Geosmin Removal by Powdered Activated Carbon and Ozone

By Anthony J. Tarquin[1], Sanaan Lair[2], Doug Rittmann[3], Member, ASCE, and Fernie Rico[4], Member, ASCE

Abstract

Ozone and various brands of powdered activated carbon were tested for their ability to remove geosmin from drinking water. The unit cost for geosmin removal was determined by dividing the amount of geosmin removed (ng) by the cost of the ozone and each carbon tested. The results showed that ozone was far more cost effective than any of the powdered activated carbons. The amount of geosmin removed by ozone was 34.3 ng per dollar (amortization and operating cost) while the best carbon tested removed only 13.1 ng per dollar.

Introduction

Taste and odor is a common problem encountered in surface water treatment plants, especially in hot summer months. One of the main offenders in this regard is Geosmin, a metabolite byproduct produced by cyan bacteria and actinomycetes (Saadoun et al 2001). It imparts an odor best described as earthy to musty with a very low odor threshold (Suffet et al 1999). The average concentration at which geosmin may be detected by most people is 10 ng/L (Izaguirre et al 1982), but highly sensitive or specially trained persons may detect concentrations as low as 1.3 ng/L (Young et al 1996).

Conventional water treatment processes are ineffective at removing geosmin, as are membranes that are designed for removing relatively large substances (microfiltration and ultrafiltration membranes).

[1]Professor, Civil Engineering, University of Texas at El Paso, El Paso, TX 79968
[2]Environmental Engineer, Parsons, 8000 Centre Park Drive, Ste. 200, Austin, TX 78754
[3]Consultant, 2626 N. Mesa, No. 156, El Paso, TX 79902
[4]Water Supply Manager, El Paso Water Utilities, P.O. Box 511, El Paso, TX 79961

This project was undertaken as part of a pilot study to evaluate the effectiveness of a flocculation, sedimentation, and ultrafiltration system for treating water from the Rio Grande. Various powdered activated carbons were tested for taste and odor control and, because the pilot study was set up at a treatment plant that used ozone, the effectiveness of ozone for geosmin control was also determined.

Procedure

Twelve different carbons were involved in this study. Various preliminary tests were conducted using both river water and deionized water to identify the best PACs to use in a quantative geosmin analysis. The tests included qualitative odor tests, methelene blue adsorption, COD reduction, and trihalomethane removal. On the basis of these tests, five carbons, the three best and two worst (including one that was tauted as effective for taste and odor removal) were then quantitatively evaluated for geosmin removal. Deionized water was spiked with geosmin (at concentrations at least three times greater than normally found at the intake of the water treatment plants) and mixed with 25 ng/L of each test PAC for 15 minutes. The samples were filtered through fiberglass filters to remove the PAC and then sent to an EPA-approved laboratory for geosmin analysis (the number of samples tested was limited because of the $500 per sample cost). For the ozone evaluation, geosmin-spiked deionized water was placed in a one-liter graduated cylinder and ozonated at 0.5 L/min and 1.0 L/min rates for 0.5, 1.0, and 2.0 minute periods. Ozone residuals were measured using HACH accuvac vials. The samples were analyzed for geosmin by an outside laboratory just like the PAC-treated samples discussed above.

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Results

The results from the geosmin tests are shown in Table 1. The initial geosmin concentration of 470 ng/L was reduced by 80% to 94 ng/L by the best performing PAC, identified as PAC A. This resulted in a geosmin removal rate of 15.0 ng/mg. The two worst performing PACs removed only 49% even though one of those, PAC I, was advertised by the manufacturer to be very effective for taste and odor control.

The results from the ozone test are shown in Table 2. In these tests, the initial geosmin concentration was 627 ng/L.

The percent geosmin removed ranged from 9% to 98%, with total removal increasing with ozonation rate and ozonation time. When the CT value obtained by multiplying the ozone concentration and the contact time is plotted against the percent removal, the curve shown in Figure 1 is obtained. Obviously, ozone is very effective for removing high concentrations of geosmin at very short detention times.

Economic Considerations

In order to compare the effectiveness of PAC versus ozone for geosmin removal, unit costs in terms of ng of geosmin removed per dollar were calculated. The five PACs that were evaluated in the geosmin test ranged in price from $0.88/kg ($0.40/lb) to $1.65/kg ($0.75/lb). For comparative purposes, the most expensive PAC that was included in the initial screening had a cost of $2.51/kg ($1.14/lb). Using the respective costs and geosmin removals from Table 1, the amount of geosmin removed per dollar was calculated for each PAC as shown in Table 3.

PAC A, which was neither the most expensive nor least expensive, performed the best for geosmin removal on the basis of unit cost. The amount of geosmin removed for PAC A was 13.1 ng per dollar. The worst performing carbon, PAC, J, removed only 7.3 ng per dollar. The unit cost for ozone treatment was obtained by calculating the cost of the ozone unit at El Paso Water Utility's 1.55 m^3/s (40 MGD) Jonathan Rogers Water Treatment Plant. The ozone contactor has a theoretical detention time of 3.25 minutes and the ozone residual is maintained at 0.3 – 0.4 mg/L. Since the CT value at the plant is slightly higher than any of those used in the test study, the costs for ozone treatment at the JR plant would be a little higher than if they were based solely on the results of this study. Therefore, they represent a worst case (i.e. higher cost) condition.

The capital cost of the ozone unit at the JR plant was $6.6 million. If that cost is amortized at 6% per year for 15 years, the cost per thousand cubic meters of water treated is $12.30 ($0.046/1000 gallons). The operating cost at the JR plant is $5.28/1000 m^3 ($0.02/kgal). Therefore, the total cost per 1000 m^3 of water treated in the ozone unit is $17.58/1000 m^3 ($0.07/kgal). In the lab studies, approximately 600 ng/L of geosmin were removed under conditions that were similar to those at the JR plant. Using the 600 ng/L removal rate and the $17.58/1000 m^3 cost, the unit cost for geosmin removal by ozone is 34.3 ng/$. This is over 2.5 more geosmin removal per dollar than was achieved by the best PAC.

Conclusions

Based on the results obtained in this study, the following conclusions can be made with reasonable certainty:

1. Different powdered activated carbons have different abilities to remove geosmin. The best of the five that were treated removed 15.0 ng/mg.

2. In order to select the best powdered activated carbon (from an economic point of view) for removing a particular pollutant, it is necessary to conduct pollutant-specific tests and calculate the unit costs for each PAC. In this study, the best PAC for removing geosmin was neither the least nor most expensive, nor was it any of the ones that were advertised to be particularly good for taste and odor control.
3. Ozone was over 2.5 times more cost effective for removing geosmin than any of the powdered activated carbons that were evaluated. On a unit cost basis, ozone removed 34.3 ng of geosmin per dollar while the best carbon tested removed only 13.1.

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Appendix.References

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Table 1 – Geosmin Removal Using 25 ng/L of Five Different PACs

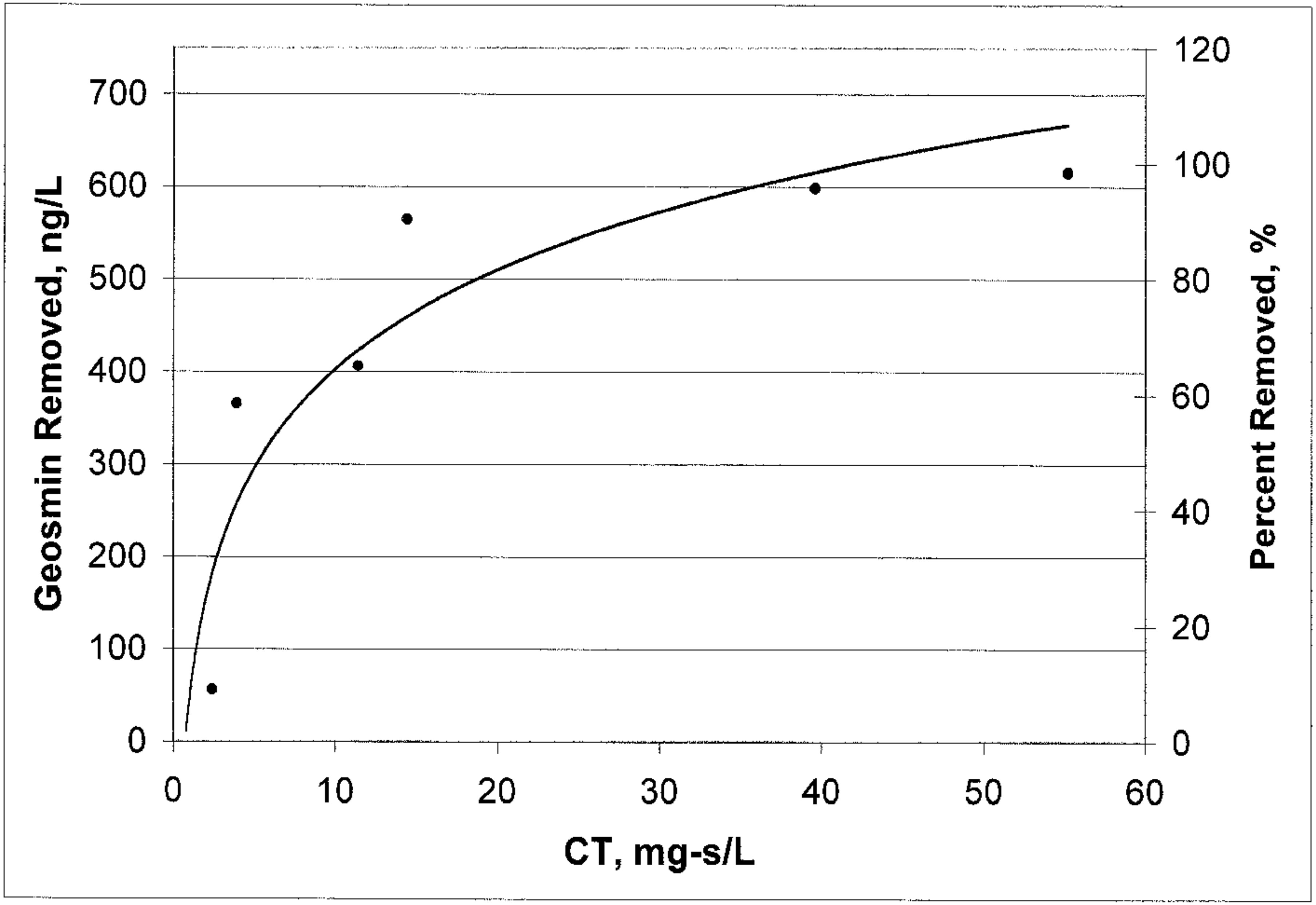
PAC CODE (1)	GEOSMIN REMAINING, ng/L (2)	GEOSMIN REMOVED, ng/L (3)	% GEOSMIN REMOVED, % (4)
No Pac	470	0	0
A	94	376	80
B	150	320	68
I	240	230	49
J	170	300	64
L	240	230	49

Table 2 – Geosmin Removal Using Ozone

OZONE FEED RATE, L/MIN (1)	CONTACT TIME, MIN (2)	OZONE RESIDUAL, ng/L (3)	GEOSMIN REMAINING, ng/L (4)	GEOSMIN REMOVED, ng/L (5)	% GEOSMIN REMOVED, % (6)
No 0_3	0	0	627	0	0
0.5	30	0.08	570	56	9
0.5	60	0.19	220	406	65
0.5	120	0.33	27	599	96
1.0	30	0.13	260	366	59
1.0	60	0.24	61	565	90
1.0	120	0.46	10	616	98

Table 3 – Unit Cost of Geosmin Removed, ng removed/$

PAC CODE (1)	PAC COST, $/kg (2)	COST OF GEOSMIN REMOVED, ng/$ (3)
A	1.15	13.1
B	0.99	12.9
I	1.04	8.9
J	1.65	7.3
L	0.88	10.4



Geosmin Removed, ng/L
0
100
200
300
400
500
600
700
Percent Removed, %
0
20
40
60
80
100
120
0
10
20
30
40
50
60
CT, mg-s/L