An Experiment in Ocean Acidification: Why Buffering Matters

Marty Cornell, March 30, 2024

Deceptive Exercises in Ocean Acidification

[dissolving seashells experiment - Search Images (bing.com)]

K-12 education material promote alarm that our oceans are becoming dangerously acid because of CO2 emissions from burning fossil fuels

This requires ignoring the impact of buffering

Quote from 8th Grade Climate Science Literature

"The ocean acts as a carbon sink in the carbon cycle, absorbing atmospheric carbon and storing it in an aqueous solution in the seawater, which can lead to the effect of ocean acidification. **Ocean acidification has a negative effect on many marine species, especially those that make hard shells**. In more acidic water, it is more difficult for these organisms to build shells, and the water can even cause shells to begin to dissolve. "

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False

Ocean Health – Is there an “Acidification” problem?

CO2 COALITION
CO2Coalition.org

Ocean Health White Paper REV 061120.indd (co2coalition.org)

Example of experimental misdirection

Modeling Carbon Absorption in the Ocean

Intent: "Build and Observe a physical model of carbon emission and absorption in the Ocean"

Materials

- Antacid tablets (2)
- 500 ml beakers (3)
- Bromothymol blue indicator solution in dropper bottle
- Container, large, sealable lid
- Graduated cylinder, 500 ml
- Marker
- Tape, masking
- Water, distilled or tap

Example of Materials of experiment

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ADVANCING EARTH AND SPACE SCIENCE

Reviews of Geophysics

REVIEW ARTICLE
10.1029/2019RG000681

Ocean Alkalinity, Buffering and Biogeochemical Processes

Jack J. Middelburg[1], Karline Soetaert[2], and Mathilde Hagens[3]

"Seawater is a solution with multiple weak acids and bases in contact with both the atmosphere and sediments containing minerals that have the potential to react when solution composition or physical conditions change. **Seawater is consequently well buffered**…"

An annual increase in atmospheric CO2 of 2.1 ppm/yr. → a pH decrease of ~ 0.0023 units/yr.

pH of Ocean Water (Alkalinity 2.3×10^{-3} M, 25 ^{o}C)

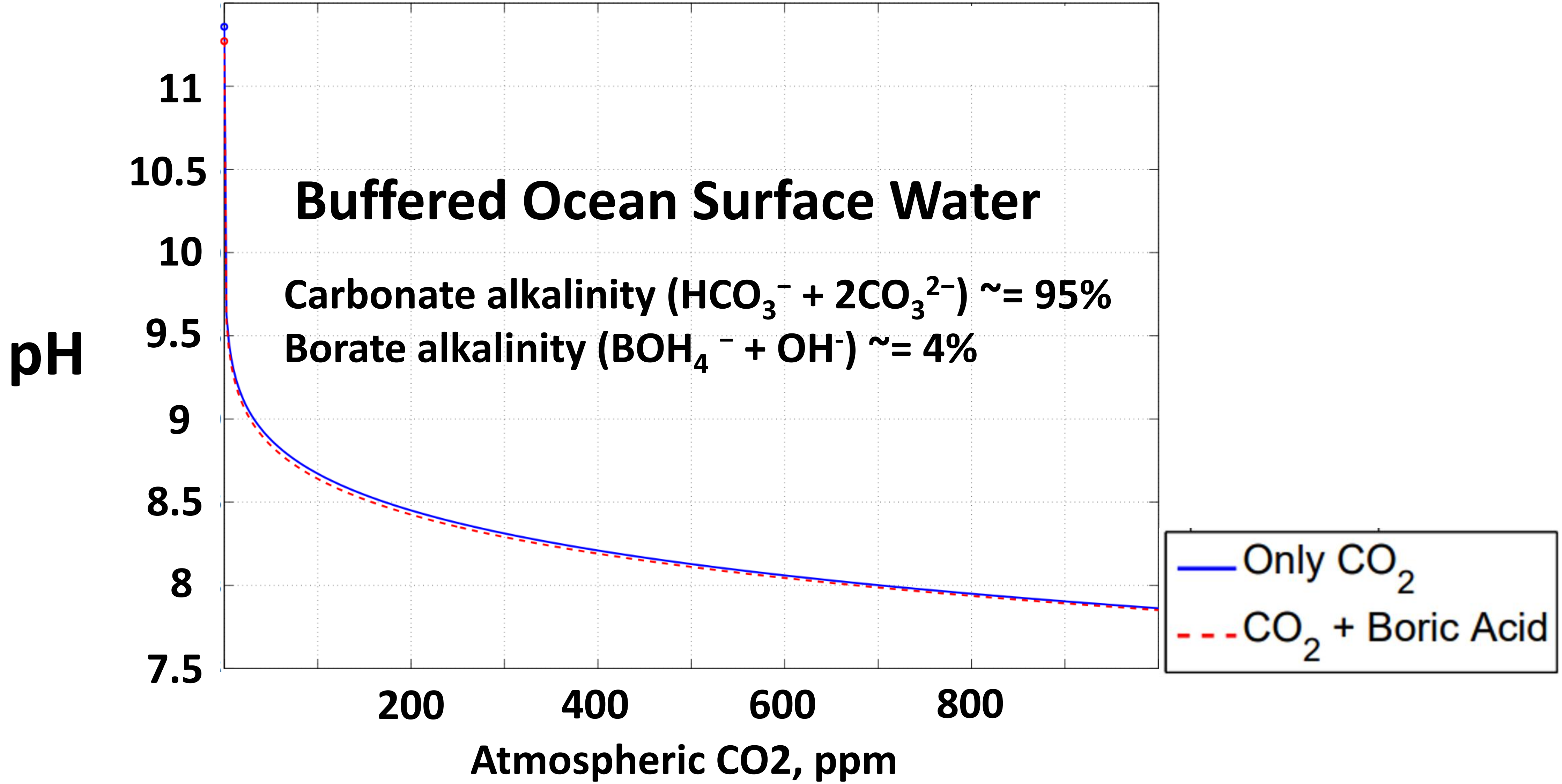


Figure from *Fundamentals of Ocean pH*, R. Cohen and W. Happer, Sept. 18, 2015

Example of experimental misdirection

Ignoring perspective

A point is often made that about 25% of CO2 emissions from burning of fossil fuels end up dissolved in the ocean. **There is no attempt to quantify this amount and to compare it to natural emissions,** i.e.,

25% = ~8.15 Gt of 293.3 Gt or ~2.8% of CO2 annually absorbed by oceans

How Added Fossil Fuels Affect the Carbon Cycle

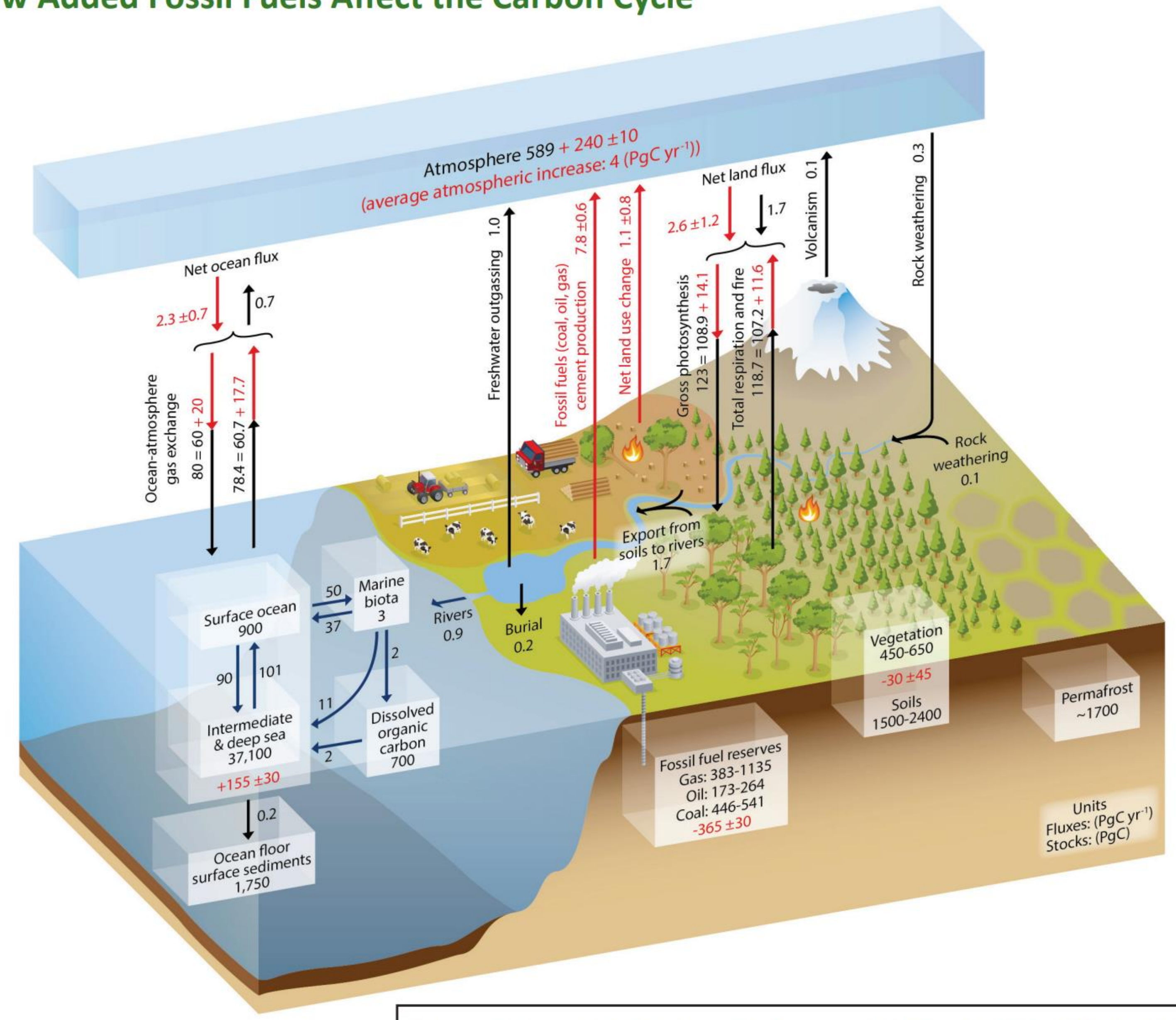


Figure 1 The Global Carbon Cycle from IPCC *CLIMATE CHANGE 2013: The Physical Science Basis - figure 6.1, p. 471*

CO2 Emissions, GT/Year

Oceans	291.1	38.3%
Respiration/Decay	435.2	57.2%
Volcanos/Rock Weathering	1.5	0.2%
Total Natural	**727.8**	**95.7%**
Fossil Fuels & Cement	28.6	3.8%
Land Use Change	4	0.5%
Total Anthropogenic	**32.6**	**4.3%**
Total CO2 Emissions	760.4	100.0%

CO2 Sinks, GT/Year

Oceans	293.3	39.4%
Photosynthesis	451.0	60.6%
Total	**744.3**	**100.0%**

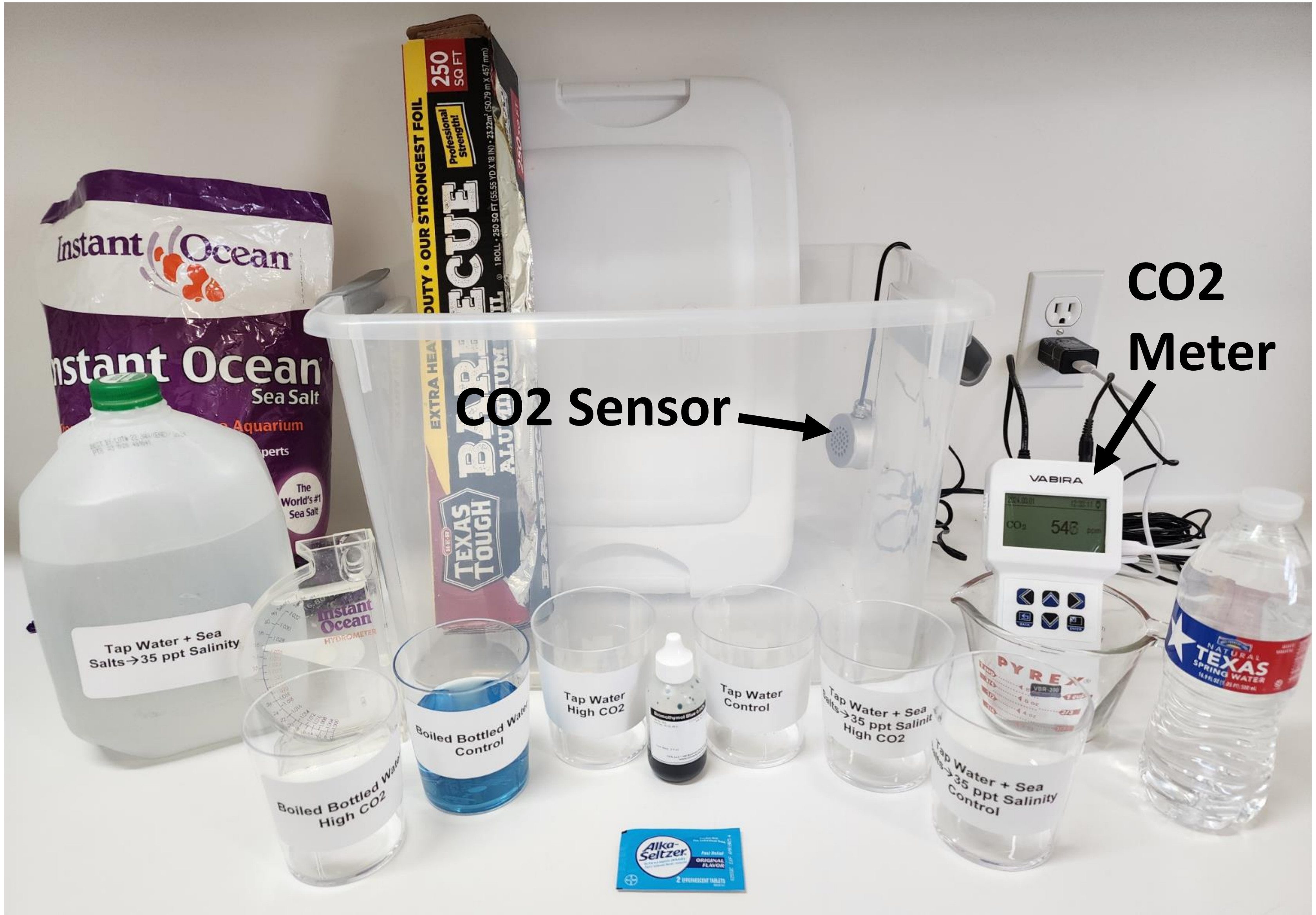
Example of experimental misdirection

Quote from 8th Grade Climate Science Literature

"Propose a solution to help reduce the effect of carbon emissions on the ocean. Support your solution with observations or data from your model."

Solution to a false problem led by a deceptive experiment!

Ocean "Acidification" of Buffered Sea Water



Materials

- ✓ Sea salts
- ✓ Bottled water
- ✓ Tap water
- ✓ Hydrometer
- ✓ Six 8-oz clear cups
- ✓ Measuring cup
- ✓ Antacid tablets
- ✓ Bromothymol blue
- ✓ CO2 meter
- ✓ Labels
- ✓ Gallon jug
- ✓ Translucent container with sealable lid
- ✓ Aluminum foil*

* Placing a sheet of foil between the container and lid will better seal and preserve high CO2 level

Experimental Procedure

Step 1

Prepare a solution of sea water by adding ~$^{1}/_{2}$ cup of aquarium sea salts to a gallon jug, then fill the jug with bottled water. Using a hydrometer, adjust the salt content to 35 ppt salinity.

Step 2

Label each cup:

- Tap Water Control
- Tap Water High CO2
- Boiled Bottled Water Control
- Boiled Bottled Water High CO2
- Tap Water + Sea Salts → 35 ppt Salinity Control
- Tap Water + Sea Salts → 35 ppt Salinity High CO2

Step 3

Boil and cool bottled water to remove residual carbonization

Step 4

Add 200 ml of the appropriate water to each cup

Step 5

Add 30 drops of bromothymol blue to each cup and stir to mix.

Experimental Procedure

Step 3

Bottled spring water is likely to have some degree of natural carbonization, and must be stabilized by degassing under open air as shown here, or by boiling and then cooling (next slide)

0 Hrs. **48 Hrs.** **60 Hrs.**

Time after adding bromothymol blue to bottled water (before exposure to elevated CO2.)
Hill Country Fair Texas Spring Water pH 6.9, alkalinity 53 in CaCO3 units.

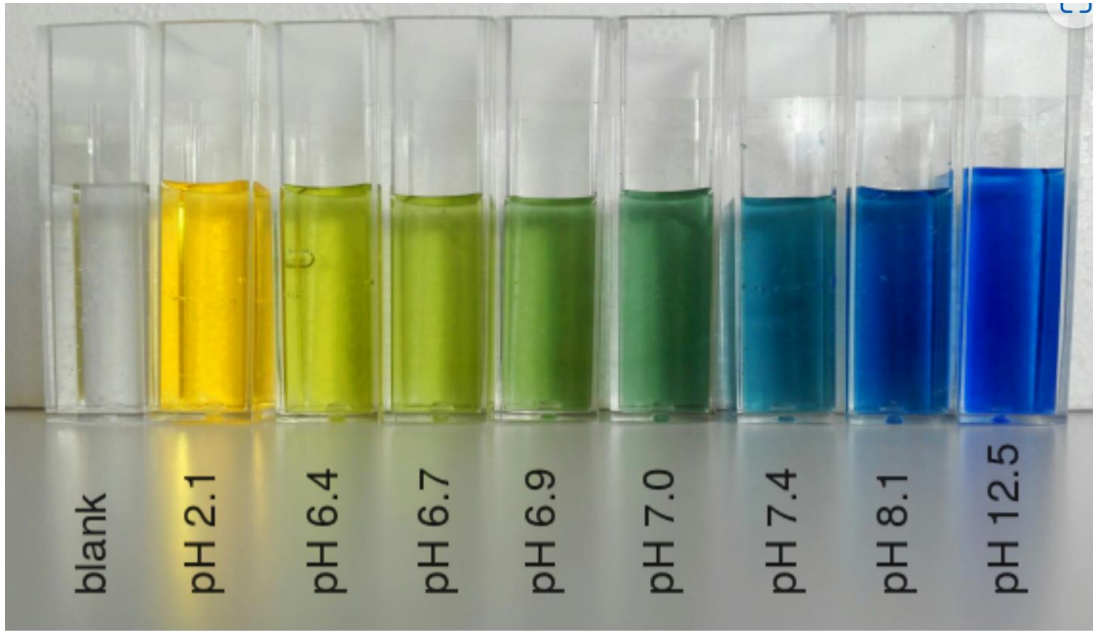
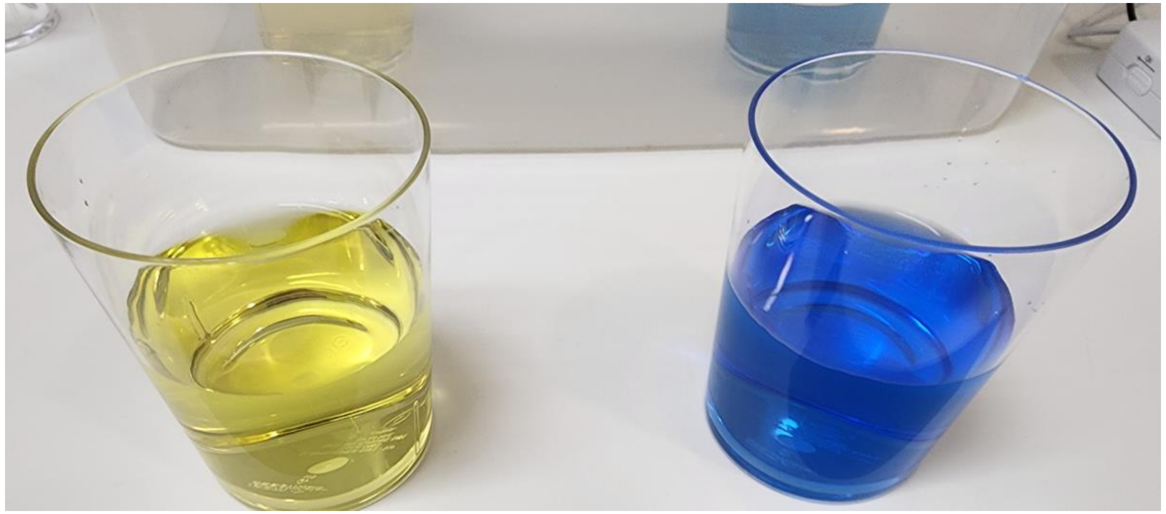


Photo from Bromothymol blue colors at different pH - Bromothymol blue - Wikipedia

Experimental Procedure

Step 3

Boil bottled spring water to remove residual carbonization, and cool to room temperature.



From bottle **After boiling**

Initial color of 200 ml Bottled Water with 30 drops bromothymol blue

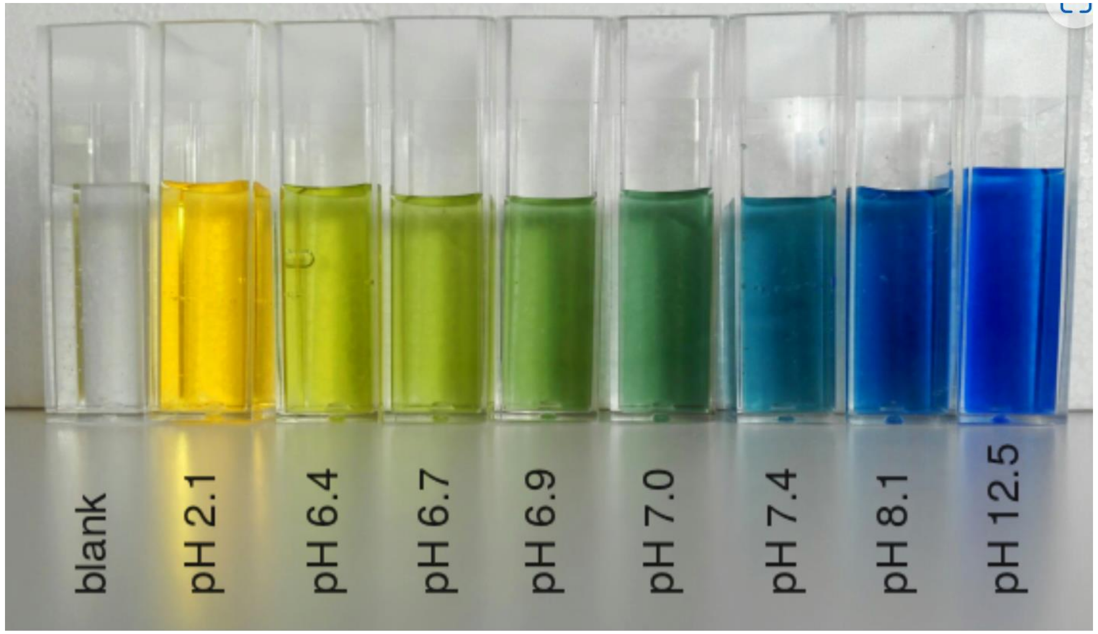


Photo from [Bromothymol blue colors at different pH - Bromothymol blue - Wikipedia]

Experimental Procedure

Step 6

Record the color of the three solutions at the start of the experiment with the bromothymol blue color chart

Water Quality Analysis (2021)

				Water Type		
				Hill Country Fare Distilled Water	Hill Country Fare Purified Drinking Water	Hill Country Fare Texas Spring Water
Substance	Units	MRL*	MCL**	Level Found***	Level Found***	Level Found***
Physical Quality						
Alkalinity in CaCO3 units	mg/L	2	NR	30	9	53
Apparent Color	ACU	3	15	ND	ND	ND
Specific Conductance, 25 C	umho/cm	2	1600	ND	46	137
Total Hardness	mg/L CaCO3	3	NR	ND	8	54
Odor at 60 C	TON	1	3	1	1	1
Total Dissolved Solids (TDS) ◊	mg/L	10	500	ND	33	95
Turbidity	NTU	0.1	5	ND	0.1	0.1
PH ◊	Units	0.1	NR	5.8	6.7	6.9
Bicarb.Alkalinity	mg/L HCO3	2	NR	36	11	63

Experimental Procedure

Step 7

Record the ambient air CO_2 content in the room. Because human breath will increase the CO_2 reading, this is best done before the room is filled with students.

Step 8

Position the sensor of the CO_2 meter on an inside wall of the container

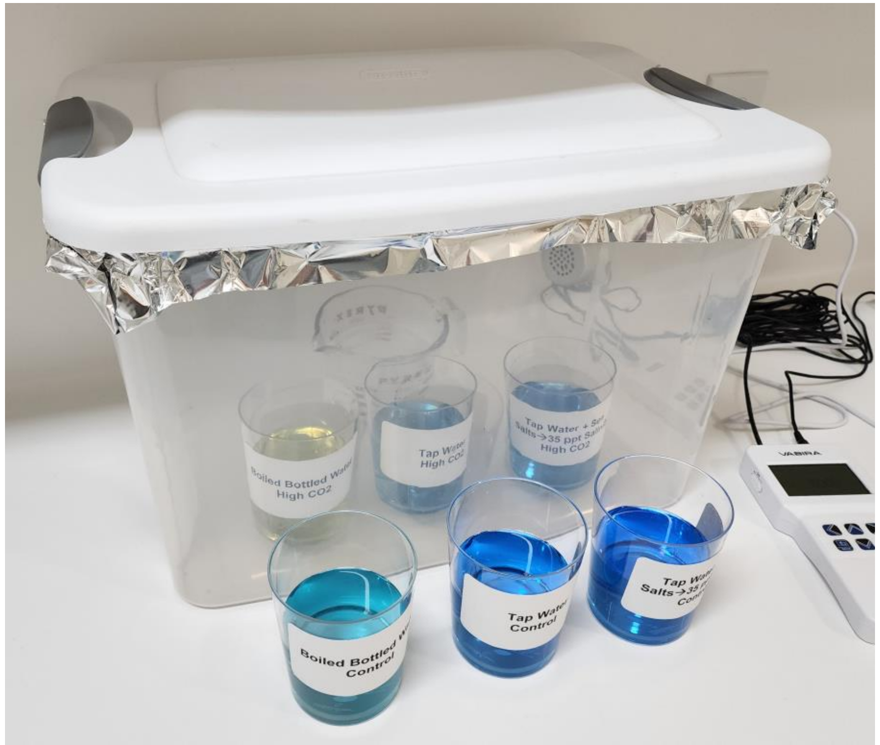
Step 9

Place the three cups labeled “High CO_2 and the measuring cup filled with ~200 ml of tap water inside the container. Add two antacid tablets to the water-filled measuring cup.

Step 10

Place a sheet of aluminum foil over the container, then cover with the lid and lock in place; this will provide a tighter seal and preserve elevated CO_2 at >5,000 ppm for at least ten hours

Experimental Procedure



Step 10

Placing a sheet of aluminum foil over the container before adding the lid will provide a tighter seal and preserve elevated CO_2 at >5,000 ppm for at least ten hours.

Start of Experiment

2 Alka-Seltzer Tablets Pegged the Meter at > 11.9 times Ambient

Ambient Room Air

Container (2 antacid tablets)

Experimental Procedure

4 Hrs. at >5,000 ppm CO_2

Step 11 Note change of color of specimen exposed to high CO_2 level with time

Experimental Procedure

24 Hrs. at >5,000 ppm CO_2

Step 11

Note change of color of specimen exposed to high CO_2 level with time

Experimental Procedure

48 Hrs. at >5,000 ppm CO2

Step 11

Note change of color of specimen exposed to high CO2 level with time

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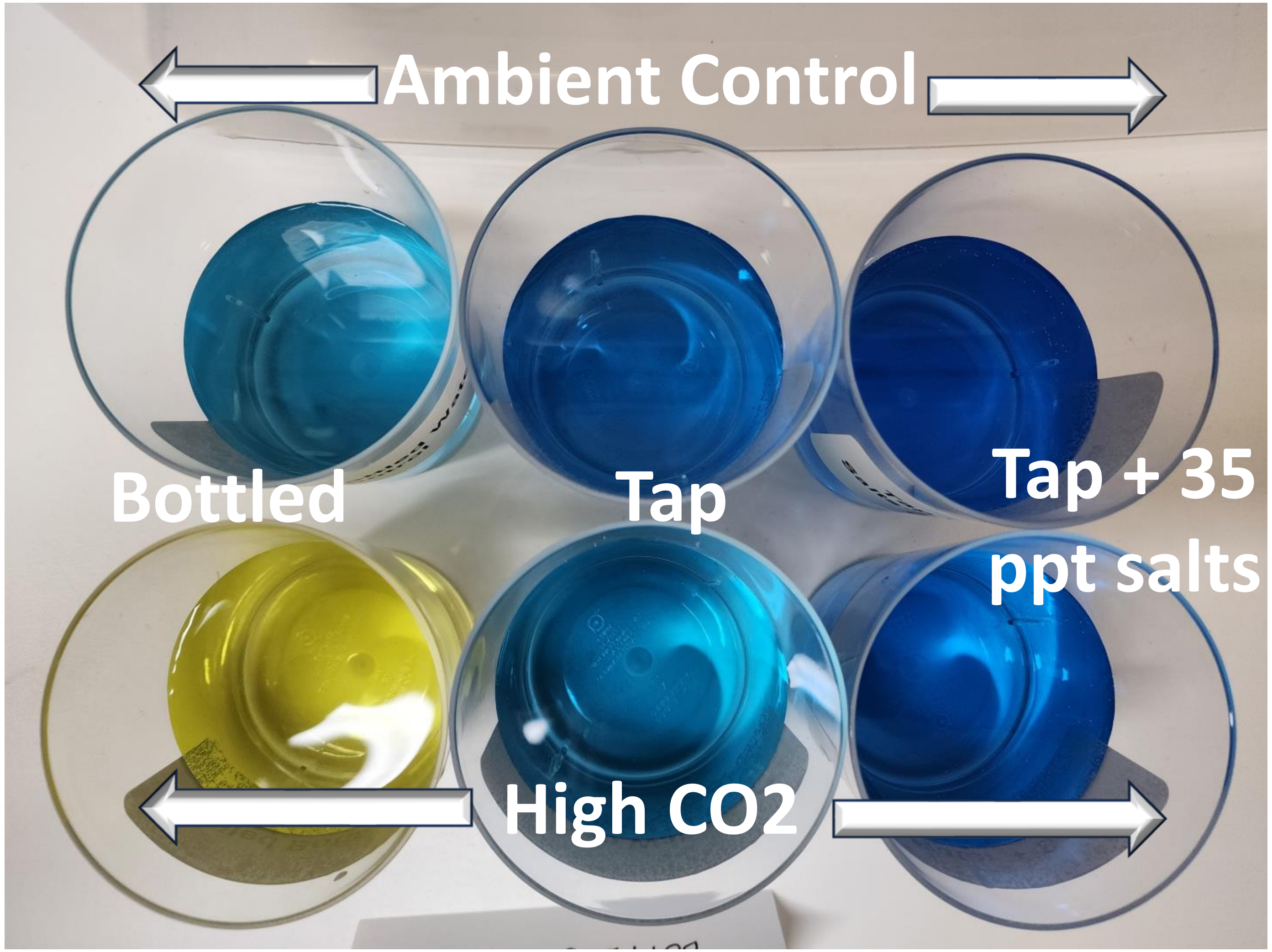

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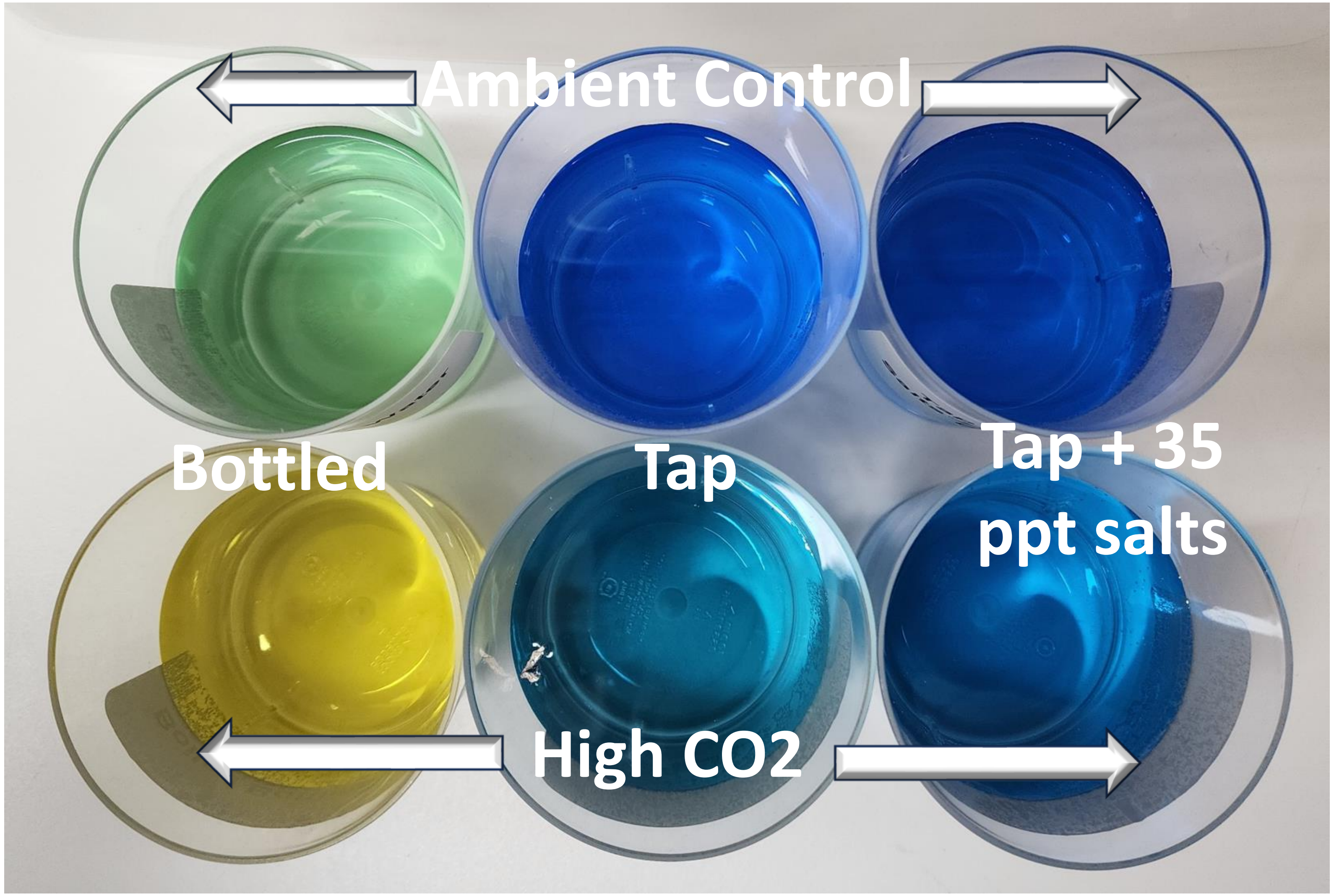

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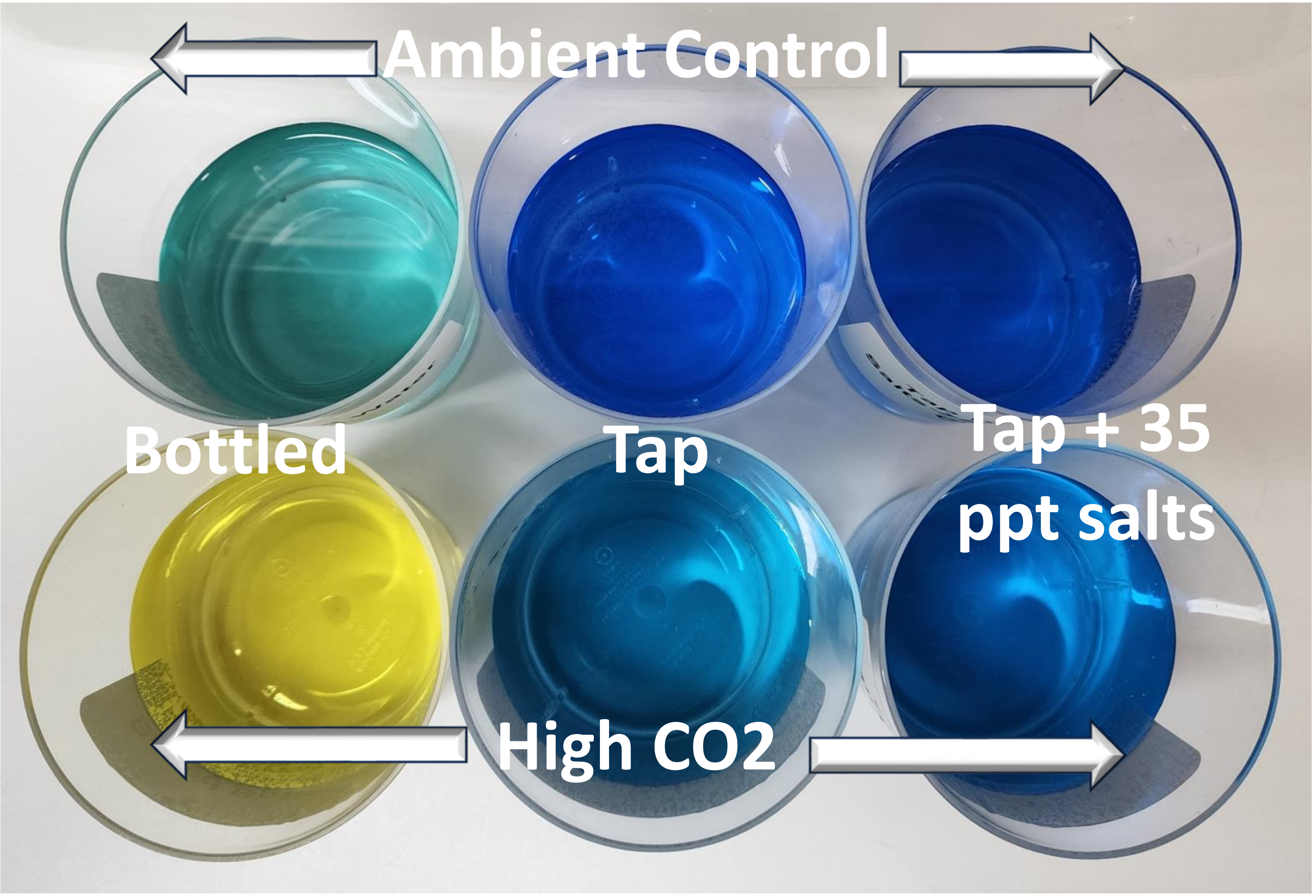

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48 Hrs. at >5,000 ppm CO2

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Experimental Procedure

Step 11

Note change of color of specimen exposed to high CO_2 level

Step 12

After two days, observe the color shift of specimen removed from a high CO_2 environment

Note return to
~pH neutral

24 hrs exposure to > 5,000 ppm CO2 + 34 hrs ambient

Conclusions

- The “textbook” experiment falsely equates tap and distilled water to buffered ocean water
- After 48 hours, >Ten times atmospheric CO_2
  - did not noticeably shift the pH of tap water buffered with sea salts
  - slightly decreased the basic pH of tap water
  - shifted the pH of unbuffered bottled water from slightly basic to acid.
- The pH of bottled water exposed to >5,000 ppt CO_2 shifted to slightly basic after return to ambient air.

Conclusions

- The concept of buffering is ignored by education material of major publishers; students are misled.
- “Textbook” mention of the CO2 level generated by antacid tablets is avoided. This level is beyond the possible amount from burning all fossil fuel reserves.
- Education material from leading publishers misdirect students on ocean acidification potential and harm to aquatic life.

Conclusions

Buffering Matters

Our CO_2 emissions are not endangering sea life