Q & A

Can you comment on the effect that the mixing will have on the pH equalization if we consider that we will add the acid and alkaline stream in the first section of the tank? Would you recommend more mixing (air) in the first zone?

The water and chemicals will mix completely quite quickly, as the vertical convection currents will carry the chemicals down, then up, then laterally, and repeat.

We are also able to dose chemicals directly into the bubble accumulator body, which upon the release of the bubble, will disperse chemicals immediately and thoroughly. Essentially all this would take is a dosing line tube to be run to one or several mixers with a metered dosing pump.

Your technology is using significantly less energy than coarse bubble, can you confirm that the mixing is as effective? If so, can you explain why?

We have attached an exhaustive explanation for this; however, I will attempt to simplify why this is the case.

When small bubbles rise through a water column, they move through the water, where very little water is displaced with each bubble, mainly due to relative surface area and drag. The rising speed of smaller bubbles is 0.05 - 0.4 m/s depending on the actual size, with coarse bubbles being on the higher side, 1-2 cm diameter (see http://www.seas.ucla.edu/stenstro/Bubble.pdf for a mathematical explanation). A very large bubble, however, can rise at a rate of about 1.1 - 1.4 m/s, in large part because of the relatively small comparative surface area of the larger bubbles, i.e. less friction/drag. A large bubble displaces a significant amount of water as it rises, in the case of the proposed bubble accumulators, roughly 40 liters, which expands as it rises and pressure decreases (i.e. the ideal gas law; $P_1V_1=P_2V_2$). The displacement and high velocity generate a vacuum of sorts below the rising bubble, essentially an unconstrained pump, which causes water and suspended solids to upwell powerfully to the surface behind the bubble. When the bubble breaches the surface, its energy / flow spreads laterally outward along the surface of the water, and eventually drops back down to the bottom – this effect is accentuated by tank walls and 'bubble walls' where the wakes of bubbles meet. Simply explained, the large bubbles induce vertical convection currents in the water, moving water at high velocities, thus keeping solids suspended.

Can you send pictures/videos of a similar installation?

We will upload documents, videos, and pictures to the project's Dropbox for you to view.

As for the secondary sludge tank, would it be possible to add a fine bubble diffusers system to minimize the risk of odors. Please let us know the requirements for the air for that extra system.

Yes, we can provide aeration equipment as well, fine bubble diffusers are optimal for this with the mixing provided by the large bubbles – for a tank of this size and purpose, 4 tubular membrane diffusers should be sufficient. If you have AOR / SOR values that you desire, please provide them and we can ensure that the correct equipment will be provided. Also, please advise if you would like a retrievable system or a hard mounted system for the aerators. You may use your SCADA system to control DO if you find it to be necessary. We can provide a variable valve if required.

Q & A

With respect to the question about coarse bubble vs large bubble and energy.

Agitation Potential of Large Bubbles for Mixing Applications

Energy is a key metric to evaluate the capability of bubbles to provide agitation in wastewater basins (essentially mixing). Assuming constant pressure at a depth below the surface of the water, the energy to create a bubble is;

$$E = \int_0^R PdV = \int_0^R P(4\pi r^2 dr) = P\int_0^R 4\pi r^2 dr = P\left(\frac{4\pi R^3}{3}\right)$$

Assuming the bubble (a) gently breaks the water surface when it rises to the surface, (b) has a negligible increase in volume during the rise, i.e., a few feet below the surface, and (c) has lost a negligible amount in viscous friction, then the energy used in creating that bubble has been transferred to kinetic energy during the rise. In large bubbles, most of this energy will be in the form of moving the water and contents rather than viscous heating. Note that the energy available to a specific bubble is proportional to cube of the bubble radius.

If smaller bubbles are used, where F is the radius ratio (R_{large} /R_{small}), requires that $N=F^3$ bubbles are used to achieve the same gas volume. The surface area ratio (SAR) of smaller bubbles of equal total gas volume is;

$$SAR = \frac{N(4\pi R_{small}^2)}{(4\pi R_{large}^2)} = F$$

Hence, as the small bubble's radius decreases, the surface area and the viscous friction energy dissipation increase proportional to the radius ratio. The viscous energy loss manifests itself in local heating of the water and does little for agitation and mixing. As a result, smaller bubbles have a smaller rise velocity.

The net result is that there is a clear advantage of using large bubbles for large scale agitation and mixing in wastewater applications.

Dr. William A. Arnold
Adjunct Professor
Department of Civil Engineering
The University of Akron