another set of trials** and the data is on the following slides.

Before we started, we took **pH** measurements of plain **tap** water and **distilled** water. The tap water's pH was **7**, and the distilled water's pH was **6**. The distilled water had **ozone** which is slightly **acidic**, leading to this measurement.

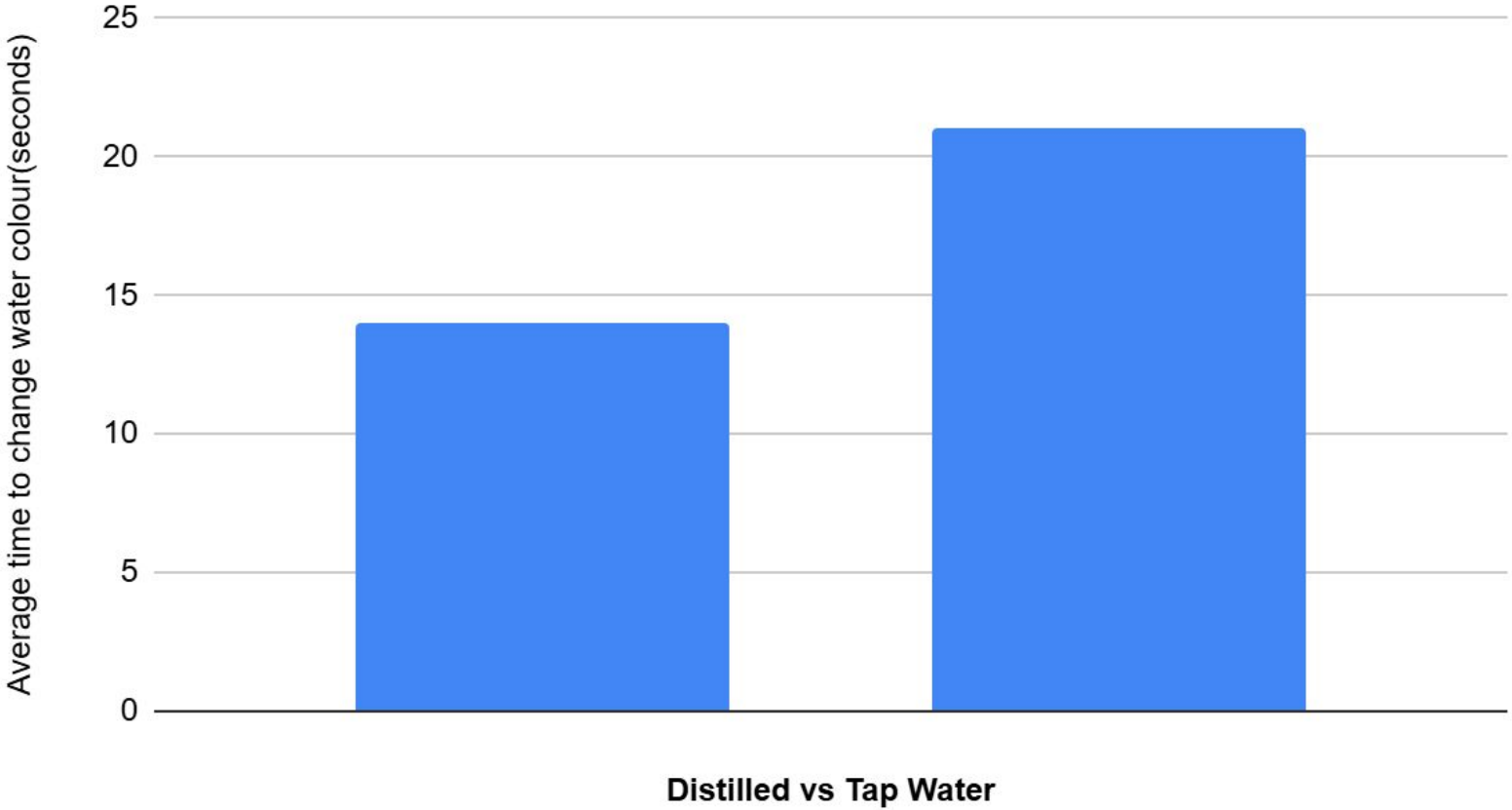
The DATA

D=Distilled Water
T= Tap Water

Navneeth (resting)

Trial #	Time to change colour (seconds)	Colour of water
1	D: 18 T: 21	D: Gold Yellow T: Deep green
2	D: 13 T: 22	D: Gold Yellow T: Deep green
3	D: 11 T: 20	D: Gold Yellow T: Deep green

Navneeth (resting)



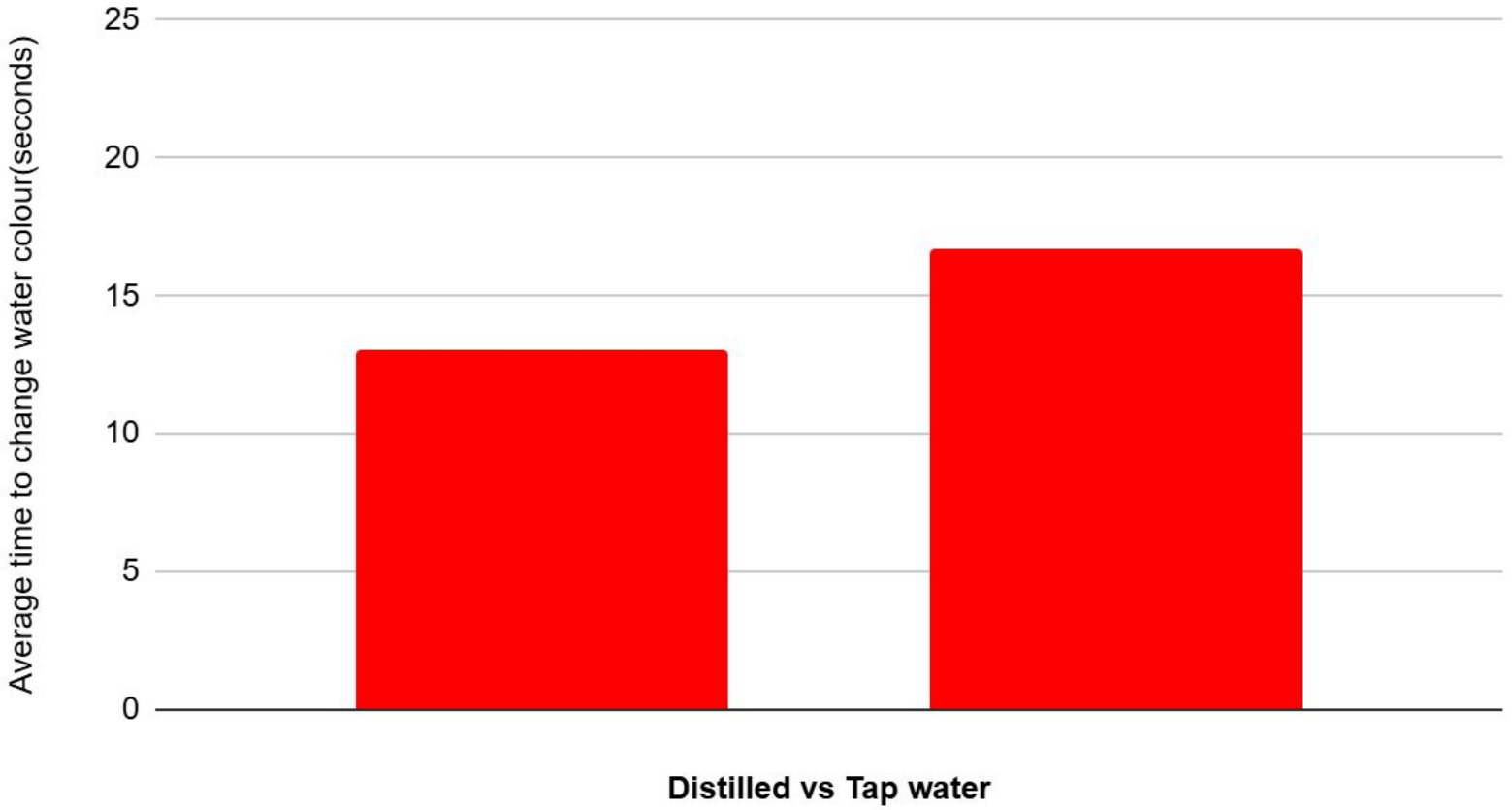
The DATA

D=Distilled Water
T= Tap Water

Navneeth (exercise)

Trial #	Type of Exercise	Time to change colour (seconds)	Colour of water
1	Jumping Jacks	D: 13 T: 17	D: Gold Yellow T: Deep green
2	Jumping Jacks	D: 13 T: 14	D: Gold Yellow T: Deep green
3	Jumping Jacks	D: 13 T: 19	D: Gold Yellow T: Light green

Navneeth (exercise)

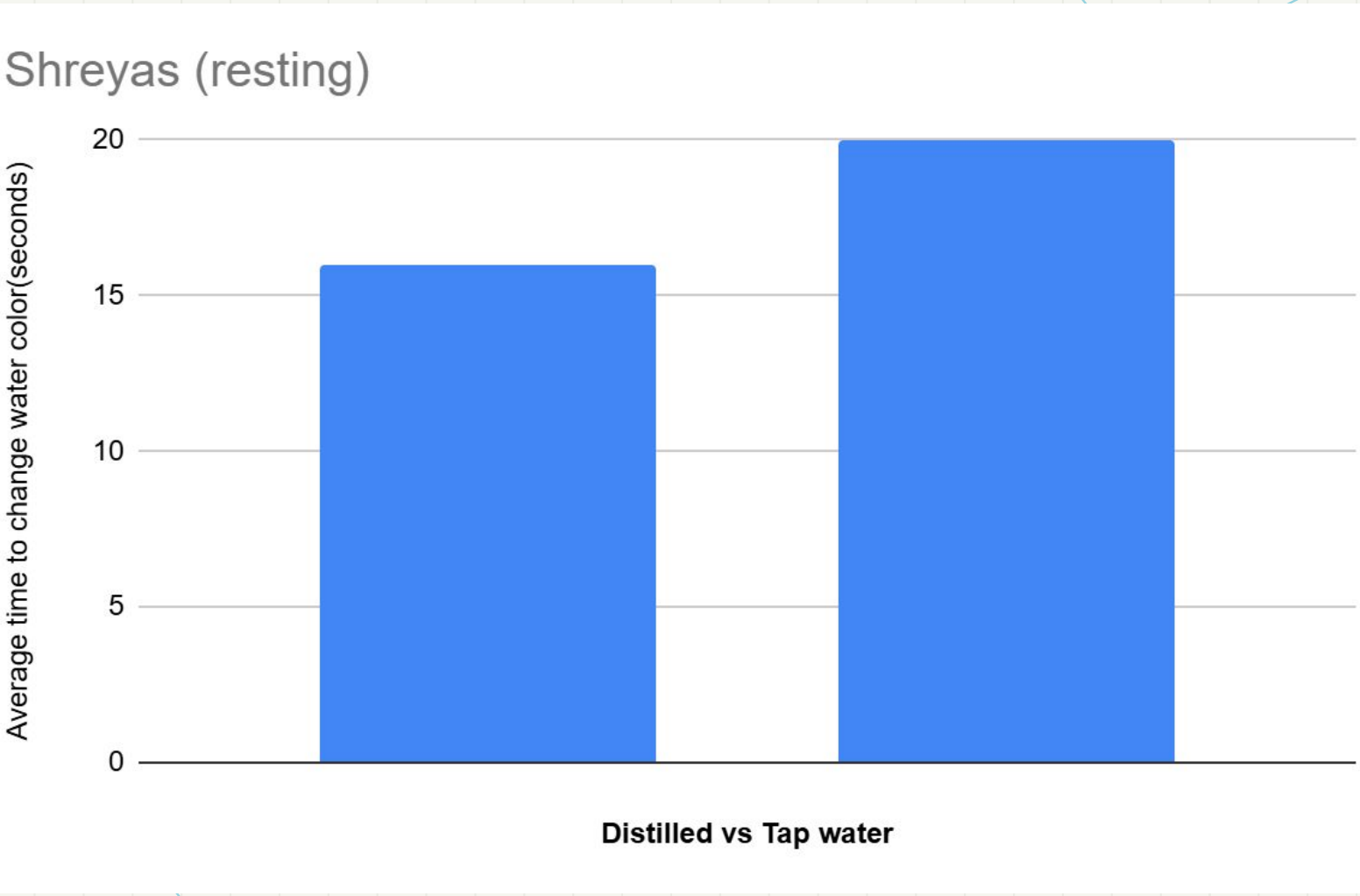


The DATA

D=Distilled Water
T= Tap Water

Shreyas (resting)

Trial #	Time to change colour (seconds)	Colour of water
1	D: 13 T: 20	D: Gold Yellow T: Deep green
2	D: 16 T: 20	D: Gold Yellow T: Deep green
3	D: 19 T: 20	D: Gold Yellow T: Deep green


Shreyas (resting)
Average time to change water color(seconds)
20
15
10
5
0
Distilled vs Tap water

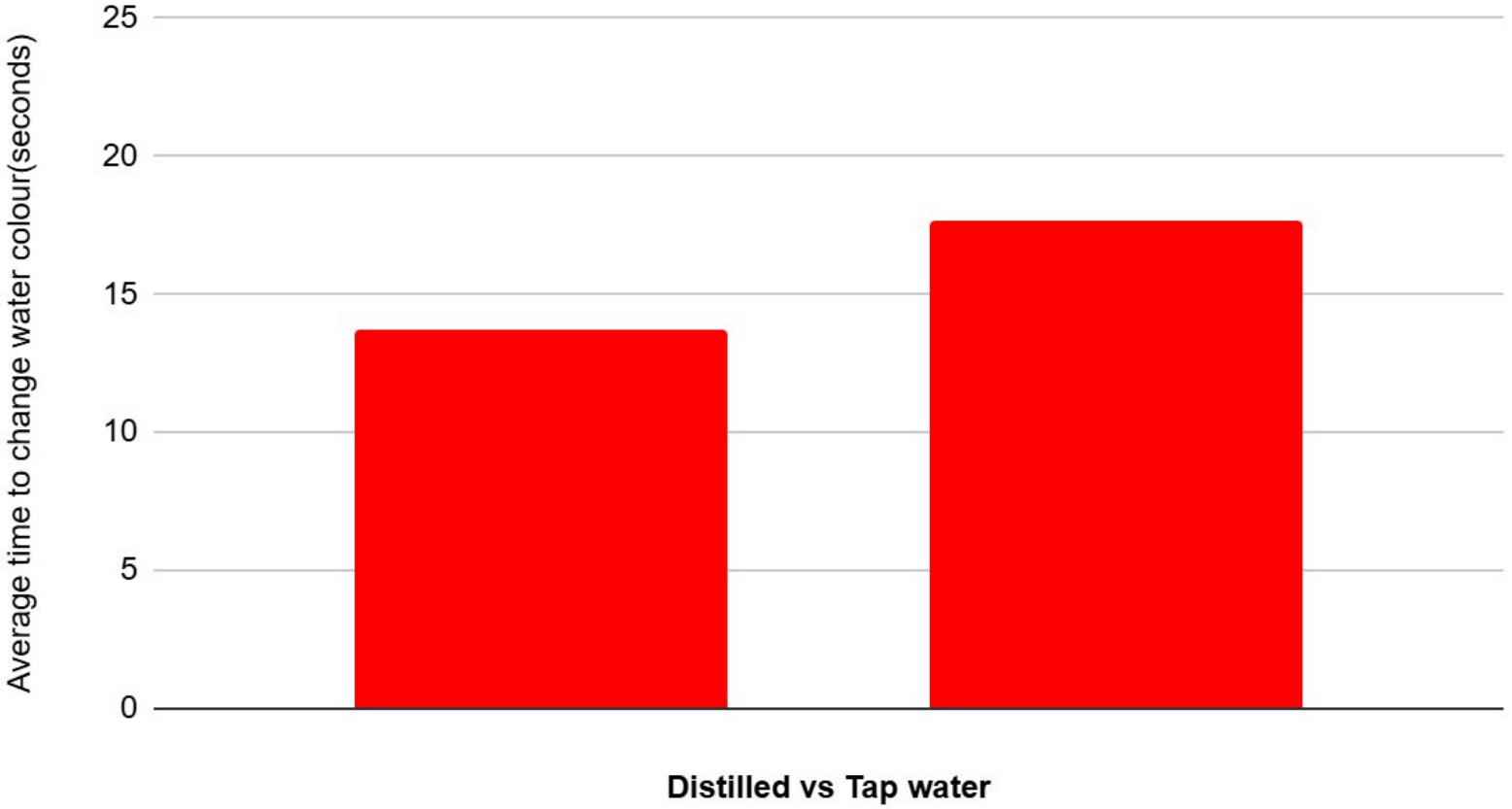
The DATA

D=Distilled Water
T= Tap Water

Shreyas (exercise)

Trial #	Type of Exercise	Time to change colour (seconds)	Colour of water
1	Jumping Jacks	D: 13 T: 18	D: Gold Yellow T: Deep green
2	Jumping Jacks	D: 13 T: 20	D: Gold Yellow T: Deep green
3	Jumping Jacks	D: 15 T: 15	D: Gold Yellow T: Deep green

Shreyas (exercise)



The DATA

During our second experiment, we noticed **multiple** things, such as:

- The starting colors of the bromothymol in our respirators being **different** than our first experiment.
- Distilled water generally changing color **faster** than tap water.

We believed that the **starting colors** of our respirators being **different** could be because of **2 reasons.**

- In our respirator with distilled water, we noticed that the distilled water we used contained **ozone**, an **acidic** solution, moving our water's pH level **down** from 7 to 6, where it had been for the **majority** of our last experiment.
- The bromothymol we got from Mr. DeGelder may have **aged**, which could have **affected** its **colour**. Further evidence of this is proved that when we placed the bromothymol **in** our respirators this time, it was noticeably **green** and we had to **mix** it a lot to make it into the colours we need.

We also realised that the theory we made earlier about the bromothymol having its **own** pH is **false** because overall, we noticed that it was **external factors**, such as **ozone** and the **type of water** we used, that **changed** pH level.

The DATA

Overall, we believe that our **second experiment** provided much **more valuable** information than our first one for **2 reasons**:

- One **issue** with the **first experiment** was that the water always **ended** up **changing** to a **green/teal** colour after a **certain amount** of **time**. This **didn't help compare** the level of **exercise** to **CO_2 levels** that much.
- So, by **measuring** how **long** it takes to **change** the **water colour** while breathing made more sense to gain a better measurement of a person's CO_2 output. This way we were able to identify which activity produced higher CO_2.
- With multiple experiments, we had more data to support our hypothesis with, proving our ideas more effectively.

VIII

The CONCLUSION...

...of our experiment.

The CONCLUSION

Our hypothesis was **correct**, as after exercising, the person's CO^2 output grew **higher** than when they did not exercise. We believed this was because in the trials we completed during our **first experiment**, generally the water was rather **dark** and **blue without exercise**, while it was more **light** and **green when we did exercise**, proving they **exhaled more CO2 than normal** after exercising. However, we realized this **data** could be a bit **mistaken**, due to the fact that our **perception of colour** may have been **incorrect**. Thus, we also gained **data** from our **second experiment,** where we measured how **long** it took the tested person **to change** the water to a certain **colour** (**teal-green for tap water, pale-golden yellow for distilled water**), and proved our **hypothesis**. Generally it took **less time** for the person to **change** the water **colour after exercising** than before (barring a few minor discrepancies).

Also, we noticed some other **interesting** things while completing the **second experiment**. First, we made the **revelation** that **bromothymol** may **age,** as when we **placed it** into our **tap water**, it turned a light shade of **teal**, and in the distilled water it turned evidently **yellow**, but during our **first experiment**, the water colour was generally in the **dark** shades of **blue**. This may have affected the results of our second experiment, but we are unsure. (more theories in sources of error)

IX

The APPLICATION...

...how does this relate to the real world? How is this significant to us?

The APPLICATION

Why is this experiment important?

- This experiment is important, as different people may do the same types of **exercises**, but it's important to consider their **external** and **internal** circumstances to make sure they're not **over-exerting** themselves.
- This experiment could be used by people (especially those with lung issues) to determine their CO_2 output for various exercise routines, Helping them manage their routine properly without affecting their health.
- Some people may have a condition known as **exercise induced asthma,** it is important for them to understand their blood oxygen levels and CO2 output to not overstress themselves.

The APPLICATION

Where/how could this respirator be used (in the real world)?

- While this respirator is basic and qualitative as it does not provide actual measurement, a device like this could be used more to help people keep a good **exercise** routine by understanding their limitations.

- This is especially useful for people who may be having long-standing **lung issues**, as they may feel like they should **exercise** at the same level as some people without these issues affecting them. However, consistent use of an enhanced version of this device could allow these people to modify these workouts to keep their **CO^2 levels/SPO2% levels** at a safe, controllable amount.

The APPLICATION

How exactly can this design be improved for use in the real-world?

While this respirator is **basic** and **qualitative** as it does not provide actual measurement, there are ways that this design could be **improved**, to show more **precise** results. One could use a **digital** pH indicator to provide actual changes to the pH of water and do this accurately instead basic it on just the colour seen by the **naked eye**. Then the duration can be compared **exactly** based on **HR** and **pH**. There could also be a proper **colour evaluation** done using **HEX** or **RGB** colour codes.

As for the actual design, the respirator is currently made in a **bottle**, however it can be made in a larger **container** with **power** operation and a **built in aerator** with some form of **AI** to detect when the bromothymol is at its **original** state. This allows for **efficiency** as well as use outside of science experiments.

Personal Significance

Why is this project important to us personally?

- **Shreyas**: This is important to me because it gives me a sense of hope for thousands across the world who don't have optimal health care access. Relatively simple medical devices like this can mean a lot to people who can't access or afford medical care, and it can tell them whether to seek help, whether that be at a family member, friend, doctor, or even the ER. My grandpa was diagnosed with dementia, and later pneumonia, and unfortunately didn't make it back home. A medical grade version of this could possibly shown us the signs of reduced breathing, and we could've given him help sooner, to possibly reduce the effects and maybe save his life.
- **Navneeth:** This is important to me as I have a sibling who has asthma. From a personal view, I understand how completing different forms of exercise to a normal level may be difficult for some people who have this lung problem, but this respirator would make it so people would know what levels of exercise suit them, ensuring they do not overexert or physically challenge themselves any more than people who may not have these issues do.

Sources of (T)ERROR...

...that may have affected our experiment.

Sources of ERROR

- The **bromothymol blue** solution was made with **tap water** instead of **distilled water** or **sodium hydroxide** because our school **didn't have** distilled water, and sodium hydroxide **wasn't prepared** before winter break. This may have affected the results since tap water contains **impurities** that could **contaminate** the solution and **interfere** with pH testing.
- We made **two** respirators to speed up testing, ensuring they were as **similar** as possible. While **minor** differences could have **affected** the data, we **avoided** any **major** issues to the best of our knowledge.

Sources of ERROR

- **Before** and **after** aeration, the bottle caps on our respirators were **open**, which may have allowed gases to **escape** and affected our results. This air loss could also have **let in** foreign **gases, particles,** or **substances**, potentially impacting the bromothymol-water solution. Additionally, the **vent** tube, while necessary for **gas flow** during respiration, may have introduced **foreign gases**. However, keeping the lid open was **unavoidable** for taking **measurements** like pH and color readings.
- The **pH strips** provided only **whole-number** readings (e.g., 1, 2, 3) rather than **decimal** values. While unavoidable, a more **precise** measurement would have allowed us to round up or down based on the trial. For example, if a strip showed a pH of 6 but the **actual** value was 6.9, it could have led to i**naccurate conclusions** and **affected** our results. This also made the bromothymol solution appear **too acidic** or **basic** in some trials.

Sources of ERROR

- During our **second** experiment, the bromothymol solution **wasn't blue** as expected. Instead, it appeared **teal** with tap water (green before mixing) and **yellow** with distilled water. This could be due to the bromothymol **aging** over the week between experiments, differences in the water (potentially from changes in city water processing), or the use of **ozonated distilled** water, which naturally has higher acidity. These factors **changed** our understanding of bromothymol, and we believe this trial was **valuable** in learning more about the **interactions** between water, bromothymol, and CO_2.

XI

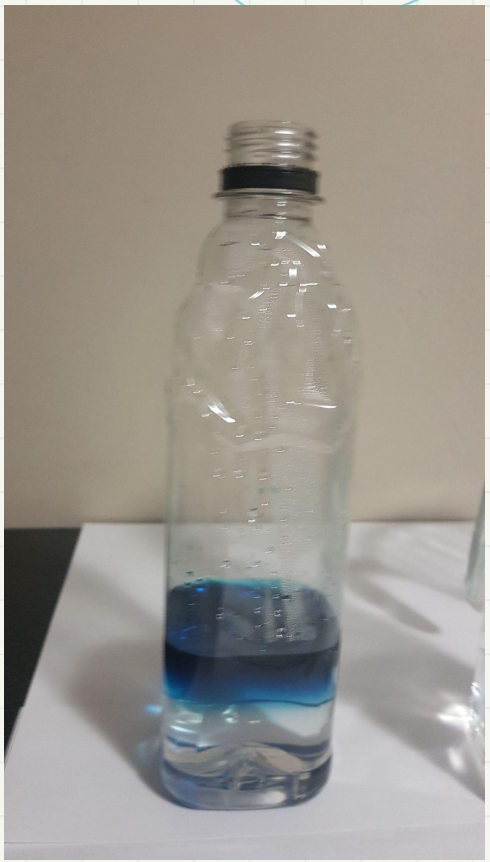
The IMAGES...

...to show you how the trials went.

The IMAGES

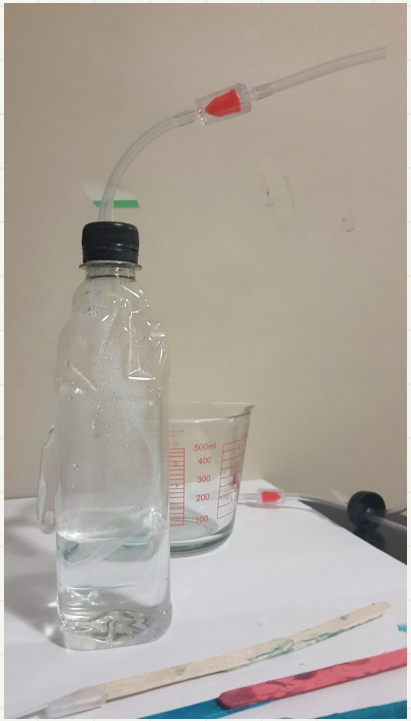
The respirators, before we added the bromothymol.

The oxygen aerator we used between trials.



The respirator just as we added the bromothymol. The bromothymol is above the water.

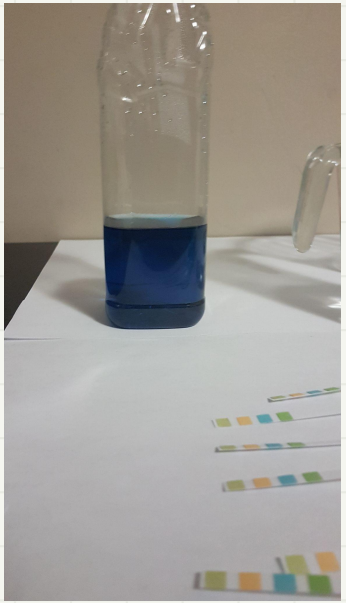
The IMAGES



Another picture of a respirator prior to adding the bromothymol.

Bromothymol sulfonephthalein, also known as bromothymol blue. The raw chemical-water compound we added to more water inside the bottle. This chemical, when exposed to CO^2 (carbon dioxide) changes colour from dark blue to lighter blue, to teal, to green, to yellow. We used this chemical to get an approximate reading of how much CO^2 a person breathes out in a given period of time.

The IMAGES



The bromothymol blue in the water after it combined.

A respirator being aerated in between trials. Notice the colour of the solution has changed to green after the trial.

The IMAGES

The distilled water respirator. Notice the yellow colour.

The two respirators side by side. The left one (yellow) is distilled water, while the right one (teal) is tap water.

The IMAGES

Another picture of the aerator. This is it in action aerating the respirator with tap water in it. Notice the bubbling as it removes all CO^2 content from the machine.

XII

The BIBLIOGRAPHY...

...sources we used during the research and experimentation.

The BIBLIOGRAPHY

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Science Buddies. “Effects of Exercise: Changes in Carbon Dioxide Output.” Science Buddies, 1 May 2021, https://www.sciencebuddies.org/science-fair-projects/project-ideas/Zoo_p013/human-biology-health/exercise-changes-in-carbon-dioxide-output. Accessed 5 December 2024. (this was the source of the actual experiment idea, so huge credit here!)

Notes we took in class, and general knowledge.

Acknowledgements

This project took a lot of effort, so we'd like to thank some people that made the whole process a lot clearer, easier and fun to do:

Thank you...

...Ms. Martin, our science teacher, who introduced us to body systems in class and corrected any mistakes she saw in our work for this year's science fair, as well for approving our proposal form as well.

...Mr. DeGelder, for supplying us with information, help, as well as preparing 11 times the amount of bromothymol we actually realized we needed :). He also coordinated a bunch of meetings to get us up to speed with how the application and other processes work.

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Thanks...

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Thanks a lot,
Navneeth V (8-5).

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...wow, you made it to the end :) ! Thanks for watching, listening, reading, and supporting! Thanks to all of you who helped us out, in the biggest and smallest of ways! It's been a blast, and we hope you enjoyed!

- Shreyas H (8-3)