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How Do You Know If Your Ozone Contacting System Is Well Mixed?

Source: Mazzei Injector Company, LLC

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Mixing is something that is often taken for granted when designing systems for water and wastewater treatment. Perhaps "taken for granted" is too harsh a term. Let's instead say that while designing a treatment unit operation or process, mixing as a phenomenon is *automatically* assumed to occur — an assumption that forms the basis for process controls, performance guarantees and measurement methods and locations.

In this article, we will examine where this assumption is generally true, where it might not be true, and what the ramifications are when mixing is not achieved as expected.

Water and wastewater treatment processes are typically designed from a macro, civil engineering (hydraulics, construction) and aesthetic point of view while the actual physical/chemical processes depend on local and often micro-scale flow patterns. While millions of dollars are spent on a treatment system, the inherent errors associated with grab sampling can be easily overlooked. Now, consider that even the grab sample that we are looking at is often an aliquot of an aliquot. Add to that the issue of *where* the sample is obtained.

We will focus on ozone contacting for water, wastewater and reuse applications in this article. Broadly, we need to worry about the following:

- Is mixing occurring?
- If mixing is occurring, how do we quantify it?
- If we can quantify it, do we know the technological limits of our measurement tools?
- Once measured, do we know the limits of applicability of our statistical analysis of the data?

Is mixing occurring and how do we quantify it?

In many ozonation applications, there is no specific index to look at mixing. Mass transfer efficiency (MTE) is king and as long as a given system achieves the target MTE, everyone is happy. Mass transfer is mainly a function of ozone demand and available system pressure. Mixing ensures that the mass that is transferred is put to good use.

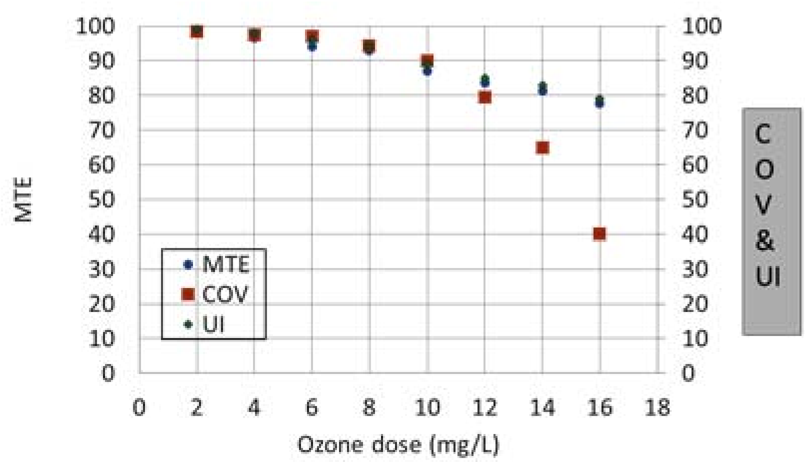
That is why a system can have a phenomenal MTE but poor contacting — effectively not treating a sizeable percentage of the influent.

When a crucial quantity such as the ozone residual is measured in an ozone contacting system, indices such as the coefficient of variation (COV) are used as a measure of variability, and in an indirect way, measure the homogeneity of a mixing process. The way this works is that the ozone residual is measured at three points in an over-under basin or at one point in a pipeline contactor, using an on-line sensor. This reading is fed back to the ozone generator to determine if ozone production needs to be ramped up in order to keep the MTE at or above the target value. Often, project specifications will call out for a target COV to ensure that the ozone residual does not vary by more than ± 5%.

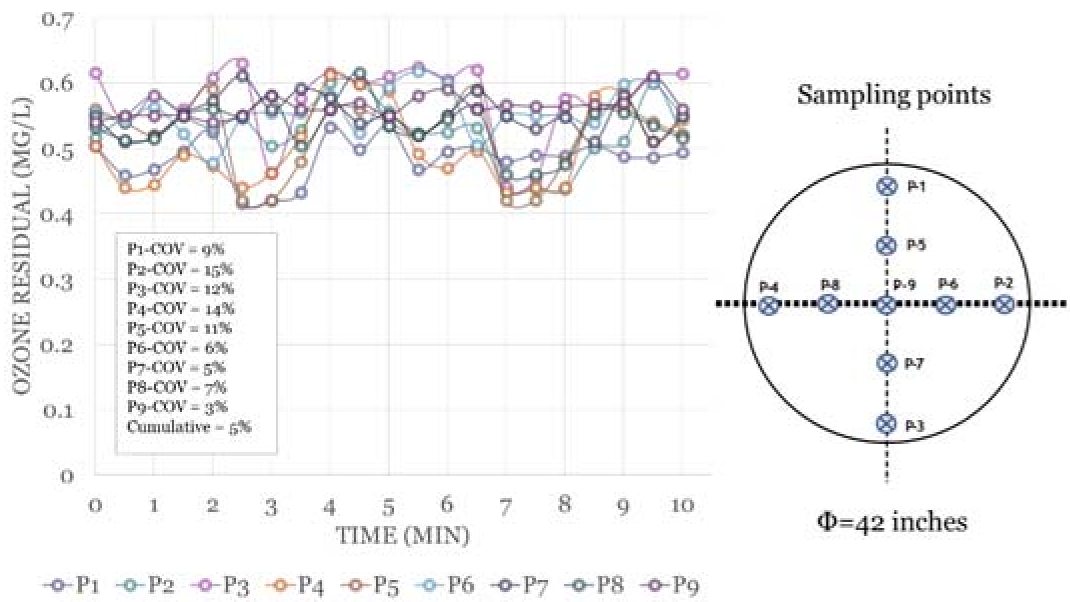
Considering the importance of this process and the energy costs associated with the increased ozone production, it is all the more crucial to ensure that the ozone residual that is measured is indicative of the *actual* mixing that is occurring in the contacting system. In an era of critical high ozone dose applications, such as for water re-use, it is worthwhile to take a long hard look at the way we have looked at mixing in the past.

Oh, ozone residual, where art thou?

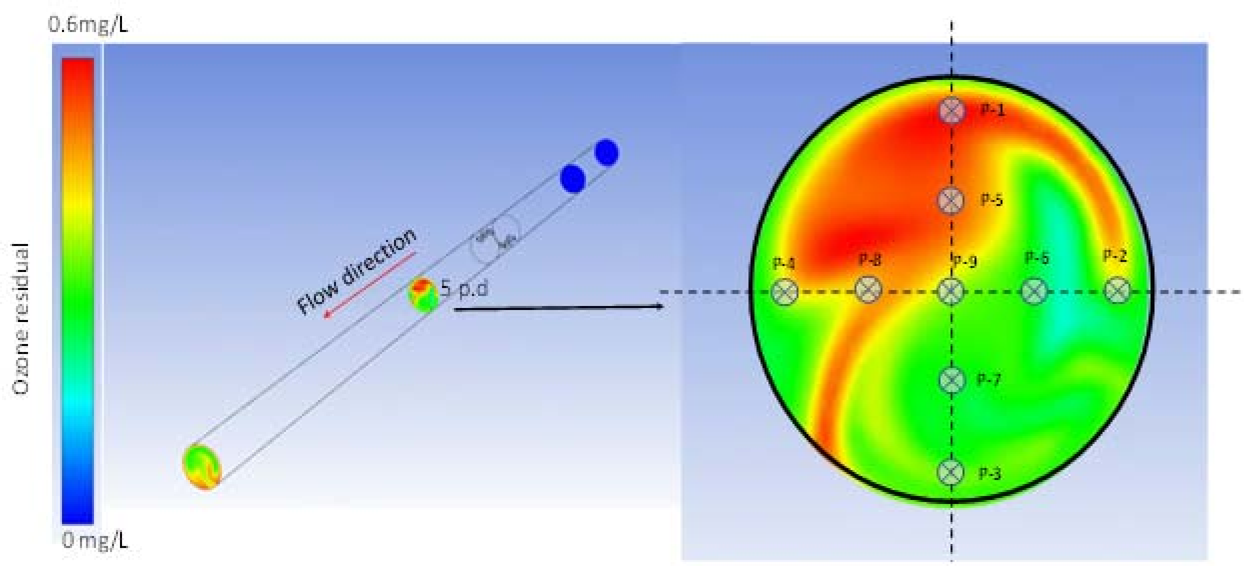
Using the power of multiphase computational fluid dynamics (CFD) analyses, Mazzei is able to identify if a COV is indeed a good indicator of mixing and mass transfer, in particular, for high ozone doses. The COV is compared to an area-weighted uniformity index (UI) derived from CFD analyses in the figure below.



This analysis for ozone residual measurements taken across the *entire* cross section of the pipeline contactor, effectively representing **thousands of points sampled** across the 42 inch diameter pipe model. Even with thousands of points sampled, it is clear that the COV is not a good indicator of actual mixing for ozone doses greater than 10 mg/L. Note that, in reality, in a treatment plant, only one point is sampled. Here's what it would the ozone residual COV would like if sampled at one random point in a pipeline that is 42 inches in diameter:



Clearly, the location of the sample probe matters. Here is why:



Results of the CFD analysis above confirm what we have always suspected — ozone residual measurement location matters – there can be a big difference in the residual measured depending on where it is measured. Here are some ways ozone residual is measured in practice:

It is important to stop here to point out to the reader that the variations that you saw in the CFD results above are for pipeline contacting — a much more controlled, bounded flow scenario. An open channel condition such as in an over-under basin brings a lot more uncertainty and requires a lot more care when it comes to pinpointing measurement locations. Fortunately, careful CFD analysis can help with this.

Measure with care

CFD analysis yields several important lessons for people designing an ozone contacting system, including:

- Traditional methods of ozone residual sampling need improvement to determine the actual exposure of the water to ozone.
- Unlike a model, in real-life it is clearly impractical to sample a thousand points across a cross-section of pipe or basin. That being said, there are methods that have been used in the past and should be considered when it comes to getting the best sample possible. For instance, for high-dose ozone applications, a cross-sectional planner concentration mechanism can be designed to get a representative sample.
- Finally, it is recommended to use an area-weighted uniformity index when CFD analysis is used to design contactors.

For readers interested in the details of the CFD analysis, please refer to my recent paper co-authored with Dr. Dan Smith of the University of Alberta, available here:

https://mazzei.net/wp-content/uploads/2018/08/Is-Coefficient-of-Variation-a-Realistic-Index-of-Characterizing-Mixing-Efficinecy-in-Ozone-Applications_IOA-PAG-2018-Pathapatiet-al.pdf

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