Issue of salicylic acid dosimetry for quantifying radical production in cavitation

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Cavitation leads to many (key) engineering problems: material loss, noise, and vibration of hydraulic machinery. On the other hand, cavitation is a potentially useful phenomenon: the extreme conditions are increasingly used for a wide variety of applications such as surface cleaning, enhanced chemistry, and wastewater treatment (bacteria eradication and virus inactivation).
Despite this significant progress, a large gap persists between the understanding of the mechanisms that contribute to the effects of cavitation and its application. Although engineers are already commercializing devices that employ cavitation, we are still not able to answer the fundamental question: *What precisely are the mechanisms how bubbles can clean, disinfect, kill bacteria and enhance chemical activity?*

One of the most widespread and acknowledged explanation is that the implosion of bubbles and consequent formation of local hot spots is responsible for homolytic cleavage of H_2O molecules and formation of free radicals (•OH and •H). Being one of the strongest oxidants, •OH readily oxidize any species they encounter. The amount of generated radicals is affected by several variables such as: cavitation extent and type, cavitation time, temperature, presence of dissolved gases, viscosity and surface tension of the liquid medium, vapor pressure and above all the design of the device.

In the experimental study we set out to determine the free radical production in cavitating flow. For this, we used one of the most commonly used techniques - salicylic acid dosimetry. Radicals formed during cavitation react with salicylic acid, which leads to the formation of several products - mostly 2,3- and 2,5dihydroxybenzoic acids. To assure that the highest amount of salicylic acid reaches the gas bubble interface, where the radicals mostly form, it is suggested to acidify the samples with HCl.

However, during the course of our experiments we noticed that cavitation dynamics is significantly different in acidified water (pH = 2.5) containing 300 mg/L of salicylic acid (the concentration selected based on the previously published studies) compared to water or acidified water alone (Fig. 1). This fact puts into question all the previous studies, where the salicylic acid dosimetry was used to determine the production of radicals in cavitation. Furthermore, it even casts a shade of doubt on the conclusions of reports of other advanced oxidation processes, where flowing water is present (ozonation, UV, plasma…).

Figure 1: Image of cavitation in water and in water + 300mg/L $C_7H_6O_3$

We investigated the properties of the liquids (vapor pressure, surface tension, viscosity and gas dissolvability), yet no significant deviation in the properties was found. One possible explanation is that the addition of HCl and salicylic acid to water, which results in a protonated form of salicylic acid, promotes nucleation of the gas bubbles and results in the change of cavitation dynamics. Although the conclusions are not yet final.

Finally, a proposal for an improved and optimized salicylic acid dosimetry is given, which should be closely followed if one is to evaluate the production of free radicals in a given cavitation generator.

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