THERMAL IMPACT ON WATER SYSTEMS

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Summary

We have discussed some of the many natural and industrial processes that cause heat energy to enter or leave water systems. Some natural exchanges of heat lead to dramatic phenomena, often powerfully destructive. At the same time, under unique circumstances, natural releases of heat into water can be found support exotic forms of life or to make alternative energy sources available to humanity. On the global scale, the Earth's climate is a direct result of cycles of heating and cooling water. Events in which the oceans become anomalously warm can lead to natural upheavals in global climate. By altering the amount of heat retained by the oceans, humanity can also affect changes in global climate. Frequently, the thermal impacts on water systems are seen as environmental problems. In the industrial sector, innovative attempts to mitigate these impacts have led to new technologies that may reduce fossil fuel usage and allow the exploitation of waste heat in secondary work processes.

1. Introduction

Heat energy may enter or leave water systems through a variety of natural and technological interactions. When this occurs, measurable changes in the systems are always induced. The term "thermal pollution" is often used when such change leads to degradation in the fresh or marine water system. On the other hand, in some natural

systems, the introduction of heat energy can sustain ecosystems. These ecosystems are usually comprised of organisms that have adapted themselves to draw sustenance from the reliability of a heat source over very long time scales. In other circumstances, heat from natural sources can increase the kinetic energy of water to the extent that highly energetic events result. This article gives examples of several kinds of thermal impacts upon fresh and marine water systems. Both natural phenomena and heat-exchanging systems developed by humankind are reviewed.

2. Interactions of Heat and Water in Natural Phenomena

2.1 Solid Earth Thermal Interactions

In regions on Earth near tectonic rift zones, subduction zones or geological hot spots, the heat of hot rocks and molten material from the Earth's interior reaches close enough to the surface to transfer energy to groundwater or seawater. When this occurs on land the result may be a geyser or a boiling lake such is shown in Figure 1.

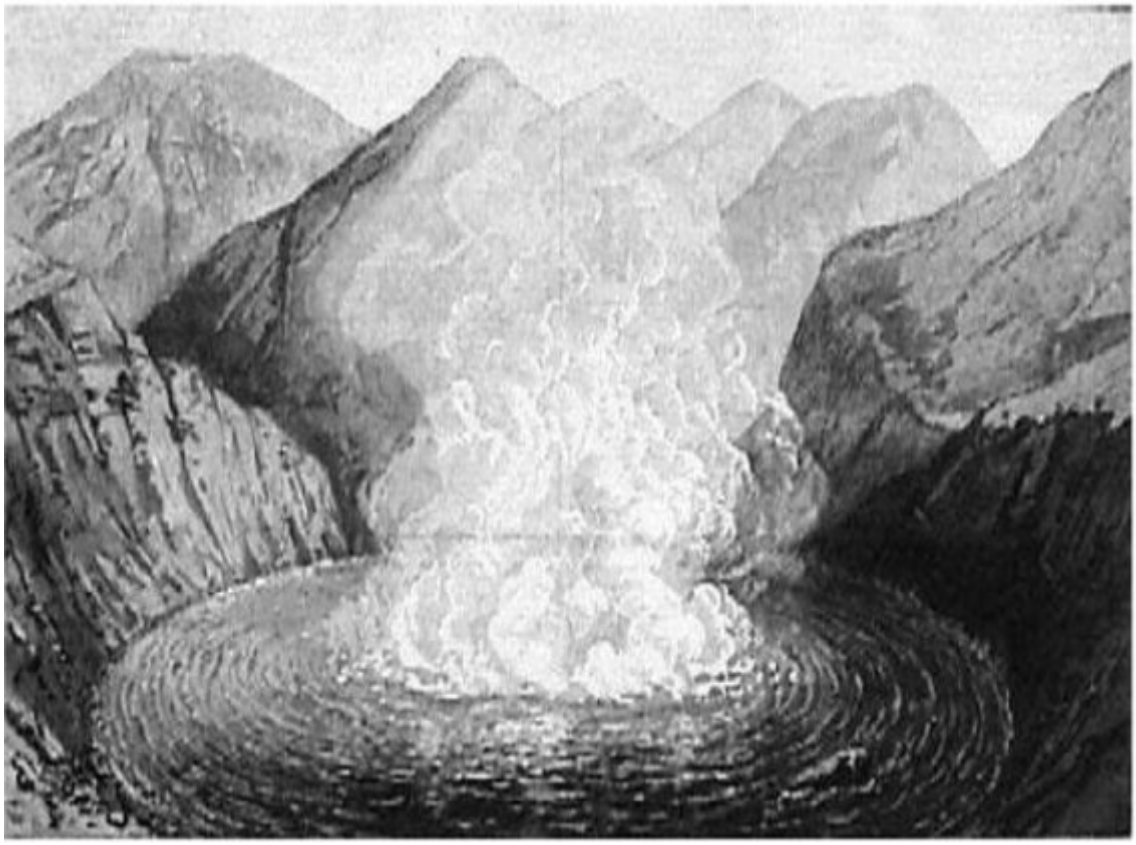

Figure 1: Geothermally heated Boiling Lake, Dominica, West Indies, looks today the way it did in this 1878 lithograph.

The high-climbing geysers of Yellowstone National Park in the United States are a dramatic example of naturally occurring heat from the earth's interior interacting explosively with groundwater. The heated water gains enough kinetic energy to reach as high as 100 meters into the air. The fountain of water and steam often makes a

spectacular display. There are approximately 700 geysers in the world, with the most found in Iceland, New Zealand and the United States. In addition to providing interesting visual experiences, geysers may also be exploited for energy extraction. In several countries, the heated water and steam of geysers are captured in pipes and directed into turbines, which convert this geothermal energy into electricity. The Geysers Power Plant in California is the world's most productive geothermal power plant. It generates 1.7 billion Watts of electrical power.

When a geothermal source makes contact with water in the ocean, a number of fascinating phenomena may result. In several places on the global seafloor, seawater enters cracks in the oceanic crust and contacts hot rocks or magma, the molten material in the interior. Heated past 100^{o} Celsius, the water, which is under great pressure, is returned to the sea through vents in the ocean floor. (This phenomenon occurs in fresh water as well: it was observed at the bottom of Lake Baikal in Siberia.) The interaction with magma also transfers chemicals to the seawater, which results in the formation of chimneys as the minerals in the seawater congeal around the vent. Active chimneys may be called "black smokers" or "white smokers" depending on their appearance. They are occasionally the sites of unique collections of organisms called vent communities.

Nutrients collected in the interaction of geothermal heat with water can sustain these marine vent communities. These are among the few animals on Earth that are sustained by chemosynthesis, based on the energy and nutrients from the vents, rather than by photosynthesis.

Volcanoes that may explode because of the presence of water in their magmas provide additional examples of the interaction of heat with water. Water present in the magma is released when ambient pressure on the magma is relieved. Water may also enter from external sources as seawater or groundwater. In submarine volcanoes, such as "Kick 'em Jenny" in the Caribbean Sea, the transformation of water into steam is often the cause of explosions. The explosiveness of surface volcanoes can also be attributed to the penetration of water to the magma.

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