ABSTRACT

The deteriorating water quality in South Africa and changing legislation requiring the industrial implementation of waste minimisation and pollution prevention technologies has highlighted the need for the investigation of new effluent treatment technologies such as advanced oxidation processes.

This investigation details the evaluation of ultrasound, an emerging advanced oxidation process, to degrade organic compounds during water treatment. The objectives of the investigation included the design of a suitable ultrasonic laboratory reactor to investigate ultrasound chemistry and the sub-processes occurring during sonication. Atrazine was used as a model compound to compare the performance of ultrasound with that of ozone and hydrogen peroxide, already established advanced oxidation processes. Recommendations have also been made for the scale-up of ultrasonic processes.

A 500 mL ultrasonic cell containing an ultrasonic horn as an energy source was designed and constructed. The measurement of hydrogen peroxide concentration was used as a tool to indicate the process conditions under which the formation of free radical reactions during sonication are enhanced. These include the application of oxygen and air sparging or the addition of a commercial source of hydrogen peroxide. It was found that oxygen sparging and a high acoustic power input should be used in ultrasonic processes with a short retention time, and conversely, that air sparging and a lower acoustic energy source should be used in processes with a long retention time. A flow loop system should be considered to maximise oxidation both within and beyond the sonicated zone, gas sparging should only occur within the sonication zone else the degradation of hydrogen peroxide is encouraged. Ultrasound is most effectively applied in water treatment as a pretreatment stage in combination with other technologies and not as a stand-alone process.

Atrazine was used as a model compound to compare the performance of ultrasound with ozone because of its persistence in the environment and resistance to degradation. Atrazine was degraded during sonication and ozonation, degradation increased with the addition of hydrogen peroxide. Ozone decomposition (and hence free radical reactions) was enhanced when ozone was combined with ultrasound or hydrogen peroxide. Enhanced ozone decomposition during ozonation combined with sonication is due to the conditions (high temperatures and pressures) as well as the free radical reactions occurring within the collapsing cavitation bubbles and at the gas-liquid interface. The enhancing effect of combining ultrasound with ozone was greatest at the low ozone concentrations typically applied during water treatment.

Atrazine degradation during sonication and ozonation is predominantly due to the reaction with hydroxyl radicals. Atrazine degradation products identified using gas chromatography and mass spectrometry were deethylatrazine, hydroxyatrazine and deethyldeisopropylatrazine (tentatively identified).