

# Dissolved Oxygen Levels Restored In the Pools of Carlsbad Caverns

By Cliff Chetwin

You are walking along the paved cavern trail, marveling at the speleothems, which range from massive columns to delicate helictites. On your left is a small pool of water which appears to be several feet deep and which has a dark hole in the center. However, as you edge closer, you notice a mild odor of rotten eggs and it becomes apparent that the deep "hole" is in fact a black sludge of decaying organic matter . . .

Well over 26 million people have visited Carlsbad Caverns National Park since 1923 and in recent years this was an increasingly common experience at several locations throughout the Cavern. In 1982, the park RM&VP staff began to investigate the causes of the sludge, with a goal of correcting the situation.

It was quickly observed that the only pools which appeared to be suffering this fate were those in close proximity to the established visitor trail. Those pools which were smallest and closest to the trail seemed to suffer the most, and in some cases, had "black zones" which reached the surface, releasing hydrogen sulfide gas.

Analysis of the sludge in the "black zone" revealed that a variety of organic and inorganic compounds were being washed/thrown into the pools. These compounds settled to the bottom of the pools where sulfates were reduced to hydrogen sulfide, which in turn was reacting with iron molecules found in the native calcite deposits, to form a black semi-decomposed mass. The limiting factor in this process was the reduced amounts of dissolved oxygen found in most cave pools. Over the years, the decomposition has reduced the oxygen levels to where the bottom level of most of these pools was anaerobic and some of the worst pools had become entirely anaerobic.

We decided to first identify the specific sources of contaminants and devise methods to prevent further contamination of the pools. Once this was accomplished we would then clean the existing sludge from the pools and artificially increase the dissolved oxygen to natural levels.

In order of increasing importance, we found the following sources: 1) organic/inorganic substances that were transported from the surface via natural infiltration; 2) body wastes from small mammals who followed man into the Cavern; 3) organic/inorganic substances contained in the effluent from trail cleaning; 4) organic food stuffs thrown into the pools by park visitors.

There was little that could be done practically to alter the natural infiltration routes so we chose to ignore this source for the time being. The body wastes from mammals, primarily raccoons and ringtails, proved to be the most difficult. They would enter the cave nightly and follow the same route as park visitors, raiding trash cans and the concessioner's underground lunchroom facility. Live trapping and removal to remote areas of the park had little effect, with some individuals traversing 7+ miles to return to be captured in the cave the next night. They also proved to be ingenious in defeating our efforts to secure the trash cans and the concessioner's food storage areas. Finally, in the spring of 1986, we came up with a combination of locks, trash can lids, and a maintenance schedule which they have not been able to defeat, and we feel that this source is now

negligible. The trail cleaning problem has been temporarily resolved by a method that allows R&T to catch the effluent at the trail edge and remove it from the cave. However, this is fairly labor intensive and risks spills. We are looking into some kind of an electric sweeper machine which could scrub the trail and collect the effluent at the same time.

We were able to determine that although many visitors brought food into the cave with them, the main source of organics in the pools was from food sold in the underground lunchroom. By 1983 we were able to identify particular food items that were most likely to end up in the pools and, with the concessioner's cooperation, these items were replaced with other products which have proved far less likely to go the pool route. Also, in 1985, the superintendent established a special regulation which prohibits food in the cave, except in the lunchroom.

By early 1985 we felt the pollution sources were sufficiently controlled that we could begin to restore the pools. Since the Cavern is a relatively dry cave we could not rely on aeration from natural drip rates. We also determined that convective overturn was a significant factor only in deeper pools located near the natural entrance where annual air temperature fluctuations are greatest. When visitation is not heavy, moderate drip rates and convective overturn were found to be adequate to maintain oxygen levels throughout the pools, and visitation was low enough in mid-winter for this to be effective. However, the rest of the year, higher visitation resulted in significantly higher loads of organics, which the pools were unable to overcome.



**Park Ranger Donna Giannantonio** uses dipstick to fish coins out of a Carlsbad Cavern pool, prior to mechanical mixing of the water.

Control pools were selected from areas of the cave not open to the public and it was determined that a dissolved oxygen level of 9.0 mg/l was the approximate natural level for shallow pools. The deeper pools were stratified, with readings of 9.0 mg/l at the surface and 7.5 mg/l at the bottom.

Fifteen of the "worst-condition" pools in the Main Corridor and Big Room were selected for treatment. First, RM&VP rangers Ran Kerbo and John Roth established surface and bottom levels of dissolved oxygen for each pool (Table 1). They then scraped

**Coins, plastic gunk, bread wrapper**, all contribute to the debris that must be fished out of Carlsbad Cavern pools before they can be restored by mixing procedures. The screen covers, one of which is shown at left, have been tried in pools far off the trail that appear as pits and are targets for thrown items, but eventually they tear and drop their loads into the pools.

as much of the sludge from each pool as was practical without damaging the pool. Initially, they had planned to use a 12v DC aquarium pump to aerate the pools but it quickly become apparent that

**Table 1.**

| <b>Pool Name</b>                      | <b>Dissolved Oxygen (mg/L)</b>    |                                  |
|---------------------------------------|-----------------------------------|----------------------------------|
|                                       | <b>surface<br/>(before/after)</b> | <b>bottom<br/>(before/after)</b> |
| Billing Dove Tunnel                   | 7.8/9.2                           | 6.8/9.2                          |
| Black Gunk Pool                       | 7.1/8.8                           | 4.6/8.6                          |
| Top of the Cross                      | 7.8/9.4                           | 7.8/9.4                          |
| Leptothrix Pool                       | 3.2/8.8                           | 1.8/7.9                          |
| Gypsum Block Pool                     | 5.5/8.6                           | 1.8/8.4                          |
| Crystal Spring                        | 7.8/9.1                           | 6.2/9.0                          |
| Celery Stalk #1                       | 5.9/9.1                           | 0.4/9.0                          |
| Celery Stalk #2                       | 6.8/9.2                           | 0.1/9.0                          |
| Devil's Spring                        | 7.8/10.2                          | 7.1/10.0                         |
| Signature Pool                        | 7.9/9.8                           | 6.6/9.6                          |
| Green Lake                            | 8.0/9.3                           | 7.3/9.2                          |
| National Geo-<br>graphic Pool         | 6.0/8.4                           | 0.4/4.2                          |
| Sword of Damocles                     | 7.6/9.2                           | 7.6/9.2                          |
| Longfellow's Bath-<br>tub (longside)  | 7.5/8.8                           | 1.9/6.3                          |
| Longfellow's Bath-<br>tub (shortside) | 7.4/8.8                           | 1.4/7.4                          |

the pools were too large for this to be effective. They then developed a process of mechanically mixing the water using a large paddle, which immediately proved effective. Throughout 1985 and early 1986 they continued the mixing with each pool being treated for approximately 10 minutes per month. Each pool was brought into the target range of dissolved oxygen within the first few months and all 15 have now been held at their new levels for over a year (Table 1). These new levels have been successful in preventing sludge return in all but three of the pools, and the buildup has been only minor in these three.

For the immediate future, we intend to expand the program to other pools in the visitor use areas as well as increasing the number of pools sampled in other areas of the cave to increase our control base. When the park returns to guided tours this winter, we also intend to study the relationship between the amount of organics thrown into pools and guided versus self-guided tours. We will also continue to analyze the three pools still exhibiting problems to discover why they did not respond in the same manner as the other 12 pools.

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