



High School Water Investigators Program (Version 1.1)

Reaching Out to High School Students and their Teachers

Compared to their elementary school counterparts, high school students may seem a bit more subdued. This should not necessarily be interpreted as disinterest. The students appreciate new information that is pertinent to their lives and enjoy hand-on activities. High School teachers are interested in programs that enhance the curriculum and provide their students new experiences. They appreciate it when students have the opportunity to use real-world test methods and equipment. They have less flexibility than elementary school teachers in scheduling school visits or field trips because their students each have different class schedules.

Water Investigators Program

This program requires preparatory work including sample collection, analysis, and collection of watershed information. The forty-five minute program itself consists of two parts, five minutes of introduction and forty minutes of hands-on analysis called the Water Investigators Challenge.

The core of this program is the Water Investigators Challenge which can be used as a springboard to related topics. Briefly, the students receive and analyze water samples that are to them, of unknown origin. Once the analyses are complete, the students compare their results to the results shown in a table. They select the water sample in the table which best matches their own. Their hypothesis is verified (or refuted) when the instructor presents them with a sealed envelope marked only with their sample's I.D. number. Opening the envelope reveals the actual sample source. The difficulty level of this exercise can be adjusted to fit the audience's skill level. For example, a few samples of very different water quality are easily differentiated and identified. A greater challenge is attempting to identify a sample from a list of many samples, some with similar analytical profiles. Typically however, with sufficient analysis, students will successfully identify their sample.



Rather than the straightforward approach above, a more exciting environmental crime scene investigation framework may be used. For example, the students might be asked to determine the source of water found in the fictitious bilge of several boats suspected of illegal

dumping. The student teams would then be assigned a bilge sample. The one bilge sample matching the lake water quality from the crime scene would lead to the arrest of that boat's owner – the suspected culprit.

Sample Selection

The instructor determines which water samples will be of most interest to the students. Consider lakes, rivers, culverts, tap water, and precipitation. Very turbid samples should be avoided. Bottled waters provide a convenient source of water from far off places and unique water sources. Typically, one sample per station works well. If there are few stations and/or many students, two or three unique samples per station may be used. In this program, five samples are used.

Sample Collection and Analysis



The instructor collects the water samples and analyzes each one using the same equipment and methods the students use. Because some analyte concentrations can change over time, it is best to analyze the samples the day before the program. Analytes that change quickly, like chlorine residual, can simply be recorded as “present” or “absent”. After analysis, the water samples should be dispensed into separate clear containers that are marked with an I.D. number known only to the instructor. In these bottles, the samples will all “look” identical emphasizing that their differences are invisible to the eye. The instructor then prepares a Water Analysis Results and Sample Key table that does not contain the sample I.D. numbers, rather, it lists each sample's origin and the analysis results determined previously

by the instructor. See Appendix A.

Sample Stations

A sample station contains all the equipment and supplies needed to safely analyze a water sample of “unknown origin”. A list of station supplies used in this program is at the end of the document. Multiple stations are needed to allow participation and the stations need to be set up to allow easy access to student teams, ideally in pairs. Easy access to water and a drain are needed. If these are not available, a filled wash bottle and bucket suffice. This program has been successfully performed in a picnic shelter and regular class rooms.

The Introduction/Presentation

During this time, the students are seated and an introductory presentation is queued. This is the time for the instructor to introduce themselves, describe what they do and to outline the program. During the brief presentation, the instructor explains where the water samples were obtained and preferably shows pictures of the exact locations. Google Maps satellite views often



provide fantastic aerial photos of sample sites. This review leads to a discussion of how the water quality may differ between the different bodies of water. Watershed information can also be drawn into this discussion if time permits.

At the conclusion of the presentation, students are paired off and assigned to a sample station. They are instructed to don safety glasses and not to touch anything until instructed. Safety related issues are addressed (eye wash locations, MSDS location, etc.).

The Water Investigation

The students record their name and sample I.D. on the bench sheet (Appendix B) found at their station. They are then told, step-by-step, how to proceed with each analysis (Appendix C). We have found it most useful to discuss the significance of each analyte individually just prior and following each analysis. For example, just before the students are told how to measure hardness explain its relevance. After the analysis, engage the student team by asking which water they think would contain more minerals, surface or ground water. In this way, they begin to identify the source of their sample. After each analysis, the students record their results on their bench sheet.



Once all of the parameters have been measured, each team is given the results table. The students compare their bench sheet values to the results table in an attempt to determine which sample they analyzed. They should do this independently. Some will be dismayed that their results do not match any of the results in the table exactly. Encourage them to do their best and to select the sample that has the best match. Once they have done this, they should record their selection on their bench sheet. They are then handed a sealed envelope labeled with their sample's I.D. number on the front. This "reveal" is often marked with excitement as unsure students observe for themselves the power of objective science. Those that incorrectly identify their samples either conducted the analysis incorrectly or had to select between two very similar samples. They are often very close to a correct identification. The instructor should review the results and attempt to determine the cause of the error. This may then be discussed with the students.

If time permits, each team may be asked to explain how they figured out which sample they had. Which parameter(s) "gave it away" ? As each team reveals which water sample they identified, this is a good time to draw contrasts between them. For instance, if the conductivity of a spring time retention pond sample is extremely high, it may be due to the use of road salt during the winter. Or if the students had a snow melt or rain sample, the instructor may ask why the pH was lower than the other samples.

Ah-Ha's

Students learn that although most water looks exactly the same, they are indeed different. They learn that water contains many things. They recognize the strong influence our environment has on water quality. By using different test methods, they see for themselves that basic scientific tools work and work in their hands no less. They realize the legitimacy of the adage "we need more data". If just one

parameter was measured, it would be difficult to determine which sample they had. But, as the number of analyzed parameters increased, sample identification became easier. Interestingly too, the results do not have to match perfectly to make an accurate identification.

Feedback

We want to make this program better! If you have suggested improvements or other input, please let us know. Contact Bill Soucie at Soucie@clcjawa.com or 847-582-9215.

Appendix A

Water Analyses Results and Sample Key

Sample Source	Iron	Hardness	Alkalinity	pH	Conductivity	Chlorine	Phosphate
	mg/L	mg/L as CaCO ₃	mg/L as CaCO ₃	None	uS/cm	mg/L	mg/L as o-PO ₄ ³⁻
Lake Villa, IL Tap (well water)	0.3	236	320	7.5	630	Yes	0.20
Grandwood Park, IL Tap (well water)	0.3	256	240	8.1	700	Yes	1.31
Lake Michigan (surface water)	0	140	140	8.1	320	No	0.05
Crystal Geyser – Salem, SC (spring water)	0	22	60	7.0	80	No	0
Lake Michigan, IL Tap (surface water)	0	140	160	7.8	360	Yes	0.44
Ice River Springs Ontario, Canada (spring water)	0	359	240	7.0	537	No	0.1
Snow Melt	0	1	0	5.3	15	No	0
Gray's Lake, IL (surface water)	0	257	120	7.0	961	No	0.1
Avon-Freemont Drainage, Third Lake, IL (surface water)	0	290	240	7.0	1245	No	0.03
Grayslake North H.S. Water Retention Pond, IL (surface water)	0	208	80	7.0	1955	No	0
Highland Lake, IL (surface water)	0	116	180	6.0	486	No	0.12
Ice Mountain Springs, PA (spring water)	0	24	40	5.3	73	No	0
Springfield, IL Tap (surface water)	0	118	80	9.3	340	Yes	0.40
Lake Springfield, IL (surface water)	0	216	200	8.7	490	No	0.31
Washington Park Lagoon Springfield, IL (surface water)	0.4	224	200	8.4	910	No	0.1

Appendix B

Water Investigator Challenge Bench Sheet

Name: _____

Sample Number _____

Background Information and Observations

	Iron	Hardness	Alkalinity	pH	Conductivity	Chlorine	Phosphate
U.O.M.	mg/L	mg/L as CaCO ₃	mg/L as CaCO ₃	None	uS/cm	mg/L	mg/L as o-PO ₄ ³⁻
Results							
Notes	Found primarily in ground water. Originating from minerals in rock. Makes water yellow or orange colored and stains surfaces but is otherwise harmless .	The amount of Ca ²⁺ , Mg ²⁺ , and Sr ²⁺ in water. These minerals come from rock. Hardness consumes soap and leaves tell-tale white spots when it dries. It is found in virtually all natural waters and is harmless to people.	The amount of carbonate (CO ₃ ²⁻) and bicarbonate (HCO ₃ ⁻) in water. These compounds come from rock and are often associated with hardness compounds. Alkalinity acts as a buffer in water making it resistant to pH changes.	The hydrogen ion concentration in water. Low pH indicates acidic water and high pH indicates alkaline water. Precipitation is naturally acidic.	A measure of how conductive water is to electricity. The higher the conductivity, the more minerals or dissolved solids are in the water.	Chlorine is added during water treatment for disinfection. Its use eliminated what used to be a common cause of death, cholera. In 1849, 1 in every 35 Chicagoans died of this disease that is now raging in Zimbabwe.	Phosphates are often added during water treatment to reduce Fe coloration in water and to keep Pb and Cu from leaching out of household plumbing into the water as required by law. In water bodies phosphates are a nutrient leading to excessive algal growth.

Comparing our results to the key suggests that our water sample is _____

Appendix C

Water Investigators Challenge Analytical Procedures

Iron (Color Wheel Method, 0-5 mg/L)

1. Fill both tubes to the first line with 5 mL of sample.
2. Place one tube (the blank) in the top left of the comparator.
3. Shake the powder in one FerroVer powder pillow down to the bottom of the packet.
4. Tear or cut open one powder pillow and add it to the second tube, swirl to mix.
5. Place this tube in the top right of the comparator.
6. Hold the comparator up to a light and rotate the color wheel until the colors match.
7. Record the results on the bench sheet.
8. Rinse all lab ware with distilled water.

Hardness (Digital Titration Method – This method takes about 5 minutes more than the one that follows)

1. Collect a 50 mL sample using a graduated cylinder.
2. Dispense the sample into an Erlenmeyer flask containing a stir bar.
3. Place the flask on a stir plate and stir gently (the vortex should not reach the bottom of the flask).
4. Add approximately 2 mL of hardness buffer (pH 10) to the sample using the eye dropper.
5. Shake the powder in one ManVer hardness indicator powder pillow down to the bottom of the packet.
6. Add the powder pillow to the flask and completely dissolve.
7. Dispense a few drops of titrant (0.8 M EDTA) from the titrator onto a paper towel and rinse the titrator tube with distilled water.
8. Reset the titrator digits to 0000.
9. Submerge the tip of the titrator tube into the sample. The tip must stay submerged.
10. Slowly dispense titrant into the sample by turning the titrator knob until the end point (marked by a color change from red to blue).
11. Multiply the number of digits displayed on the titrator by **2** to calculate the sample hardness.
12. Record the results on the bench sheet.
13. Rinse lab ware with distilled water.



Hardness (Drip Titration Method)

1. Fill the plastic tube with the sample.
2. Pour the tube's contents into the small square bottle.

3. Place the bottle on a stir plate.
4. Add the tiny stir bar and turn plate on to mix.
5. Add approximately 3 drops of hardness buffer (pH 10) to the sample using the eye dropper.
6. Add one drop of ManVer hardness indicator to the sample using the eye dropper.
7. Count drops from the eye dropper as you drip EDTA titrant solution into the bottle until the solution turns from red to blue. Take your time to make sure the titrant falls directly into the sample and to make sure the endpoint is not exceeded.
8. Record the results on the bench sheet.
9. Rinse lab ware with distilled water.



Alkalinity (Drip Titration Method, 20-400 mg/L as CaCO_3)

1. Fill plastic tube with sample.
2. Pour tube into square mixing bottle.
3. Shake the powder in one Bromcresol Green-Methyl Red indicator powder pillow down to the bottom of the packet.
4. Tear or cut open the powder pillow and pour into the bottle, swirl to dissolve.
5. Count drops from the eye dropper as you drip sulfuric acid (0.035 N) standard solution into the bottle until the solution turns red.
6. Multiply the number of drops times 20 to determine total alkalinity and record results on bench sheet.
7. Rinse lab ware with distilled water.

pH (Electrode Method)

Before measuring pH, the probe should be rehydrated (30 minutes) in water and then calibrated. Calibrate by pressing the ON/OFF button to switch on. Uncap and rinse the electrode with the pH probe to be measured. Dip electrode ~3 cm into sample pH buffer. Press the CAL button. Gently swirl until reading stabilized. Press the HOLD/ENT button to confirm the point. Rinse. Repeat with next buffer and/or then hit the CAL button to finish.

1. Pour the water sample into a beaker.
2. Remove the cap from the pH meter. Over a drain, rinse the tip with distilled water and then with a small quantity of the sample.
3. Fully immerse the glass tip into the sample.
4. Gently stir with the probe until the reading stabilizes. This should take less than 2 minutes.
5. Record the result on the bench sheet.
6. Rinse tip with distilled water. Shake off excess water. Recap the instrument.

Conductivity (Electrode Method)

Before use, the instrument should be calibrated. Remove the cap and rinse tip with distilled water and then standard solution. Immerse tip into the standard solution and swirl gently until stable. Adjust reading to match conductivity standard by pressing the buttons hidden under the removable screw top.

1. Pour a water sample into a beaker.
2. Remove the cap from the conductivity meter. Over a drain, rinse the tip with distilled water and a small quantity of the sample.
3. Immerse the probe tip into the sample.
4. Gently stir with the probe until the reading stabilizes. This should take less than 2 minutes.
5. Record the result on the bench sheet
6. Rinse tip with distilled water. Shake off excess water. Recap the instrument.

Chlorine (DPD/Colorimeter Method, 0 – 2.00 mg/L)

1. Fill the glass sample cell for the DR850 with 10 mL of sample.
2. Shake the powder in one DPD total chlorine or free chlorine powder pillow down to the bottom of the packet.
3. Tear or cut open the powder pillow and pour the powder into the sample.
4. Cap and invert the sample cell a few times.
5. Holding the cell against a white background, determine if the sample has a pink coloration.
6. If no color is visible, wait at least 3 minutes. If a pink coloration is not visible, sample does not contain chlorine.
7. If the sample has any pink coloration, the sample contains chlorine.
8. Record the results on the bench sheet.
9. Rinse the glassware very thoroughly with distilled water. DPD residue may interfere with the phosphate test.

Note that DR 850 may be used to quantify the chlorine concentration. Press ON then PROG then 9 then ENTER. Fill two cells with 10 mL of sample each. Place one cell, the blank, into the instrument. Cover the cell with the instrument cap. Press ZERO. Pour one DPD powder pillow into the other cell. (For total chlorine only, press TIMER then ENTER to begin a timer). Invert sample cell gently to dissolve DPD. (for total chlorine only, after the timer beeps) replace the blank cell with the sample cell and cap instrument. Press READ.

Phosphorous, Reactive (Ascorbic acid/ Colorimeter Method, 0 – 2.5 mg/L)

1. Turn the DR 850 colorimeter on.
2. Press PRGM then 7 then 9 then ENTER.
3. Fill both cells with sample
4. Shake the powder in one PhosVer 3 powder pillow down to the bottom of the packet.
5. Tear or cut open the powder pillow.
6. Dispense the powder into one of the sample cells and cap cell.
7. Shake the cell containing the sample and powder for 15 seconds.
8. Press TIMER then ENTER. A two-two minute timer begins.
9. Place the sample cell containing the sample only, the blank, into the instrument and cover with the instrument cap.
10. Press ZERO.
11. After the timer beeps, replace the blank with the sample containing the powder and replace the cover.
12. Press READ.
13. Record the result on the bench sheet.
14. Rinse all glass ware with distilled water.

Materials List

Analyte	Method	Units	Description	Supplier	Catalog Number
Hardness	Digital titration	5	ManVer 2 Hardness Indicator (100 PP)	HACH	851-99
		5	Buffer Solution Hardness 1 pH 10.1 (100 mL)	HACH	424-32
		5	erlenmeyer flask, 250 mL	HACH	2489446
		5	stir bar, "+" shape, 3/4"	HACH	29286-02
		5	EDTA Tetrasodium salt 0.8 M	HACH	14399-01
		5	digital titrator	HACH	16900-01
		25	delivery tubes	HACH	17205-00
		5	stir bar arrestor	HACH	2928501
Alkalinity	Drip titration	5	square mixing bottle	HACH	2327-06
		5	measuring tubes, plastic, 5.83 mL	HACH	438-00
		5	Sulfuric Acid Standard Solution 0.035 N (100 mL)	HACH	23497-32
		5	Bromcresol Green - Methyl Red (100 PP)	HACH	943-99
		5	Phenolphthalein (100 PP)	HACH	949-99
Iron	Color Wheel	10	viewing tubes, plastic with cap	HACH	46600-04
		5	color comparator box	HACH	1732-00
		5	color disk, (iron phnanthroline 0-5)	HACH	1713-00
		5	FerroVer Iron Reagent for 5 mL (100 PP)	HACH	927-99
pH	Probe	5	water proof pH tester 10	HACH	29561-00
Conductivity	Probe	5	water proof EC tester	HACH	28455-00
Total Chlorine	Colorimeter	5	DPD Total Chlorine Reagent for 10 mL (100 PP)	HACH	21056-69
Free Chlorine	Colorimeter	5	DPD Free Chlorine Reagent for 10 mL (100 PP)	HACH	21055-69
Phosphate	Colorimeter	5	PhosVer 3 Phosphate Reagent (100 PP)	HACH	21060-69
		5	DR 850 Colorimeter	HACH	48450-60
		10	sample cell, 10-20-55 mL with cap	HACH	24019-06
		5	graduated cylinder, Nalgene PP, 100 mL	HACH	108142
		5	Stir Plate	IKA	2669913
		5	Waste buckets	Rubbermaid	296300
		5	Scissors	VWR	HS8104
		5	500 mL wash bottles	Nalgene	