ABSTRACT

The brewing industry is considered to be among the economically strategic industries in most nations since it creates large scale employment opportunities and generates revenue to governments through different forms of taxations. However, the brewing industry faces a serious water consumption and pollution problem. This is because during beer production large volumes of clean water are consumed; consequently large quantities of wastewater contaminated with high concentrations of pollutants are generated. It is estimated that for every litre of beer produced, close to ten litres of fresh water is used. Recently, the complete treatment of brewery wastewater for reuse and disposal has become particularly important due to increasingly scarce water resources, ever increasing wastewater disposal costs, and stricter discharge regulations that have lowered permissible contaminant levels in waste streams. Currently, a good number of brewery wastewater treatment methods are either in operation, being piloted or under evaluation. Each method has its uses, advantages and disadvantages, and the removal of contaminants using these technologies can be complex and costly. Therefore, it is imperative that new and cheaper technologies are developed for the treatment of brewery wastewater. With the advent of carbon nanomaterials, the aim of this study was to access the suitability of using carbon nanotubes (CNTs) as heterogeneous coagulants and/or flocculants in the treatment of brewery wastewater. In addition, CNTs were also evaluated as adsorptive filter media in granular filtration.

Using already existing chemical vapour deposition (CVD) techniques, CNTs used in this research were synthesized from carbon dioxide (CO_2). The CO_2 was used in the production of CNTs because compared to the most widely used carbon precursors such as graphite, methane, acetylene, ethanol, ethylene, and coal-derived hydrocarbons, CO_2 is cheaper with relatively high carbon yield content. In addition, the proposed technique could be scaled-up in future so that it contributes to the efforts of utilising CO_2 in the control of its impact on global warming. The results showed that in the synthesis of CNTs from CO_2, temperature plays an important role. The results showed that when the temperature was lower than 750°C or above 840°C, there were no CNTs formed. The optimum growth temperature was about 800°C. The influence of CO_2 concentration and flow rate were also studied. Very high concentration and flow rates negatively affected the CNT growth rates.

Subsequently, a series of experiments were conducted in which the efficiencies of pristine and hydrochloric acid functionalised CNTs were compared with the efficiency of ferric chloride in a coagulation/flocculation process. Both pristine and functionalised CNTs demonstrated the ability to coagulate colloidal particles in the brewery wastewater. Overall, ferric chloride was found to be a more effective coagulant than both the pristine and functionalised CNTs. In granular filtration, the treatment scheme in which CNTs were added to both the coagulation/flocculation tanks and the filter bed was found to be the best option for the treatment of brewery wastewater. This treatment scheme removed 96.0% of chemical oxygen demand (COD) and residual turbidity of only 5 NTU remained in the effluent. In its guidelines, World Health Organisation (WHO) recommends turbidity should be maintained at less than 5 NTU, but if water is disinfected, it would be better to aim for values of less than 1 NTU.

To summarise, this research has demonstrated new applications of CNTs - heterogeneous coagulation and/or flocculation of colloidal particles, and as a granular filter media. The study has also highlighted the potential human health effects of CNTs with respect to drinking water such as cancer, granulomas, inflammation and fibrosis, etc.