Heat itself can be a pollutant

Thermal pollution occurs when heat released into water harms organisms in that ecosystem. Water can look clear and contain no newly added toxic chemical while a temperature change still causes harm.

1. FOLLOW A HEATED COOLING-WATER DISCHARGE

WITHDRAW

Water is taken from a river or lake.

→

ABSORB HEAT

Cooling water receives heat from equipment.

→

RETURN WARMER

Discharge adds heat to the receiving water.

Illustrative once-through cooling pathway. Power stations and industrial facilities can transfer waste heat to water. The heat passes from the equipment into the cooling water; the water does not have to mix with fuel to become warmer.

2. EXPOSURE DEPENDS ON THE RECEIVING WATER

A heated discharge mixes with the surrounding water rather than instantly warming the entire river or lake equally. Its effect depends on discharge temperature and volume, receiving-water flow, mixing and existing conditions. A local warm-water plume may expose organisms near the outlet more strongly.

3. EXTENSION: OTHER TEMPERATURE DISTURBANCES

Removing streamside vegetation can increase solar heating. Runoff from warm pavement can carry heat into streams. Dam releases can also change downstream temperature, sometimes cooling rather than warming the water. These broader temperature disturbances should be distinguished from this topic's central example of harmful heat release.

Thermal pollution concerns the conditions experienced by aquatic organisms, not simply whether a facility is hot or whether the weather is warm.

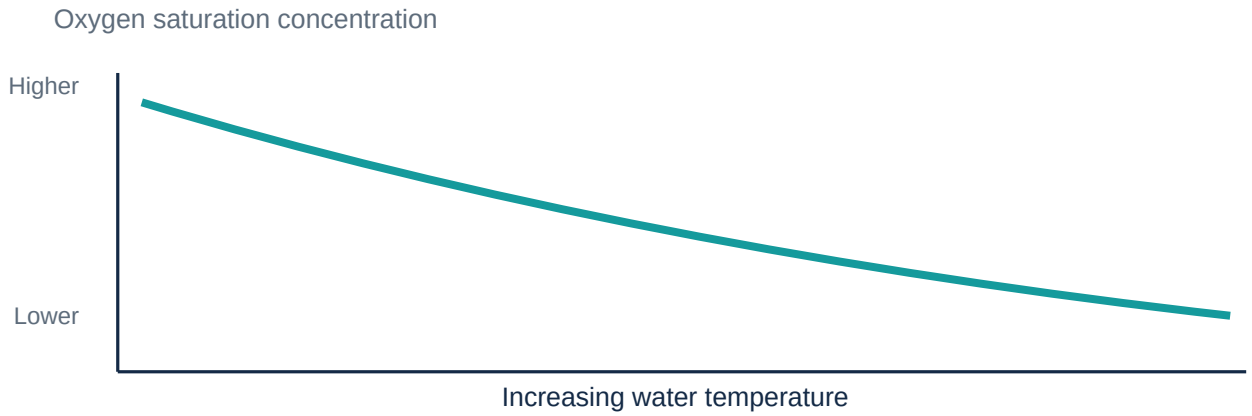
Cooling-water heat transfer: USGS, Thermoelectric Power Water Use.
Cooling arrangements: US EIA, Many Newer Power Plants Reuse Water.
Temperature sources and site context: US EPA, Temperature.

Scope: College Board AP Environmental Science CED, Topic 8.6, p. 163.

Less oxygen capacity, greater demand

Warm water holds less dissolved oxygen at equilibrium than cold water under otherwise comparable conditions. This physical change can combine with biological responses to make warming especially stressful.

1. TEMPERATURE AND OXYGEN SOLUBILITY



Schematic relationship, not measured data. Pressure and salinity are held constant. Actual dissolved oxygen also reflects photosynthesis, respiration and mixing.

2. OXYGEN DEMAND CAN RISE AT THE SAME TIME

Within their tolerable temperature range, many aquatic organisms have faster metabolic and respiration rates as water warms. Their oxygen demand can rise while oxygen solubility falls. This does not mean that heat chemically consumes oxygen, or that metabolism keeps increasing indefinitely beyond lethal temperatures.

3. ORGANISMS HAVE DIFFERENT THERMAL LIMITS

Temperature affects growth, development, reproduction and survival. A rapid change can cause thermal shock; sustained warming can alter which species thrive. Coldwater species may lose suitable habitat even when some warmwater species remain. The size, duration and speed of the change all matter.

Compare Topic 8.5: eutrophication increases oxygen-consuming decomposition; thermal pollution directly changes temperature and oxygen solubility. Both pressures can occur together.

Oxygen solubility: USGS, Dissolved Oxygen and Water.
Metabolism and aquatic life: USGS, Temperature and Water.
Species responses and temperature change: US EPA, Temperature.

Scope: College Board AP Environmental Science CED, Topic 8.6, p. 163.

Release less heat to the water body

Cooling systems transfer waste heat elsewhere before water is reused or discharged. The goal is to reduce harmful heating of the receiving ecosystem, not merely to hide or dilute a warm discharge.

1. COOLING TOWERS AND COOLING PONDS

In a wet cooling tower, contact with air and evaporation cools the water. A cooling pond provides space and time for heat exchange with the atmosphere. Recirculating systems cool and reuse water rather than drawing a fresh volume for every pass. Heat is transferred, not destroyed; cooling performance depends on design and weather.

2. REUSE HAS TRADE-OFFS

Recirculating cooling generally withdraws less water than once-through cooling, but evaporation can consume a larger share of the water withdrawn. Towers, ponds and associated equipment need space or infrastructure and operating resources. Compare both withdrawals and consumption; lower withdrawal does not mean zero water use.

3. CHECK THE ECOLOGICAL RESULT

Measure temperature upstream, near the discharge and downstream, alongside dissolved oxygen. Compare similar times and account for seasonal conditions. Reducing a discharge temperature is useful evidence, but also check whether the receiving water returns to a suitable range for its organisms. One measurement cannot describe every habitat or time period.

4. EXTENSION: AN IDEALIZED MIXING CALCULATION

River flow: 4 m³/s at 20°C. Added discharge: 1 m³/s at 35°C.
Assume complete mixing, equal density and heat capacity, and no heat loss.
Mixed temperature = (4 × 20 + 1 × 35) / (4 + 1) = 23°C
The mixed average rises 3°C. Near the outlet, incomplete mixing may leave hotter water. This calculation does not establish ecological safety or approve dilution as a control.

Evaporative cooling: USGS, Thermoelectric Power Water Use.
Once-through and recirculating systems: US EIA, Cooling Systems.
Spatial and temporal monitoring: US EPA, Temperature.

Scope: College Board AP Environmental Science CED, Topic 8.6, p. 163.