Deliberate Biodegradation in a Closed System Cooling Tower

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Abstract

A series of experiments was made on an experimental cooling tower with a 30 gpm circulation rate and with a feed of make-up water consisting of the mixed and settled effluents from an edible oil plant and a fatty acids distillation plant. Summer conditions were simulated by heating the circulating water to 105 F, thus permitting a 20 F temperature drop through the tower. Almost immediately some aerobic degradation of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) was observed. It was suggested that the biota be fed by the addition of nitrogen and phosphorus while the pH was maintained at neutral. This increased the rate of biodegradation about fourfold, the tower leveling off with 6% blow-down relative to the rate of feed with BODs and CODs substantially equal to, or lower than, their level in this feed. Thus, overall biodegradation of 94% was realized, attributed to: (a) aeration in the tower; (b) high water temperature of 85 F; (c) feeding of nitrogen; (d) feeding of phosphorus. and (e) pH adjustment. Similar results were obtained in tests on a larger cooling tower used for handling the total effluent water from the barometric system of a single edible oil batch deodorizer. All of the water was recirculated for a period of three months with no blow-down whatever. In this test the COD and BOD leveled off at about 1730 and 360 ppm respectively. The obvious benefits of a biological cooling tower are water conservation and elimination of waste treatment and disposal.

One of our major water pollution problems concerns either the purification and disposal, or the bottling-up of waste water from our edible deodorizer barometric condensers, and our fatty acids distillation plant barometric condensers.

To the best of our knowledge, the most promising approach to purification and disposal of these large amounts of water, generally running about 3,000 gpm, appeared to be the use of jet scrubbers, or Scrub-vactors, to decrease the biochemical oxygen demand (BOD) of the waste water prior to discharge.

The nearest approach to the bottling-up and recirculation of these waste waters seemed to indicate the use of a cooling tower. To accomplish this, it was necessary to ascertain as nearly as possible the quantity and characteristics of the blow-down required by a cooling tower in this service. The present paper, therefore, deals with the discoveries made in this area using two pilot plant cooling towers, vastly different in size and throughput, as they were operated under controlled conditions and with various organic loads.

The first of these tests was started in June of 1966 using a small experimental cooling tower operating at a 30 gpm circulation rate while being fed with make-up water consisting of the mixed barometric condenser effluents from a batch deodorizer edible plant and fatty acids distillation and fractionation plant, the latter being operated solely on coconut fatty acid products. These effluents were first settled for about 30 min in a conventional skim basin, and thereafter passed through a Colloidaire Separator. Collaborating on this program was E. G. Paulson of Calgon Corporation. A photograph of this cooling tower is shown in Figure 1.

To simulate summer conditions, the circulating water was heated in a shell and tube exchanger to 105 F on its way to the cooling tower, thus permitting a 20 F temperature drop through the tower, giving a tower basin temperature of 85 F.

On a full sized tower, that is, one capable of cooling and recirculating the full water load, much of the make-up water would come from condensed steam from the ejector system. If further make-up water was required it would not be economically unsound to use even softened water. Therefore, our main concern on a full-sized unit would not be with water hardness but rather with the build-up of chemical oxygen demand (COD) and BOD within the tower system, and how much blow-down it would take to keep this under control.

Paulson already had two towers that had "gone biological," meaning that aerobic bacteria were feeding on the organic matter present in the feed, thereby decomposing much of it, and this experience indicated that blow-down might amount to very little in a full-sized tower if proper conditions were maintained. Since one of Paulson's towers had unexplainably developed severe corrosion problems, test specimens of various metals were placed in strategic

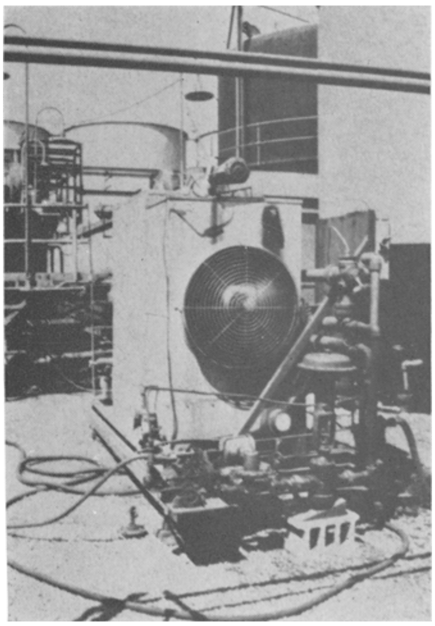

Fig. 1. 30 GPM cooling tower.

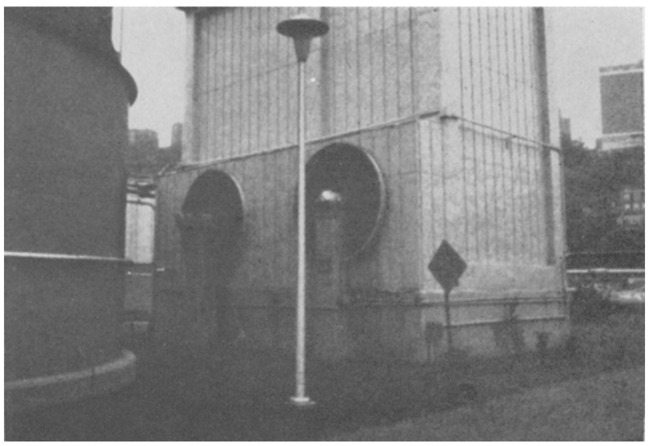

Fig. 2. 725 GPM cooling tower (½ of above unit).

TABLE I

Analyses	Run No. 1	2	3
	2.5 weeks	5.0 weeks	5.0 weeks
Average input, ppm			
Chloride	13	10	10
COD	98	77	141
BOD (5 days)	61	48	48
Ending analyses, ppm			
Chloride	118	170	142
COD	450	340	158
BOD (5 days)	164	85	28
Concentration			
Chloride	9.1:1	17:1	14.2:1
COD	4.6:1	4.4:1	1:1:1
BOD (5 days)	2.7:1	1.8:1	0.6:1
Average, gpd			
Make-up (or feed)	900	948	762
Blow-down	63	42	47
Per cent blow-down	7.00	4.54	6.17

places on all our tower runs to provide a check on this aspect of the problem. Likewise, the circulating water on all runs was maintained at a pH of approximately 6.8–7.2 by chemical injection, not only to minimize corrosion problems, but also to provide a proper environment for biota growth. In runs where water hardness predominated, pH was controlled by sulfuric acid injection. In runs where trace fatty acids predominated, caustic soda was injected to control pH.

In the first three runs made on the small cooling tower, where water hardness governed the blow-down rate, and where the shell and tube heater had to be used, blow-down was maintained so as to keep the chloride concentration below 200 ppm to control hardness deposition and scaling up the tubes of the heat exchanger. With a starting chloride level of 10–13 ppm, this meant that no more than a 15 to 1 concentration of the circulating tower water could be permitted.

Since there was a marked breakdown of organic contaminants in the first two runs, as evidenced by reduced CODs and BODs relative to the chloride concentrations attained, it was decided on the third run to do two things: First, feed the biota by adding phosphorus and nitrogen to the system, and second, take the make-up water directly from the edible skim basin, thereby deliberately increasing the organic load by virtue of eliminating passage through the Colloidaire units.

The phosphorus and nitrogen feeds in Run 3 consisted of adding about 30 cc daily of 75% phosphoric acid, and 50 cc daily of 28% ammonium hydroxide. This maintained a level of about 0.4 ppm as phosphorous and 6.0 ppm as nitrogen in the cooling tower recirculating water. The result of these first three runs is shown in Table I. Thus, Run 3 shows the very promising result of a 95.9% removal of BOD, and a 92.1% loss of COD, due only to organic biodegradation. Thus, after five weeks of continuous operation, the final BOD was less than the average input BOD, and the COD was of about the same order of magnitude as the average input COD. This was accomplished with only a 6.17% blow-down.

On a full size scale, where water hardness was not a factor, it might be found that no blow-down at all would be necessary.

The success of these runs was attributed to the aeration taking place in the tower, the nitrogen and phosphorous being fed, the maintenance of a neutral pH, and the relatively high water temperature, all of which produced a most favorable environment in which the biota could multiply.

These most promising results led to Run 4 where a tower of sufficient capacity was used to handle the total effluent water from the barometric system of a single edible batch deodorizer. The system was started up on city water. Figure 2 shows a photograph of this tower, only half of which was needed for Run 4. In this run conditions were not as favorable as in the first three runs. For one thing, the water circulation temperature had to be maintained at 74 F instead of 85 F to maintain a proper vacuum on the deodorizer with the existing ejector system. Secondly, aeration was probably not as complete since the larger tower used had a fill to volume ratio of only 2.9/1, whereas in the smaller tower this ratio was 12.7/1. Similarly, the skim basin preceding the cooling tower was undersized by comparison with that used for Runs 1 to 3, its retention time being only 12 min as compared to 30 min. Otherwise, conditions were maintained about the same except that no blow-down was found to be necessary over a 12 week period of continuous operation, with no evidence whatever that this condition could not have been extended indefinitely.

What happened was that after four weeks of operation, the COD in the circulating water of the completely closed cooling tower system leveled off at about 1730 ppm and the BOD leveled off at about 360 ppm, and both remained at substantially these levels for the remaining eight weeks of Run 4, fluctuating only slightly from day to day. Incidentally, no odor ever came from these towers as long as the water was kept circulating over the weekends at about 75 F. Even corrosion of grey cast iron and carbon steel was not so great but what they could be used throughout, economically, as long as extra heavy piping was used, particularly in the underground installations. There would, however, be a problem in designing the cooling tower basin and skim basin so that settled sludge (dead biota) could be allowed to build up or be made readily removable, or both, at least on an annual basis. In Run 4 this thick, slimy, grey sludge built up to about a 6 in. depth in the cooling tower basin, and to about ½ in. depth in the skim basin during the three months of operation of the system. Very little of this slime collected on the tower fill throughout Run 4, in fact, less than in the earlier, shorter runs, probably because the fill in the larger cooling tower was plastic, whereas that in the smaller tower consisted of rough wooden slats. It did not appear that slime buildup in the tower itself would be any problem.

The final results of Run 4 are: circulation rate, 722 gpm; pH, 6.7; COD (during 8th to 12th week), 1,730 ppm; BOD (during 8th to 12th week), 360 ppm; Blow-down, 0 gpm; City water make-up, 0.7 gpm; Water from cooling tower, 74 F; Caustic to maintain pH, 2.7 lb/day; 28% NH_4OH fed, 0.44 gpd; 75% H_3PO_4 fed, 0.10 gpd; Excess nitrogen present, 2.79 ppm (less than in runs 1–3); Excess phosphorous present, 8.79 ppm (more than in runs 1–3).

Further tests, using the small tower fed with fatty acid plant waste waters only, gave the following results.

In Run 5, operation was substantially the same as in Run 3, except that the organic load in the feed was much greater, the COD being 850 ppm instead of 141 ppm, while the BOD was 700 ppm instead of 48 ppm. This was brought about primarily by the fact that a substantial amount of low molecular weight fatty acids from the fractionation of coconut oil was actually soluble in the barometric cooling water. In spite of this solubility, and heavy organic loading, the tower system worked well for two months, reducing the COD to 162 ppm and the BOD to 33 ppm. However, at the end of this period the run had to be terminated since the tower slats became completely plugged with dead biota slime, and very large quantities of this material had to be removed throughout the run from the tower basin.

Because of this problem, it seemed impractical to further pursue biodegradation in a cooling tower when dealing with such extremely high organic loads, and much more practical to first remove as much as possible of these organics by other means. Hence, a Scrub-vactor was installed in the system.

This reduced the incoming organic loads to 269 ppm COD and 175 ppm BOD. The small cooling tower handled this loading very well. After two months of operation the COD of the circulating water had leveled off at about 100 ppm, and the BOD at about 12 ppm. Dead biota slime presented no abnormal problem, and although a 12% blow-down was used to control water hardness, there was every reason to believe that with a full sized cooling tower no blow-down whatsoever would be required.

Thus, we proved that biodegradation in a cooling tower properly operated, and not organically overloaded, could be relied on to bottle-up and reuse waste waters of this nature indefinitely, even though much of the organic loading was water soluble. It would be interesting to determine whether glycerine waste waters would behave in a similar manner.

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