Why Owens Lake is Red

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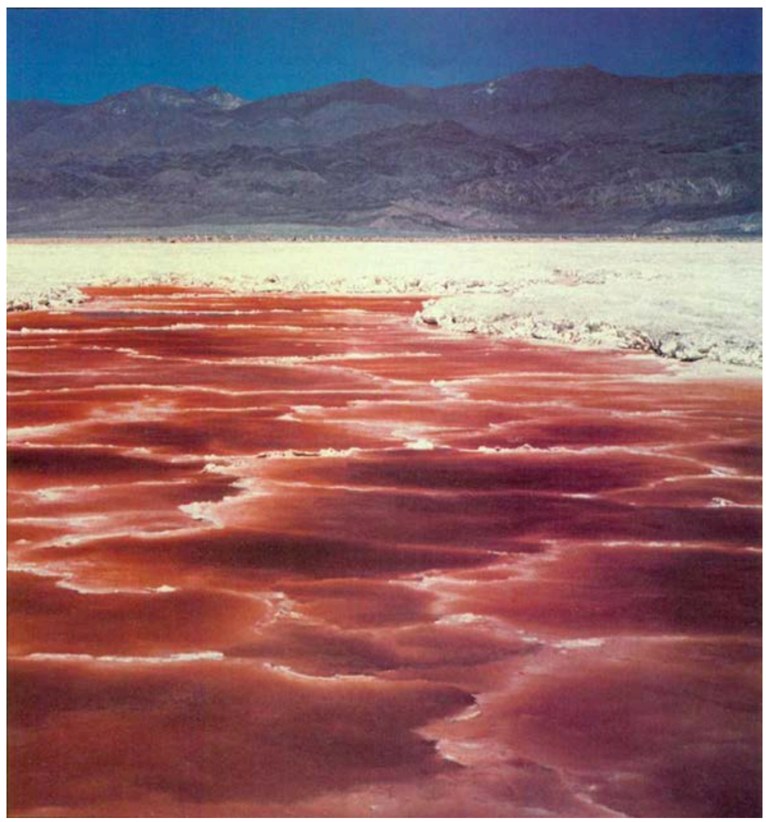
One of nature's most remarkable biological phenomena is the pink and red coloration of salt lakes and playas. Here is the explanation, known hereto/ ore only to a handful of scientists.

IF YOU HAVE ever driven north on U.S. Highway 395 along the eastern side of the Sierra Nevada in late summer, you may have noticed the vast, pinkish-red, crusted surface of Owens Lake glowing in the desert sun. Near the abandoned Columbia-Southern soda plant at Bartlett, along the northwestern end of the lake, solar evaporation ponds may be colored a brilliant red. Pink salt lakes and playas, and the bright red evaporation ponds of salt recovery plants along their shores, are among nature's most remarkable biological phenomena, occurring in arid regions throughout the world. Similar and related biological phenomena are responsible for the coloration of hot springs, other bodies of water, and snow in the high mountain ranges.

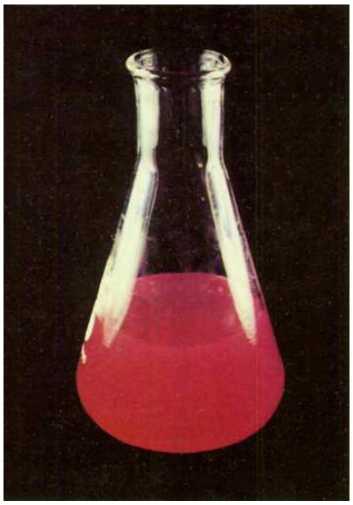


Owens Lake is actually a playa, an intermittent dry lake that may contain standing water during wet years, but even when the lake appears dry, a layer of brine occurs beneath the salty crust. It is fed by the Owens River and all the tributaries that drain the snow-covered Sierra Nevada. Before the river was diverted into the Los Angeles Aqueduct in 1913, Owens was a large, blue, salt lake 30 feet deep and covering 100 square miles. Several thousand years ago, the lake was more than 200 feet deep and nearly twice as large. Remnants of ancient beaches are still preserved at several places around the lake.

Owens Lake, in fact, had been gradually drying up for thousands of years, and was already saline when the Owens River was diverted to supply Los Angeles with water. Brine fly pupae (*Ephydra*), common insects of saline ponds and lakes, were an important food in the diet of local Paiute Indians. The pupae, which look like grains of rice, occur in enormous numbers and can still be found around the shoreline where there is standing water. They can also be found by the thousands, embedded in the salty crust.

The coloration of Owens Lake is caused by astronomical numbers of microscopic organisms, which can be conveniently classified into two major groups, algae and bacteria. Algae and bacteria include thousands of different species, but only a few kinds are able to tolerate the extreme salinity of playas such as Owens Lake. The group of organisms primarily responsible for the red coloration of the salt crust and brine pools are the halophilic (salt loving) bacteria.

The amount of salt in a lake or sea is often expressed as a percent, and refers to the total grams of dissolved salts in 100 milliliters of water. The total percent of salinity includes all salts present, such as sullates, chlorides, carbonates, magnesium, calcium and sodium; however, the most abundant salt in the brine where halophilic algae and bacteria thrive is ordinary table salt, or sodium chloride. The percent of salinity may vary in a salt lake or playa, depending upon where the water is tested, such as close to freshwater springs or a river inlet. For example, in the northern arm of the Great Salt Lake, the total dissolved salt content is more than 30 percent, whereas in the southern arm (where the rivers enter) the salt concentration ranges from 12 to 20 percent.



Unlike most living things, the halophilic bacteria thrive in saline lakes with salt concentrations of 15 to 30 percent. This is roughly four to nine times the salinity of sea water (3.5 percent). Their optimum growth condition is 20-30 percent salinity. They can even live in saturated salt and remain alive in salt crystals for years. In fact, they cannot survive if the salt concentration drops much below 12 percent. Very few life forms on earth are known to be adapted to this extreme salinity. The brine ponds of Owens Lake are so alkaline and hot in mid-August that they can actually burn and dehydrate your fingers. In many places, the brine is saturated with sodium chloride (over 30 percent salinity) and salt is precipitating out. So, when you consider the extreme environment of the brine, it is rather easy to narrow the field of possible organisms responsible for the startling coloration.

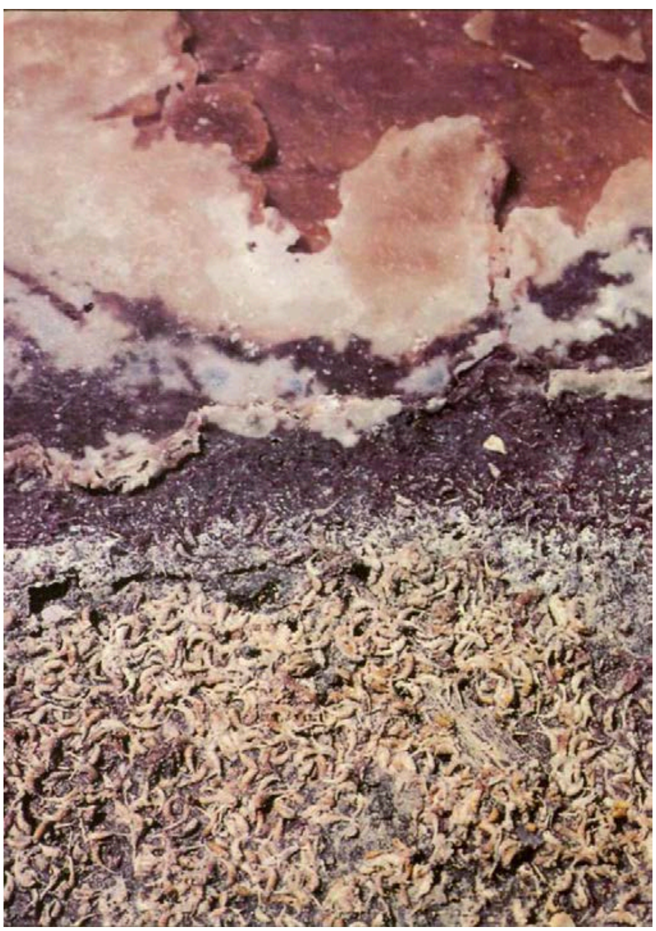
If samples of the red brine are spun in a high speed centrifuge at 5,000 rpm, the water becomes clear as the red bacterial cells are forced to the bottom under about 3,000 Gs. The bacteria may then be grown in a special nutrient agar containing at least 25 percent sodium chloride, incubated in a warm oven. After several weeks, small reddish colonies of bacteria begin to appear in the culture dishes.

There are two main kinds of extreme salt-loving bacteria, the rod-shaped halobacteria and the spherical halococci. They are extremely small unicellular organisms, visible only under high magnification. To get a rough idea of how small these bacterial cells really are, it would take more than half a million to cover the surface of an ordinary pinhead. A single drop of brine from Owens Lake may contain millions of the minute, rod-shaped *Halo-bacterium*, squirming about with seemingly perpetual motion. They are able to swim about by means of minute, hairlike flagella at their ends. The bacterial cells contain a red carotenoid pigment which, depending upon their concentration, may color the water pink, orange, vermilion, or mauve-red. The red pigment is similar to that found in tomatoes, red peppers, and many colorful flowers and autumn leaves. It has been suggested that the bright red pigments protect the delicate cells from the intense desert sunlight. They are found in salt lakes and brine ponds throughout the world, including the Great Salt Lake and the Dead Sea.

The halophilic bacteria may be a nuisance to industry using evaporation ponds for the production of solar salt. Freshly produced solar salt is often heavily contaminated with these organisms, and they occasionally cause spoilage of fish, sausage casings, meat, vegetables and hides when salt (sodium chloride) has been used in the preservation process. They may also cause an unsightly, pinkish discoloring of pickled foods. The discoloration is known as "pinkeye" in salted fish and "red-heat" in salted hides.

THE EXACT chemical explanation for the extreme salt tolerance of these bacteria, and their need for salinity at least three to four times that of sea water, is very complicated. The cells themselves contain a very high internal salt concentration, about equal to their environment. Otherwise, they would be rapidly dehydrated (plasmolyzed) in the brine. It has also been shown that the highly saline environment is essential for normal enzyme function within the cells, and to maintain the fragile protein coating or "wall" around the delicate cell membrane. In fact, if the salt concentration drops too low, the outer protein "wall" actually dissolves and the inner cell membrane disintegrates, thus destroying the cell.

The salty crust and brine of Owens Lake is sometimes greenish, due to the abundance of another organism called *Dunaliella*. This is a unicellular green alga, much larger than the bacteria, though visible only under high magnification. Each individual oval or pear-shaped cell has two whip-like tails or flagella at its anterior (head) end. The moving flagella propel *Dunaliella* through the water in a spiral motion. Under high magnification, numerous *Dunaliella* can be seen swimming among the gleaming, geometrically-shaped crystals of salts. *Dunaliella* is clearly a green alga because of a distinct, green, cup-shaped chloroplast that occupies most of the cell. In nearby Searles Dry Lake to the southeast, *Dunaliella* and a closely related species, *Stephanoptera*, may be so abundant that they color the salt crust a bright green. Here they thrive in water with 33 percent dissolved salts, and where the salt forms a solid surface crust strong enough to bear the weight of an automobile. In solar evaporation ponds of the large Kerr-McGee Chemical Plant at Trona, *Dunaliella* sometimes forms a thick, green, "pea soup." A single drop of this thick water may contain several thousand individuals of *Dunaliella*.



Under unfavorable conditions, *Dunaliella* produces a red carotenoid pigment similar to that found inside the halophilic bacteria. The red pigment may completely mask the green of its chloroplast, and salt lakes practically anywhere in the world may be colored reddish by *Dunaliella*. For decades, scientists in Russia were puzzled by the pinkish coloration of salt lakes in the hot, lower Volga region, north of the Caspian Sea. The pinkish water was finally attributed to the presence of *Dunaliella salina*, either dying naturally or excreted in the fecal mass of brine shrimp (*Artemia*), which feed exclusively on it. *Dunaliella* in the very saline northern arm of the Great Salt Lake in Utah are brilliant red. There the water is colored red by both the *Dunaliella* and the red halophilic bacteria. Some authorities recognize a red and a green species of *Dunaliella*; however, all the *Dunaliella* I have observed in Searles Lake and Owens Lake were bright green. It appears that the brilliant red coloration of brine in these lakes is caused primarily by bacteria.

The distribution of *Dunaliella* throughout the world in very specialized, highly saline habitats is convincing evidence that its dormant cells are dispersed by the wind in the form of dust clouds. Much to the chagrin of Owens

Valley residents, alkali dust clouds are a common sight over Owens Lake. This is also happening to Mono Lake to the north as its main supply streams are diverted to provide Los Angeles with more water.

In addition to red saline lakes, micro-organisms are responsible for the coloration of other bodies of water, tree trunks and even rocks. Enormous populations of algae are responsible for the coloration of the Red Sea and for a periodic condition of coastal waters known as the "red tide." Another alga, closely related to *Dunaliella*, thrives and multiplies by the millions in snow banks. The individual cells are bright red, and from a distance the snow actually appears pink. Compacting the snow increases the density of the red cells and heightens the color.

Algal cells also color the trunks of trees velvety green, and the trunks of Monterey cypress on the Monterey Peninsula in California a brilliant orange. The colorful crusted growth on rocks and boulders throughout the west is caused by an intimate association of algae and fungi known as lichen. Several different kinds of algae and fungi are responsible for the many colors of lichen, including black, red, orange, green, yellow and chartreuse. For years, people have wondered about the peculiar green coats of polar bears in zoos, particularly during the warmer months. It has been shown that green algal cells actually live and multiply inside the hollow core of each hair, thus producing the "green polar bear syndrome." There are numerous other examples of colorful algae and bacteria in our environment.

Except for coloring salt lakes red, the salt-loving bacteria probably seem insignificant to most people; however, they have been studied extensively in recent years by biologists and biochemists. A pigment has been discovered in the cell membrane of *Halobacterium* that is remarkably similar to the light sensitive pigment (rhodopsin) in the rod cells of human eyes which enables us to see in dim light. When we enter a dimly lighted room, it takes several minutes for our eyes to adjust as the pigment rhodopsin gradually increases in concentration. In fact, during World War II night-flying aviators sometimes wore special goggles just before the start of a mission. The goggles enabled the pilots to see and carry on normal activities while stimulating rhodopsin production in the eye for maximum night vision. The pigment in salt-loving bacteria (called bacterior-hodopsin) enables them to utilize sunlight for energy, just as green photosynthetic plants are able to capture the sun's energy. Future studies of these amazing solar-powered bacteria may lead to new and more efficient uses of the sun as a source of energy, and perhaps a better understanding of the remarkable mechanisms of vision.

The gleaming red salt flats of Owens Lake can be quite spectacular in the early morning or late afternoon of summer, but not nearly so beautiful as the enormous blue Owens Lake that once filled the deep, sunken valley between the massive Sierra Nevada and Inyo ranges. Like Mono Lake today, Owens Lake was once a haven for many forms of life, from insects and brine shrimp to water fowl. As the water evaporated and the salinity increased, only the most salt tolerant micro-organisms could survive in the brine. This appears to be the fate of Mono Lake unless the natural drainings of nearby streams is restored to its shores. In the case of Owens Lake, the Los Angeles Aqueduct has destroyed a beautiful blue lake, but has created an enormous pink playa of thriving, salt-loving bacteria and algae.