The Industrial Watershed

Activity Guide

Tsongas Industrial History Center

This project is funded by generous grants from theToyota USA Foundation through the National Park Foundation and the Institute for Museum and Library Services

Program Description

The **Industrial Watershed** will be a hands-on exploration of the impacts of the Industrial Revolution upon our water resources. The Lowell National Historical Park and the Merrimack River will be the focus of our exploration.
The day will begin at the Tsongas Industrial History Center in the Boott Mill. The groups will then start with either the tour or workshop segment of the program. The tour first group will travel to the Suffolk Mill and the workshop first group will remain at the Boott Mill. Lunch will be limited to half an hour between the tour and workshop segments of the program. Groups will eat their lunches in the lunch space at the Tsongas Center. If the weather allows, students may take the option of eating their lunches outside in Boarding House Park. Please advise all participants to dress appropriately for the season.

Your Day

The program will combine a 90 minute workshop and a 90 minute tour. The workshop will take place at the Tsongas Industrial History Center in the Boott Mill. Students will investigate the movement of groundwater and contaminants using ground water modeling tanks. During the tour the student will be investigating the industrial use of water resources at the Suffolk Mill. The tour will highlight the great changes and impacts of the Industrial Revolution upon our water resources. They will also visit the weave room at the Boot Cotton Mills Museum.

Theme and Objectives

Theme

The Industrial Revolution was a defining era in American history. All that we consider "modern" in technology, politics, art, culture, the nature of work, or the environment around us, was shaped by the period.

During the nineteenth century, industrial centers began to spring up along waterways all over northeastern America. In conjunction with industrial growth came the spread of urbanization. The same waterways used for powering machinery and drinking water were also used as wasteways for factories and mills and for city sewers. These uses had profound effects on these waterways, and more often than not, these effects were negative.

The effects of industrialization and urbanization on surface water are often visible and dramatic, and great progress has been made on cleaning up our polluted waterways. Less obvious is the damage that has been done to the much larger "underground ocean," the unseen and unseeable groundwater supply.

Groundwater is an important source of fresh water for many communities both in New England and across the country. Because of its location beneath the land's surface, groundwater traditionally has been assumed to be a clean and basically unassailable supply. During the last two centuries of technological development, however, industrial, agricultural, and municipal wastes dumped both on the land and in the surface waters have threatened the purity of the underground reservoir that serves nearly half of our nation's population.

Environmental history, a relatively new area of academic concern, undertakes to place in a historical context the effects of human society and technology upon the natural environment. Historical decisions about how to utilize our natural resources and beliefs about our relationship to the natural world have shaped the way our industries have functioned, shaped the growth of our cities, and how we have dealt with the wastes of our industrialized society. The **Industrial Watershed** program delves into the present day consequences of our environmental history.

Program Objectives

After visiting the Lowell National Historical Park and using the activities in this guide, the students will be able to:

- Discuss the nature of groundwater and surface water to explain that all water sources are ultimately interconnected.

- Explain how groundwater flows and how groundwater contamination moves by using models.

- Describe how human activity can affect the health of surface bodies of water like the Merrimack River.

- Describe the importance of informed and concerned stewardship for water and other natural resources.

- Explain why there is no "ideal place" to dispose of wastes where they will not affect (sometimes drastically) some environmental system.

- Describe the role of National Parks as environmental resources and the significance of Lowell's mills to America's environmental and industrial history.

The Industrial Revolution and the Environment

The Industrial Revolution was not only a turning point in the economic development of the United States, it marked a change in the relationship between the people and their environment. With the development of technologies to harness waterpower and the evolution of the machinery for mass production, previously labor-intensive activities, such as cloth making, took place in integrated factories where all steps of the production process were completed “under one roof.” Home production and cottage industries were replaced by the integrated factory system. Factories required expansive areas of land for building sites, huge amounts of raw materials, significant power sources, a large work force, and a complex infrastructure of support systems (transportation, waste disposal, etc.).

Many of those familiar mill buildings are abandoned now. They are silent testaments to a period of productivity and economic expansion that began in the nineteenth century and continued into the early twentieth century. However, in a sadder sense, they were very nearly monuments marking the demise of the water resources upon which they had relied. For instance, the textile mills in such places as Lowell and Lawrence dammed the Merrimack River to collect the large volume of water needed to power the mills. Miles of canals were dug to divert the water out of the river and distribute it among scores of mills. These modifications affected not only the physical state of the river, but the flora and fauna of the river as well. The extinction of spawning salmon, shad, and herring from the Merrimack is directly attributable to the damming of the river.

Textile mills and related industries not only altered the river’s flow but also became major polluters of the watershed. They discharged dyes, bleaches, soaps, and solvents into the river. Organic waste from cleaning the raw cotton was dumped into the canals and river. “Suint,” the greasy coating covering wool fibers, constituting 50% of the weight of raw wool, was scoured from the fleece with caustic solvents and often discharged directly into the waterways.

In the 1890's the textile industry in Lowell used and discharged approximately 40,000,000 gallons of water per day (in comparison, according to the USGS, the average water use for a typical present-day household of four is about 320 gallons per day). Coal waste from steam power generation and other by-products used as fill and buried in dumps contributed to ground-water contamination. The textile industry was, of course, only one of many types of industry relying upon and affecting the water resources. Pulp mills, tanneries, coal gasification plants, among others, all added to the contamination of the Merrimack and its tributaries. In addition, cities within the watershed disposed of their waste into the waterways. The industrialists and the public believed that running water would purify itself and that "dilution was the solution to pollution." Ideas such as these contributed, in part, to the social and political environment that allowed the Merrimack by the 1960's to become one of the most polluted rivers in the United States.

By the 1870's the inherent contradiction between using the river as a municipal and industrial sewer and using it as a source of drinking water became evident. After several studies on pollution of the Merrimack River and its tributaries, the Massachusetts State Board of Health (MSBH) proposed legislation to prevent the discharge of municipal and industrial waste within 20 miles of a municipal water supply. The law was neither enforceable nor effective, as it exempted the Merrimack and lower Concord rivers from any regulation. Contaminated drinking water caused regular outbreaks of typhoid fever that plagued Lowell, Lawrence and other cities along the Merrimack. Between 1890 and 1891 there were 200 hundred confirmed deaths from typhoid fever in Lowell alone. Scientists and engineers from the MSBH's Lawrence Experimental Station, the birthplace of modern water science in America, traced the epidemic to contaminated municipal water that was drawn from the river. Under the oversight of the Experimental Station, Lawrence installed an effective filtering system. Lowell stopped drawing drinking water from the river and developed a municipal well system. Both responses significantly decreased the mortality rate from water borne disease. As early as the 1870's scientists, physicians, and government officials were demanding protection for water resources. Few heeded their demands since it was more convenient and cheaper to dump the waste and filter drinking water than it was to treat and clean municipal and industrial sewerage. Little or nothing was accomplished for nearly a century to clean and protect the the Merrimack River watershed.

The Clean Water Act of 1972 marked a turning point for the Merrimack River and its tributaries. The Act legislated efforts not only to clean the rivers but also to prevent and monitor pollution that enters the watershed. Today a renewed interest in reusing the old industrial sites and buildings is contributing to the clean-up and protection of our water. Developers are rennovating mills and factories that then are used for housing, office space, and new industry. Contaminated sites are being cleaned and remediated. New businesses, parks, and sports facilities are replacing old, unusable buildings and empty, abandoned industrial sites. Lowell's Tsongas Arena is on the site of what was once a huge mill complex and the University of Massachusetts at Lowell is refurbishing some of the Lawrence mill buildings for its Graduate School of Education. Toxic contamination that threatens water resources is removed or reduced by remediating these old sites. Utilizing these sites instead of building upon undeveloped land, reduces urban sprawl, aids in revitalizing cities, and helps to protect watershed areas.

Only since the 1960's has the environmental impact of the Industrial Revolution become a serious topic of discussion and analysis for both scientists and historians. We are just beginning to identify and solve the environmental problems we have inherited from the Industrial Revolution.

Pre-Visit Activities

#1 Topographic Map Activity

By doing the following activity, students will be able to understand and interpret how the contour lines of a two dimensional topographic map relate to the three dimensions of land formations they represent. After the activity they should be able to identify simple land formations on a topographical map, such as, hills, valleys, and bodies of water. The skill of reading topographic maps will help the students to understand the relationship between landform elevation and the movement of water both above and below ground. Please have the students complete the following pages.

#2 Water Table Contour Activity

When we think of where the earth's water is located we often think of lakes, ponds, streams, and rivers. But there is a source of water that is not visible to our view, water beneath the surface of the earth: groundwater. An easy way to envision groundwater is to think about drilling or digging a well in the earth. You drill or dig down until you "hit" or find water. If you were to drill or dig deeper you would find that the bottom of your hole would be filled with water. In some places around the world, you might have to go down hundreds of meters below the surface of the earth to find water. However, in other places the water may be less than a meter below the ground.

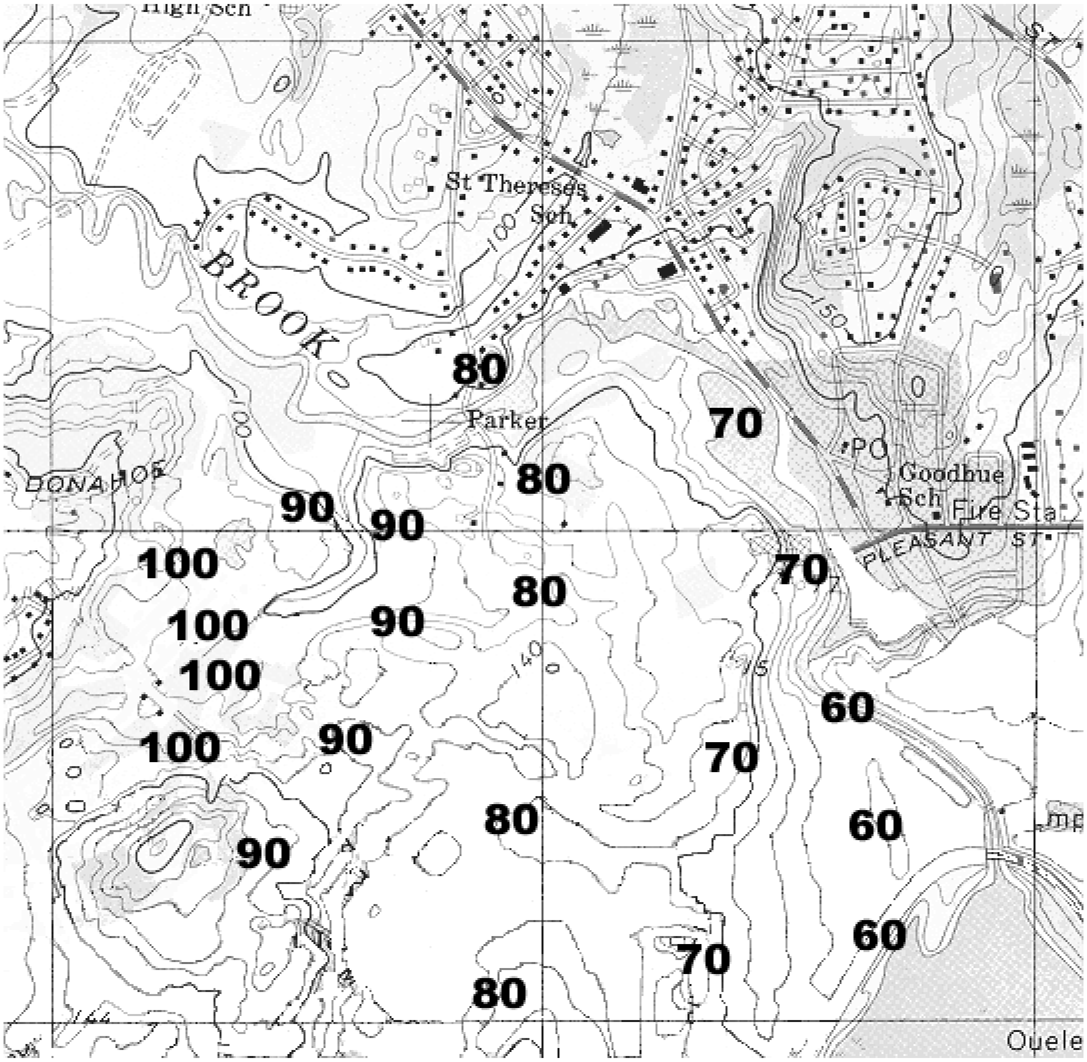
Look at the illustration of *The Mountain Profile*. Some of the water that falls on the surface of the ground seeps down through the soil. This is called “infiltration.” Eventually it reaches the level of the “water table.” Below the water table, the soil is saturated or in other words all of the spaces between the particles the soil are filled with water. When you dug your imaginary well, the point at which you hit water was the water table.

As you know from your every day experience, water flows on the surface of the earth from higher elevations to lower elevations ---- that is, it flows "down hill." Though you cannot observe it directly, water flows beneath the surface of the earth as well. In fact, groundwater flows in much the same way that surface water does ---- from high to low.

Now think back to the exercise you have completed on topographic maps. Each contour line on the map represents a particular elevation of the surface of the ground above sea level. You can also show or map the elevation of the water table in the same way that a topographic map shows the elevations of the surface of the earth.

Let's say that you are standing in a field that is 50 meters above sea level. You now dig a well and you reach the water table after digging 15 meters. That means that the water table is 15 meters below the surface of the ground. Knowing these two variables how would you find the elevation above sea level of the water table? (Subtract the depth of your well from the elevation of the ground above sea level). In this case, 50-15=35. 35 meters is the elevation of your water table at that spot. Now, let’s say you were to determine (by drilling wells) a number of the points in a certain area where the water table elevation was the same and marked these spots on a map. If you connected these points on the map by a line, you would have created a ground water contour.

Look at the accompanying map: *Water Table Contour Activity*. You will see numbers where wells have been drilled and the elevation of the water table determined. Connect the numbers of equal elevation by a line and map out the ground water contours. Once you have completed this, can you determine in which direction the groundwater will flow? (Remember that the water is going to flow from a higher elevation to a lower, perpendicular to the contours.) Mark the direction of the flow with arrows showing the direction of the flow. The arrows showing the direction of the water flow are called “vectors.”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#3 Got The Blues: Citizens Respond to an Environmental Problem. Part 1.

This pre-visit activity is intended to encourage the students to think about how they would respond to the presence of toxic contamination in a residential area. The exercise is intended to elicit responses and concerns of the non-specialist citizen. This problem can be revisited in more detail as a post-visit activity. Please have the students read the accompanying articles: "*Lowell Residents Beset by Chemicals in Soil, State Fences off Yards*" and "*More Toxic Sites Found, Say Activists in Lowell*" and have them answer the following questions. You may want to break the class into several groups to discuss the problems. Some may represent the neighborhood residents and others the agency officials.

If you lived on or near one of these sites, what agencies or officials would you contact about the situation?

Write down four questions that you would want addressed by the officials or agencies you would contact. Rank the questions in order of importance to you.

If you were an official or representative of an agency and had to respond to these four questions, how would you answer them?

What do you think you would have to do to get the information to answer these questions?

Lowell Residents Beset by Chemicals in Soil
State Fences off Yards

State environmental officials yesterday erected a chain link fence around the back yards of homes built over an old dump after increased traces of cyanide were found in the soil. Meanwhile, rattled residents of the neighborhood asked the state to relocate them.

Denise Hansford, who bought one of the four new duplexes built on Billerica Street along the Concord River eight years ago, said she is worried about the health of her two children and said the state should buy the residents homes and find them a place to live in the meantime. "I was trying to sell my house just before this happened, " she said sadly in the kitchen of her two-bedroom home, where nervous residents had gathered as state Department of Environmental Quality Engineering workers worked to put up the fence. Dagma Martin, who owns one of the new homes and rents it out, said the properties could not be rented or sold. "Right now, they are not worth a penny," she said.

The fence was a precautionary measure, DEQE spokesman Myles Brown said, until further soil analyses could be completed. He said tests over the last month showed the land contained cyanide and more chemicals they believe came from the covered-over dump. The previous owner of the land, who has died, operated a dump for half a century, taking wastes from area businesses and hospitals, said Jan Schlichtmann, a lawyer hired by the residents. He said

Colonial Gas Co. dumped unknown quantities of coal gasification byproducts that contained high levels of cyanide and phenol, a deadly chemical.

Brown, though, said, "We don't have anything that shows an imminent health threat or shows they would have to move." Some of the people who live in the area of the modest homes in South Lowell, where small, old homes surround the new duplexes, disagreed. "We were told everything was clean when we bought," said Lillian Klosowki, an elderly widow who lives in one of the new homes with sons. "It was a dump. Now we have cyanide, we have phenol, barium, cadmium," she added.

Problems with the land surfaced earlier this year but DEQE officials three days ago ordered stepped up tests because cyanide concentrations had turned some parts of the land blue, including spots under the children's swing sets. Hansford said when she bought "I wasn't aware it was a dump. The Realtor said it was a small problem ... being stuck on top of it is another matter."

Schlichtmann said, "The place in not a place for people to live. It's unhealthy and unsafe." He said "We are urging DEQE to cooperate with the families to work out a relocation plan so they can end their exposure. The homes are absolutely worthless and unsafe." While he said, "Our immediate concern is the health problem," he added, "We want to make the people responsible for this hazardous waste dump to pay for this."

Colonial Gas vice president-general manager John Harrington said, "We have found nothing that connects us with that." He said the company has undertaken its own investigation and was cooperating with the DEQE. Dumping of coal gasification byproducts ended in the 1940's he said.

Noreen Brodeur of the Greater-Lowell Environmental Campaign said, "We say, get these people out. They have no place to go." She said the developers of the property are out of business or can't be found.

Andrew J. Dabilis *Boston Globe* 12/18/1987

More Toxic Sites Found, Say Activists in Lowell

Standing outside a chain-link fence barricading eight homes on Billerica Street that were built on a toxic waste dump, leaders of an environmental group yesterday said a half-dozen other locations in the city have been similarly contaminated by the same company. Jan Richard Schlichtmann, a lawyer hired by Greater Lowell Environmental Campaign, blamed Colonial Gas Co. for what he said was a century-long pattern of disposing of the dangerous byproducts of coal-gas processes. "They treated the city of Lowell as their own private sewer and …toxic waste dump," Schlichtmann said. He said he has established that the company arranged for the waste to be dumped in wetlands and fields around Lowell.

Colonial Gas said later that Schlichtmann's contention that the additional sites are newly discovered is inaccurate, that each of them had "previously been brought to the attention of the public" and the Massachusetts Department of Environmental Quality Engineering. In addition, company spokesman Jack Rourke said in a prepared statement that "each of the sites is part of DEQE's cleanup program under the Massachusetts Superfund law."

The state agency last winter moved eight families out of their homes on Billerica Street after tests showed compounds dumped there before the homes were built in the late '70's including cyanide and phenols, had turned the soil blue. The families are living in condominiums in nearby Tewksbury, at state expense, while officials try to determine who is responsible for doing remedial work at the site.

Now, said Norine Brodeur, a leader of the environmental group, there is evidence of the same sort of contamination at other sites housing about 40 families. "We don't want to look at testing for the next 10 years. We want a solution, " she said. The group identified the other neighborhoods contaminated by dumping as being along Monarch, Martin, Steadman, Dutton, and Riverby streets and Broadway-streets that are distant from each other.

Brodeur said gas company officials have long known about the history of dumping the coal-gas byproducts, much of which was done more than 40 years ago. She said the company has consistently denied any wrongdoing and will not accept responsibility. The group called for an immediate cleanup of all areas where toxic wastes are found, and for a new authority or commission to oversee the procedure.

A lawyer representing Colonial Gas responded that the firm has never denied it might bear some responsibility for coal-gas waste deposits scattered around Lowell. He said it has insisted only that it has few records that would clearly link its actions to the dumping. At the same time, said Ralph Child of the Boston law firm of Palmer and Dodge, "Colonial has received notices of potential responsibility from DEQE, and has agreed to take responsive action at all these sites."

However, this is likely to take some time. Child said no action can begin until state-funded tests now under way are finished next month, and their results are reviewed by both the state agency and Colonial's environmental consultants. Child said the DEQE's final site-cleanup orders also will be subject to regulatory and legal appeals.

Schlichtmann said delays could be critical because "the waste is extremely dangerous and poses a serious health threat." Schlichtmann said he used public records to find out how the gas company had disposed of wastes from 1849 to 1951, though the company had a different name during that period.

Anne Welcome, who lives near Monarch Street area the group said is contaminated, said she remembers how 10 truckloads of wastes were dumped in a wetlands there in 1944, when she was 16. "As soon as it hit the water, there was a mist that engulfed the neighborhood. You couldn't even go out," she said. She said her husband and at least three other area residents, including a child, have died of cancer in recent years. "I've been trying to draw attention to this for 20 years," she said. In 1944, she said, more than 200 residents signed a petition and went to the board of health to force an end to the dumping.

Tim Keely, who lived in one of the off-limits Billerica Street homes, said he blamed the gas company. "Their involvement is implicit, whether it was 50 or 100 years ago. It was their waste being dumped." Denise Hansford, another resident of the area where the wastes were first found, agreed. "It's immoral-for them to ruin our lives," she said.

And Lillian Klosowski, a widow who also left a Billerica Street home behind, said families are still paying mortgages of $ 1,000 a month or more on what she said was now a worthless property. "This is my life savings here," she said, peering through the chain link fence at the home she can't live in. "I cry every time I go by here. It's really sad."

Andrew J. Dabilis *Boston Globe* 9/17/1988

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POST-VISIT ACTIVITIES

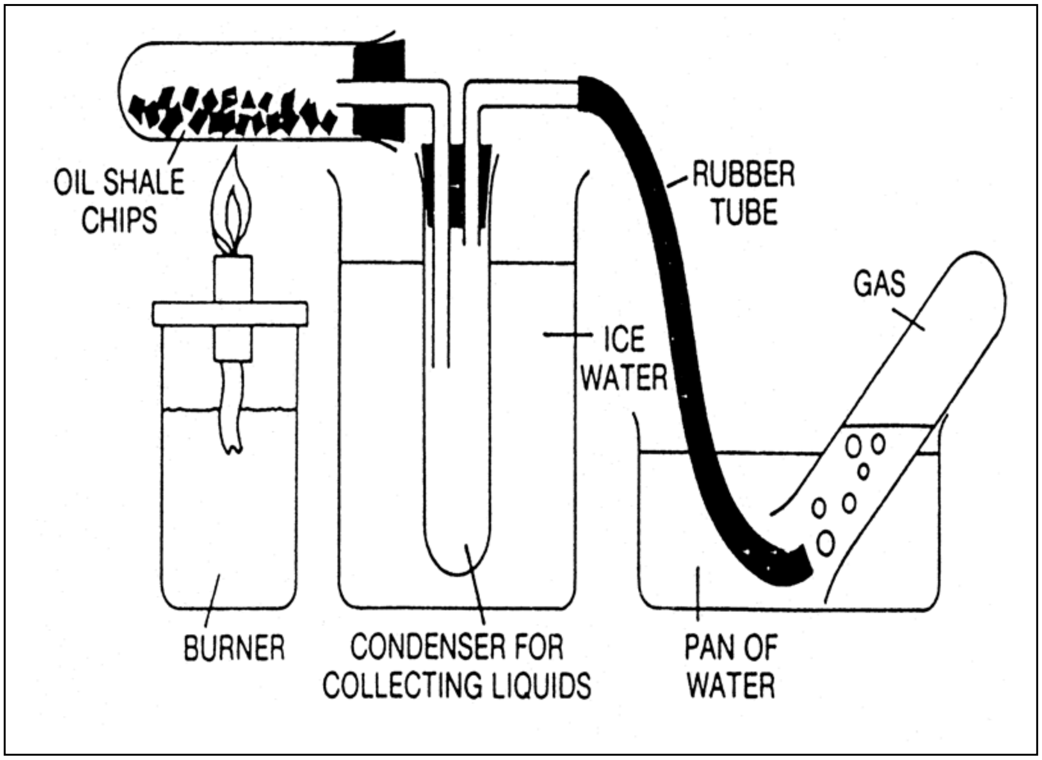
#1 Oil Shale Gasification Experiment

The purpose of this activity is to allow the students to gain insight into both the process of turning oil shale into usable natural gas and to see the bi-products of that process. This process is essentially the same as that used to gasify coal but is slower and safer. Your students will be able to see and understand that the production of a socially beneficial product (in this case natural gas as a source of power, heat, and light) can often have social and environmental costs (in this case toxic wastes) at the same time. The experiment also ties directly into the pre-visit (and the following post-visit) activity concerning toxic the waste sites in Lowell. You can purchase oil shale for the experiment at a small cost at Ward's Geology 1-800-962-2660 or at www.rocksandminerals.com/specimens/list.html

BACKGROUND:
Oil shale is a sedimentary rock (marlstone) containing solid organic matter of high molecular weight called kerogen. When heated (retorted), the kerogen breaks down, yielding substantial amounts of synthetic crude oil and hydrocarbon gas.

PROCEDURE:
Set up the apparatus as shown in the diagram. However. before inserting glass tubing into the rubber stoppers, moisten the end of the tubing with either glycerine, motor oil, or water. Also wrap a towel around the glass tubing. These two precautions can prevent serious injury should the glass tubing break or your hand slip.

Now pack the horizontal Pyrex test tube with oil shale chips. Heat the mid-portion of the tube strongly with the burner flame and observe what happens. Try lighting the gas that comes out the exhaust. The exhaust gas may be collected using the setup shown in the diagram. It you don't choose to collect the exhaust gas, keep it burning as long as you can. if the gas comes out in puffs, you may have to re-light it frequently. This keeps foul odors in the room to a minimum.



The retort tube should be heated for 15-20 minutes.
Finally. being careful not to burn your fingers, remove the condensing tube before you stop heating the retort tube. This will prevent cooled liquids from "backing up" into the retort.
Questions to answer during the Lab:

1. What did you observe in the condenser (the clean test tube)?

2. What did you discover about the exhaust gases?

3. Make observations on any liquid collected by pouring a portion of the liquid out onto a tin can lid. How many can you see? Are they flammable? Describe the odor, if any.

4. After the retort tube has cooled, remove the one hole stopper and tap the contents out onto a piece of paper towel. Describe what you see. How has the substance changed?

Clean up and return your materials to their designated locations. Throw spent shale into the trash, not the sink.

#2 Revisiting the Blues: A Closer Look at the Coal Gasification Problem in Lowell

Now that the students have gained a better insight of the problems of the contamination of our water resources by attending the **Industrial Watershed** program, you may wish to approach the problem of the coal gasification wastes in Lowell in greater detail. If you wish to revisit the problem we will provide to you an article "*The Known and Present Danger,*" written by Jan Schlichtmann, containing a lengthy summary of the history of the problem and the types of toxins involved. Please ask the museum teacher for a copy or call the Tsongas Center at (978)-970-5080. Most of the coal gasification dumpsites have undergone remediation and have been capped. Colonial Gas settled through mediation and the case did not need to go through a lengthy court case as the litigants did in the *Civil Action* case in Woburn.

Some points you may want to consider and discuss:

The Billerica St. site is on the bank of the Concord River. The Martin and Riverby Sts. sites are adjacent to the Beaver Brook. The Monarch St. site is on a wetland and small stream. The Broadway street site is on the Pawtucket canal. All of these are tributaries of or drain into the Merrimack River.

Revisit the questions you answered in the pre-visit activities. Having learned more about groundwater and surface water during the tour and lab, would you answer any of these questions differently?

If you lived on or near one of these sites, what agencies or officials would you contact about the situation?

Write down four questions that you would want addressed by the officials or agencies you would contact.
If you were an official or representative of an agency and had to respond to these four questions, how would you answer them?

What do you think you would have to do to get the information to answer these questions?

Are there problems that are associated with the types of bi-products found in the dumpsites? What levels of contaminants are allowable for physical human contact? What about the levels for drinking water? Search the web to find your answers. Here are some places to start:

www.atsdrl.atsdr.cdc.@ov:8080/mrls.html
www.atsdrl.atsdr.cdc.gov:8080/9711st.html
www.atsdrl.atsdr.cdc.gov:8080/tfacts.html
www.atsdrl.atsdr.cdc.gov:8080/hazdat.html
www.epa.gov/ogwdw/dwh/c-ioc
www.epa.gov/ogwdw/wot/appa.html
www.epa.gov/ogwdw/ccl/cclfs.html

#3 Using the *Power to Protect* Program

Having experienced the **Industrial Watershed** Program, students should now have a clearer understanding of the nature and importance of groundwater. They've become aware of threats to this resource and possible sources of contamination.

Students are now ready to put together the ideas they have learned and deal with an in-class problem that has real implications for their lives. The video *Power to Protect*, supplied by the Massachusetts Audubon Society and available on loan from the Tsongas Center, presents accounts of three real situations, all in New England towns who rely on underground aquifers for their drinking supply. The video traces how these towns detected potential and already-existing problems with those supplies and developed plans to solve or avert those problems, demonstrating the effectiveness of action at the community level.

The accompanying workbook was written as a guide to assist communities in establishing Wellhead Protection Programs. The workbook covers such issues as:

-- making people aware of, and supportive of, the groundwater project, determining what information and data are needed and what experts to consult,
--mapping the known aquifer and delineating recharge areas, determining the condition of the aquifer's water via chemical and biological testing,
--taking remedial steps if a problem with the water quality is found, evaluating land uses in the wellhead area and potential threats to groundwater of those uses,
-- establishing fair land use (zoning) policies for industry, agriculture, business and residence,
-- organizing an on-going program of monitoring and maintenance to ensure continued protection of the aquifer.

The Power to Protect program is a valuable tool for teachers to use to tie together what students have already learned. The simplest use is to have students watch one of the 15 minute segments and discuss what they've seen. They can then:

summarize the issues they heard presented, interpret and analyze any data that were gathered, compare/contrast the opinions and attitudes of the people involved, evaluate the choices and solutions that were reached by the community, add to those solutions or formulate their own (what would they have done differently, or in addition to, what they saw), -- predict consequences (costs and benefits) of the Wellhead Protection Program to each of the groups of townspeople who were heard from, and predict consequences of taking no action at all.

By "walking through" the process, students can learn about the issues and decisions (both scientific and "people-oriented") involved in such an undertaking, and they will gain an appreciation for the difficulties that adults often face in trying to reach agreement and rectify a problem.

Alternatively, teachers can use this program as a model to help students design their own investigation of groundwater protection in their town. They could, for example, find out:

where the sources of drinking water for their town are located, where the recharge areas are, what land uses in or near the recharge area might pose a threat, what the topography of the area is, if they get water from surface sources, how those sources interact with the water table,

-- what are the town policies, laws, and ordinances governing dumping of potentially harmful substances, what kind of enforcement of these policies is in effect, what kind of monitoring and regular testing do the wells undergo (if any), is there a Wellhead Protection program in place and if so, how was it developed,

-- if no formal program exists, what could or should be done about it?

This level of investigation would involve considerable time and effort: researching the history of the issue, analyzing maps, visiting sites, interviewing town officials, getting a feel not only for the scientific but the political issues involved, and the various motivations that people have for what they do. It is, however, an ideal subject for an interdisciplinary project that could include most of the sciences, mathematics, social studies (particularly civics), geography, and language arts.

It is also a project that lends itself both to cooperative learning and to a variety of types of assessment, from traditional reports to presentations and portfolios.
There are many possibilities for creativity, skill development, and an overall rich learning experience.

Glossary of Terms

aquifer - A porous and permeable geologic underground layer that stores, transmits, and yields useful amounts of water to springs and wells.

aquitard - An underground layer of relatively impermeable material that blocks or slows the flow of water.

area of influence - The area around a well where the water table is lowered by the pumping of the well.

bedrock - Any solid rock exposed at the surface of the earth or overlain by unconsolidated material (soil). Bedrock itself is impermeable, but may contain fractures, which allow storage of water.

Clean Water Act - An act of Congress passed in 1972 to establish guidelines for the protection of our nation's water.

cone of depression - The area around a well where groundwater levels and pressure are lowered as a result of water extraction. In these low-pressure areas, the water table forms the shape of an inverted cone around the well (see also area of influence).

confined aquifer - An aquifer overlain by silts or clays that have low permeability.

contour line - A line on a topographic map that connects points on the land that are of equal elevation.

discharge area - An area where groundwater flows out of the ground into streams, rivers, wetlands, and other surface waters. Groundwater discharge occurs where the water table intersects the ground surface.

fractures - Breaks or cracks in rock or soil. Fractures in Bedrock may hold water, acting as aquifers.

groundwater - Water that fills the unblocked pores or fractures of underlying material below the water table.

hydraulic conductivity - The rate at which water can pass through a material. Hydraulic conductivity is a function of permeability, viscosity, and density.

hydraulic gradient - The ratio of vertical drop of the water table to the horizontal distance of the groundwater flow.

impermeable - A soil material that will not allow water or air to pass through it.

infiltration - A process by which water passes through soil pores or bedrock fractures.

injection well - A well used for disposing of wastes deep into the ground.

permeability - The ability of a material to transmit water.

plume - A volume of groundwater containing contaminants. Usually has an elongated shape.

porosity - The ratio of air space to the total volume of a soil or rock.

recharge area - The watershed area that contributes water to an aquifer or well.

Safe Drinking Water Act - An act of Congress passed in 1974 to regulate and manage the quality of drinking water supplies in the U.S.

septic system - An on-site system for treating and disposing of wastewater into the soil.

topographic map - A map showing the elevation of the landscape by means of contour lines.

water table - The upper limit of the part of the soil or underlying material that is wholly saturated with water.

water table contour line - A line which connects points of equal elevation of the water table level.

watershed - A land area within which water, sediments, and dissolved materials drain into a common outlet such as a stream, lake, estuary, or ocean.

wellhead protection area - An area around the recharge area of a well in which activities that may threaten groundwater quality are monitored and/or restricted.

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