Take Care of Texas
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A PROGRAM OF TCEQ

TAKE CARE OF TEXAS: EDUCATOR MATERIALS

LESSON PLAN

Water Pollution

Objectives

Students will learn about water pollution and pollution indicators. Students will identify potential water pollution sources within a watershed using sight and smell.

Prerequisites

Students should complete the Testing Water series or other water quality lessons to build context.

Duration

Two to three 40-minute lessons

Materials

- Point Source Anchor Chart
- Pollution Type and Source Handout
- Pollution Type and Source Matching Cards
- Pollution Indicators Handout
- Pollution Indicators Matching Cards
- Water Pollution Handout

Introduction

TEACHER BACKGROUND

Water pollution is defined as the alteration of the chemical, physical, or biological integrity of water. Pollution is caused by activities that affect overall water quality. Water pollution can occur naturally or from human activities.

Point Source Pollution

"Point source pollution" refers to discharge of pollutants at a specific location, such as a pipe discharging wastewater or runoff into a stream. Regulations categorize point sources and then set pollution-control requirements for those categories. To ensure compliance with water quality standards, many point source owners or operators must monitor and document the chemical parameters of their discharge.

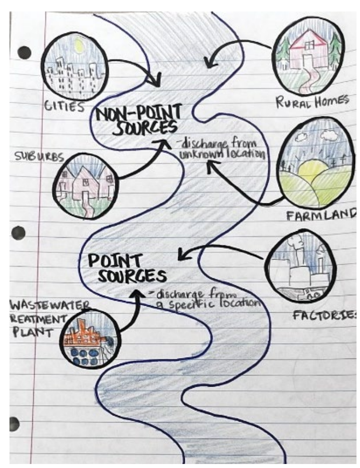

Fig. 1 Sources Anchor Chart

Nonpoint Source Pollution

"Nonpoint source" refers to pollutants that do not have a specific point of origin. These pollutants are generally carried by runoff. Nonpoint source pollution includes runoff that contains:

- excess fertilizers, herbicides, or insecticides from agricultural lands and residential areas.
- motor oil, grease, or toxic chemicals from urban areas (roadways, parking lots, etc.).
- sediment from poorly managed construction sites, agricultural lands, or logging sites.
- bacteria from a faulty septic system, livestock waste, or pet waste.
- household chemicals that were improperly disposed of.

DISCUSSION

Ask students to define point sources and nonpoint sources. Field responses from students and then introduce the Sources Anchor Chart **(Fig. 1 Sources Anchor Chart)**. Explain the difference between the two sources and have students name some other types of sources. Students will use this information during the activity portion of the lesson.

Explain to students they will be divided into groups, then assigned a number individually; each number will later go to another group where they will read their number paragraph on the **Pollution Type and Sources Handout**. For example, the students assigned the number 5 will read the #5 paragraph and learn about that pollution type. Each member needs to make sure they can go back to their original group and correctly explain the pollution type. Members of the number group can discuss, ask questions, or find ways to help each other understand each pollution type.

Once back at the original group, the group will get the pre-cut **Pollution Types and Sources Matching Cards** and work together to match the type/source to the definition. When they are done, check their work. If they are correct, the students will then return to the numbered group and now read **Pollution Indicators Handout** to learn about those types. Like before, they will return to their original group and will get the pre-cut **Pollution Indicator Matching Cards** and correctly match the indicators with definitions.

Bring the class back together and discuss the different types of pollution and sources, review the difference between point and nonpoint sources, and talk about the various indicators that can be used when observing water quality. Explain to students that they will now use that knowledge and apply it to complete the next activity.

Procedure

1. Pass out the **Water Pollution Handout** and explain to students they will use the Reference Tables to help them answer the question and fill in the blank.
2. Students can also use the matching cards that were used earlier for extra help. If needed, students can be paired up to complete the activity.
3. The activity can be used as an assessment, with the answer key provided at the end.

Glossary

- **Acute Toxicity** – high concentrations of a substance that cause immediate danger or death.
- **Algal Bloom** – an event where algae multiply at an accelerated rate and may continue to grow.
- **Bioaccumulate** – buildup of toxins in an organism's body.
- **Biochemical Oxygen Demand (BOD)** – the amount of oxygen required to decompose organic materials.
- **Dissolved Oxygen (DO)** – levels of oxygen in the water.
- **Escherichia coli *(E. coli)*** – bacteria commonly associated with human waste.
- **Eutrophic** – water bodies with high nutrient levels, capable of supporting an abundance of living organisms.
- **Nonpoint Source Pollution** – when pollutants do not have a specific point of origin.
- **Oligotrophic** – water bodies with low nutrient concentrations.
- **Point Source Pollution** – discharge of pollutants at a specific location.
- **Pollutant** – a substance that causes pollution.
- **Suspended Solids** – mineral and organic particles suspended in the water column, often small clay and silt particles.
- **Turbidity** – the amount of light blocked due to solids suspended in the water.

Applicable TEKS

Science TEKS

- **6th Grade** – §112.26.b. 1A-B; 2A; 3A-C; 5A-G; 11A-B; 12A-C.
- **7th Grade** – §112.27.b. 1A-B; 2A; 3A-C; 5A-G; 11A-B.
- **8th Grade** – §112.28.b. 1A-B; 2A; 3A-C; 5A-G; 11A-B.

Pollutant Types and Sources

1) Nutrients

Nutrients, such as nitrogen and phosphorus, are essential for plant growth. The rate of plant growth is controlled by a limiting nutrient, a nutrient available in quantities smaller than necessary for plants to reach maximum abundance. When the limiting nutrient is used up, plant growth stops even if there is an adequate supply of other nutrients available. When excessive nutrients are available, an **algal bloom** may occur, in which algae multiply at an accelerated rate and may continue to grow until the limiting nutrient is exhausted. During these blooms, the levels of oxygen in the water (**dissolved oxygen**) during daylight hours can be very high from the abundance of algae producing oxygen during photosynthesis. However, oxygen production ceases at night, and the dissolved oxygen (DO) levels may drop to lethal levels for algae and animals using the DO for respiration. Nutrients can include fertilizers and manure from agricultural activities, urban runoff containing fertilizer from lawns and golf courses, and domestic and industrial wastewater effluent.

2) Oxygen-Demanding Substances

In a body of water, the DO level will increase because of photosynthesis and natural aeration (rain, wind, waves, water currents, etc.) and will decrease from respiration. The DO level is also influenced by the water's temperature; the colder the water, the more oxygen it can hold. Organic material introduced into a water body can cause respiration levels to rise; that happens when organisms use DO and the organic materials for respiration. When respiration increases, DO decreases. Very low DO levels can kill fish. The effects of organic materials are generally long lasting, with gradual deterioration of an aquatic ecosystem over time. The amount of oxygen required to decompose organic materials is called **biochemical oxygen demand (BOD)**. When the BOD of the organic materials exceeds the available DO, the DO in the water body is reduced or depleted and is unavailable for aquatic life. Sources of oxygen-demanding substances include raw sewage, household pet waste, waste from food-processing plants, and animal feedlot waste.

3) Suspended Solids

The term **suspended solids** is commonly used to describe the mineral and organic particles suspended in the water column. Most often, they are small clay and silt particles held in suspension by water currents. **Turbidity** refers to the amount of light blocked due to solids suspended in the water. When turbidity increases, light penetration decreases. Increases in turbidity affect aquatic life in several ways:

- Primary producers are less able to produce oxygen. If light levels get too low, photosynthesis may stop altogether.
- Turbid water reduces the visibility of fish and increases their difficulty in finding food.
- If the sediment load is too high, fish gills can become clogged.
- Suspended solids carry plant nutrients and provide attachment places for other pollutants (i.e. metals).
- Turbidity increases the temperature of the water when suspended particles absorb heat from the sun.

Sources of suspended solids can include runoff from construction sites or surface-mining operations without adequate erosion and sediment controls (silt fences, sediment traps, etc.), runoff from erodible agricultural lands, and upstream soil or substrate erosion naturally caused by fast-moving water during heavy rains.

4) Sedimentation

Sedimentation is a decrease in water flow and speed, allowing suspended materials to drop to the bottom. Sediment is mostly a mixture of loose inorganic particles (sand, silt, and clay) and organic substances (decomposing plants/animals). In a natural river system, high flows scour the bottom carrying the sediment downstream; during floods, water leaves the river channel, and sedimentation occurs on the floodplain. Increased sedimentation, especially in slow-moving areas, creates problems for aquatic organisms by covering up habitats. The reduction of aquatic habitats changes the types of aquatic plants and animals living in a water body. Sources of sediment can include runoff from construction sites or surface-mining operations without adequate erosion and sediment controls (silt fences, etc.), runoff from erodible agricultural lands, and upstream soil or substrate erosion naturally caused by fast-moving water during heavy rains.

5) Toxic Substances

Substances that are considered toxic can kill or harm organisms directly and in a relatively short time. Toxins generally disrupt an entire ecosystem, severely reducing the stream's natural ability to recover. **Acute toxicity** refers to high concentrations of a substance that cause immediate danger or death, whereas **chronic toxicity** refers to the long-term effect of sublethal levels of a substance that alters growth, reproduction, or development of aquatic organisms. Common substances toxic to aquatic life are ammonia, chlorine, and heavy metals. Ammonia is a valuable component of fertilizer and is also used in household cleaning supplies (like window cleaner), but it is highly toxic in nature. Ammonia enters water bodies in a variety of ways; the most common sources are raw (or partially treated) sewage and runoff from animal-feeding operations without adequate ammonia controls. Chlorine is a very common disinfectant used in household cleaning supplies and wastewater treatment plants but is a chronic source of stress on the aquatic environment. Chlorine commonly enters the aquatic environment from treated domestic wastewater (discharged from wastewater treatment plants). Heavy metals are used in various industrial practices and in bridge pilings. Heavy metals can enter water bodies from industries that do not properly control the heavy metals in their wastewater or stormwater; they can also enter from the erosion of the bridge pilings. Certain toxic substances enter bodies of water in very low concentrations that pose no apparent risk at that level; however, these toxins can **bioaccumulate** in an organism's body. If an animal eats many organisms that contain these toxins, the toxicity level in that animal increases; this is called **biomagnification**.

6) General Land Use Sources

Different types of land use can affect nearby water in different ways. When woodlands are logged or cleared, soil can wash into streams and make the water muddy. Agricultural land—like croplands, pastures, and feedlots—can send fertilizers, manure, pesticides, and herbicides into waterways, which may cause too much algae to grow and increase sediment from erosion. In cities and towns, rainwater can wash oil, metals, chemicals, and other pollutants off streets and into streams. Industrial areas may release chemicals that change water color, create strong odors, kill fish, or lead to sewage fungus. Wastewater treatment plants can cause problems like algal blooms, foam, sludge buildup, low oxygen levels, chlorine smells, and high E. coli levels if the water isn't fully treated. Construction sites often produce muddy runoff that increases turbidity. Finally, residential areas can contribute fertilizers, oil from cars, leaking sewage from septic systems, detergents, and even litter, all of which can harm water quality.

Pollution Types and Sources Matching Cards

Category	Definitions
Nutrients	Causes harm in relatively short times; can be acute or chronic; leads to issues like bioaccumulation and biomagnification.
Oxygen-Demanding Substances	Causes water to become muddy; increases temperature because particles absorb heat; measures light blocked in the water column (turbidity).
Suspended Solids	Specific human environments (e.g., woodlands, agriculture, cities, construction) that introduce distinct pollutants into nearby waterways.
Sedimentation	Nitrogen and phosphorus; excessive amounts can cause lethal drops in dissolved oxygen (DO) at night due to rapid algal blooms.
Toxic Substances	Organic material that reduces or depletes dissolved oxygen as it decomposes; measured by BOD.
General Land Use Sources	Occurs when water flow decreases, allowing suspended materials to drop to the bottom and cover up aquatic habitats.

Answer Key:

Nutrients – Nitrogen and phosphorus; excessive amounts can cause lethal drops in dissolved oxygen (DO) at night due to rapid algal blooms.

Oxygen-Demanding Substances – Organic material that reduces or depletes dissolved oxygen as it decomposes; measured by BOD.

Suspended Solids – Causes water to become muddy; increases temperature because particles absorb heat; measures light blocked in the water column (turbidity).

Sedimentation – Occurs when water flow decreases, allowing suspended materials to drop to the bottom and cover up aquatic habitats.

Toxic Substances – Causes harm in relatively short times; can be acute or chronic; leads to issues like bioaccumulation and biomagnification.

General Land Use Sources – Specific human environments (e.g., woodlands, agriculture, cities, construction) that introduce distinct pollutants into nearby waterways.

Pollution Indicators

1) High Levels of *E. coli* Bacteria and Increased Turbidity

Historically, fecal coliform bacteria (commonly found in the small intestines of humans and other warm-blooded animals) were the most widely used indicator bacteria in surface waters. **Escherichia coli** (more commonly associated with human waste only) replaced fecal coliform as the indicator bacterium for freshwater bodies in Texas. The presence of fecal coliform or E. coli is usually associated with inadequately treated sewage, improperly managed animal waste from livestock or pets, failing septic systems, and wildlife (birds and mammals) living near water. Material that becomes mixed and suspended in the water column increases water turbidity and decreases water clarity. Increased water turbidity can cause water temperatures to rise, thus decreasing the maximum amount of DO held in the body of water. In the summer, an important contributor to increased turbidity is plankton. Planktonic organisms grow rapidly in nutrient-rich waters that are warm and receive direct sunlight. During periods of heavy runoff, silt is also a factor.

2) Fish and Benthic Macroinvertebrates

Biological communities (fish and freshwater macroinvertebrates) can be used to determine past and present water quality. Fish and benthic macroinvertebrates are placed into categories based on their tolerance to pollution and are used as indicator organisms in evaluating the health of streams. The three main categories of pollution tolerance are:

- Intolerant: sensitive to poor stream conditions.
- Intermediate: moderately tolerant of degraded habitat and water quality.
- Tolerant: most tolerant of degraded habitat and water quality.

For healthy streams, intolerant organisms will be present along with intermediate and tolerant organisms. Water quality is not always the limiting factor in the presence or absence of aquatic organisms. Physical habitat also plays a key role in whether an organism inhabits a water body. The type and number of organisms present can tell a lot about a stream. If the aquatic community is made up of more intolerant species and a few intermediate and tolerant forms, the stream can be considered healthy. The presence of intolerant and intermediate species generally means that no significant pollution exists. Poor water quality is indicated when the number of tolerant species exceeds that of intermediate species, and intolerant species are absent. The number of individuals of any one species is also an indicator of quality. A good quality stream will have a larger number of species with fewer individuals per species, increased variety, and a balanced system. An unhealthy community includes a few species with numerous individuals, lacks variety, and is unbalanced.

3) Unexpected Changes to Water Temperature

In general, aquatic organisms are cold-blooded and have body temperatures that fluctuate with the water temperature. Each aquatic species has an optimum temperature at which it functions the best. Most fish and other aquatic species in Texas are among those that can tolerate warmer water in summer and colder in winter. The effects of temperature on a stream are normally chronic, with gradual changes in the aquatic community. However, extreme weather conditions can cause die-offs due to drastic temperature changes. Removal of tree canopy and channelization of a stream reduce the thermal buffering capacity of that water body, resulting in bigger and more rapid shifts in temperature, with higher than average temperatures in summer and colder than average in winter. Native aquatic fish and invertebrate species are adapted to the normal seasonal shifts in temperature but can be affected by alterations to the normal stream conditions. High water temperatures increase metabolism, respiration, and oxygen demand of fish and other aquatic organisms (metabolic rates in aquatic organisms double with every rise of 10°C in temperature). Increased temperatures also enhance the effect of nutrients on plankton blooms. The effects of oxygen-demanding substances are intensified by temperature increases.

4) Low Levels of Dissolved Oxygen

DO is one of the most important indicators of water quality for aquatic life because it is essential for all aquatic plants and animals. DO is a particularly sensitive factor because chemicals, biological processes, and temperature often determine its availability at different times during the year. The DO saturation level tells you how much DO the water can hold at a given temperature, pressure, and salinity. Elevated temperatures, increased salinity (salts), and pressure decreases reduce the amount of DO that the water can hold. In addition to temperature, pressure, and salinity, there are other things that influence DO levels—including photosynthesis, natural aeration, and respiration. For example: during algal blooms, DO levels in daylight hours can be extremely high (often greater than 10 ppm) because of photosynthesis; at night, DO can drop to lethal levels when photosynthesis stops producing oxygen and organisms respire only using DO stored in the water. Water can sometimes have DO levels above its saturation level, called supersaturation. Water bodies with elevated nutrient concentrations (eutrophic), high temperatures, and large amounts of filamentous and planktonic algae can create supersaturated conditions during daylight hours. When DO levels fall below 2 to 3 ppm, fish and many other aquatic organisms may become stressed, and some may not survive. Many fish kills in ponds and streams during the summer months are caused by low DO levels from a combination of elevated nutrients and warm water.

5) High or Low pH

The pH scale, numbered from 0 to 14, is used to measure the acidity of a water body. Pure water has a pH value of 7.0, which is considered neutral and is neither acidic nor basic. When the pH is less than 7.0, water is considered acidic; a pH greater than 7.0 is considered basic (alkaline). Generally, the ability of aquatic organisms to complete a life cycle greatly diminishes as pH becomes greater than 9.0 or less than 5.0. The pH of an aquatic system is influenced by several factors. Water dissolves mineral substances it encounters, picks up aerosols and dust from the air, receives human-originated wastes, and supports photosynthetic organisms—all of which affect pH. When photosynthesis occurs, carbon dioxide (CO2) levels in the water are reduced, along with carbonic acid levels. When carbonic acid decreases, pH increases. Other events in the watershed that may also affect pH include increased leaching of soils or minerals during heavy rainfall runoff, accidental spills, agricultural runoff (pesticides, fertilizers, soil leachates), and sewage overflows.

6) Increased Nutrient Content

The addition of excessive nutrients to water bodies can cause an algal bloom (normally composed of phytoplankton or filamentous algae). An algal bloom is often followed by a zooplankton bloom, and later decomposition, which reduces the water's DO level. Nonpoint source runoff may contain phosphorus or nitrogen compounds; for example, rainwater could carry excess fertilizer (containing phosphates and nitrate) into a stream. Point source pollution may also contain these compounds; for example, household chemicals flushed down the drain could enter a water body if they are not removed by the wastewater-treatment plant.

Pollution Indicators Match Cards

Terms	Definition
Turbidity	A condition where DO levels are above saturation, often created in daylight hours by elevated temperatures and large amounts of algae.
Intolerant Organisms	Organisms that are highly sensitive to poor stream conditions; their presence in a stream indicates a healthy environment.
Unhealthy Biological Community	An aquatic community that includes a few species with numerous individuals, lacks variety, and represents an unbalanced system.
Supersaturation	A water body with elevated nutrient concentrations, which can contribute to low dissolved oxygen (DO) levels during the summer.
PH Scale	Material mixed in the water column that decreases clarity, can cause water temperatures to rise, and is often contributed to by silt and summer plankton.
Eutrophic	Measure of water acidity ranging from 0 to 14, where values below 7.0 are acidic and values above 7.0 are basic.

Answer Key:

Turbidity – Material mixed in the water column that decreases clarity, can cause water temperatures to rise, and is often contributed to by silt and summer plankton.
Intolerant Organisms – Organisms that are highly sensitive to poor stream conditions; their presence in a stream indicates a healthy environment.
Unhealthy Biological Community – An aquatic community that includes a few species with numerous individuals, lacks variety, and represents an unbalanced system.
Supersaturation – A condition where DO levels are above saturation, often created in daylight hours by elevated temperatures and large amounts of algae.
PH Scale – Measure of water acidity ranging from 0 to 14, where values below 7.0 are acidic and values above 7.0 are basic.
Eutrophic – A water body with elevated nutrient concentrations, which can contribute to low dissolved oxygen (DO) levels during the summer.

Table 1 – Physical Indicators of Water Pollution

If you see the color(s)...	The issue could be...
Muddy tan to light brown	Suspended solids (silt and clay) due to: • upstream erosion of the banks and substrate due to channelization, • stormwater from logging or construction sites with inadequate erosion and sediment controls, or • stormwater from one or more areas with soil erosion, such as poorly maintained croplands and rangelands, riparian zones with removed vegetation, exposed banks, etc.
Pea green, bright green, yellow, brown, brown-green, brown-yellow, blue-green	An algal bloom due to high nutrient content (phosphorus, nitrogen, or both). Water color is dependent on the dominant plankton type.
Tea or coffee	Dissolved decaying matter originating from the organic portion of the soil. This is usually seen in woodland or swampy areas.
Milky white	Paint (from a construction site) or milk (from a food processing site).
Dark red, purple, blue, or black	Fabric dyes or inks from paper or cardboard manufacturers.
Milky gray, or black	Oxygen depletion from raw sewage or other oxygen-demanding substance; a rotten-egg or hydrogen sulfide odor might be present.
Clear black	Turnover of oxygen-depleted bottom waters or sulfuric acid spill.
Orange-red	Deposits on stream beds often associated with oil production areas, but not always (check for petroleum odor). The color could be due to iron in the water.
White, crusty deposits	Common in dry or arid areas where the evaporation of water leaves behind salt deposits. These deposits are also associated with brine water discharge (from oil production areas); check to see if the stream has a petroleum odor or an oily sheen along the banks.
If you smell...	**The odor is from...**
Rotten eggs or hydrogen sulfide	Raw sewage (oxygen-demanding substance) or oxygen-poor sediment.
Chlorine	Treated effluent, swimming pool overflow, or industrial discharges.
Sharp, pungent odor	Chemicals or pesticides.
Musty odor	Presence of raw or partially treated sewage or livestock waste (organic-demanding substances). Musty odor could also be caused by algae.
If you see on the surface...	**The material is possibly caused by...**
Tan foam	Water containing organic materials with high flow or wave action. This harmless foam can be in small patches to very large clumps.
White foam (thin or billowy)	Soap in treated effluent, possibly around a wastewater outfall.
Yellow, brown, black film	Pine, cedar, and oak pollens that form a film on the surface of ponds, backwater areas, or slow-moving water of streams.
Rainbow film	Oil or other fuel type. Sheens are common after rains when oil and gas residue wash off streets. Other sources include spills, pipelines, and oil and gas-production areas.

Table 2 – General Land Uses That Might Affect Water Quality

Land Use Type	Potential Effects
Woodland	Erosion from logging, road construction, or clear cutting may cause muddy waters.
Agricultural Land (croplands, pastures, feedlots, etc.)	Fertilizers or manure draining into a stream may increase the nutrient content and cause excessive algal and aquatic plant growth. Sedimentation may occur from soil erosion. Streams may also receive pesticides and herbicides in the runoff.
Cities and Towns	Depending on the activities occurring in the city or town, urban runoff might carry a variety of contaminants such as oil, pesticides, metals, and chemicals.
Industry	Industries have numerous types of chemicals and products that could cause color changes to the water, excessive algal growth, odors, absence of aquatic life, fish kills, elevated organic matter levels, and sewage fungus.
Wastewater Treatment Plants	Effects may include excessive algal growth, white foam, sludge deposits (fluffy dark brown or gray solids), absence of fish and insects (or the abundance of tolerant forms), variable dissolved-oxygen levels, chlorine odor (and possible bleached vegetation near the outfall), sewage fungus, and elevated levels of E. coli.
Construction	Runoff from construction sites can cause water to become muddy and turbid.
Residential	Runoff from residential areas may contain fertilizers (nutrients), oil drained from cars (toxic substances), raw sewage from septic systems that overflow or leak (oxygen-demanding substances), detergents used to wash cars (toxic substances), and even litter (cans, bottles, paper, etc.).

Sources Anchor Chart