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Potential application of synthesized ferrocenylimines compounds for the elimination of bacteria in water

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ABSTRACT

This work reports a study towards a search for environmentally friendly water disinfectant. The most common method for water treatment is based on chlorine which had a wide application over the years as a water disinfectant, but suffer the disadvantage of reacting with natural organic matter to form disinfection by products. In this study, the potential application of novel ferrocenylimines compounds, namely 4-ferrocenylaniline (**1**), *N*-(3-bromo-2-hydroxylbenzylidene)-4-ferrocenylimine (**2**) and *N*-(3-bromo-5-chlorosalicyl)-4-ferrocenylimine (**3**) for the elimination of bacteria in water was investigated by evaluating their antibacterial properties against twelve different bacterial strains using microdilution method in sterile 96 well micro titer plates. The *in vitro* antibacterial activity revealed that the ferrocenylimines compound exhibit higher antibacterial activity than ferrocene, which is one of the starting materials towards the synthesis of this novel ferrocenylimines compounds. The most active ferrocenylimines compound was compound **3** with a minimal inhibitory concentration (MIC) value of 0.30 mg/ml against *S. sonnei*. In addition, all the ferrocenylimines compounds possessed excellent antibacterial activity against *B. cereus* with the same MIC value of 0.31 mg/ml. The results obtained so far show great potential in the three tested ferrocenylimines compounds for use in water treatment in killing bacteria in water.

1. Introduction

Developing a new method for the elimination of bacteria in water is very important because water is essential to life. Safe water that is free from bacteria is very important to the development of man and his environment (West, 2006). Water has a wide range of applications including agriculture, domestic and industry. As the human population continues to increase, the use of water also increases. Due to improper drainage system, the pollution of water (surface and underground) has increased as a result of improper practices such as direct deposit of faeces on surface water and rainfall runoff from agriculture to surface and underground water (Medema et al., 2003). The consumption of contaminated water with bacteria, is the leading worldwide cause of deaths and diseases, accounting for the deaths of more than 14,000 people daily (West, 2006; Westblade et al., 2015).

Microbial waterborne diseases affect both the developing and developed countries (Medema et al., 2003). The bacteria are usually present in human and animal faeces and transmitted through water contaminated with faeces (George et al., 2001). The most important bacterial diseases transmitted through water are acute diarrheas, gastroenteritis, typhoid fever, cholera and bacillary dysentery (Grabow, 1996). These are some of the bacterial agent responsible for these waterborne diseases: *Vibrio cholera*, *Salmonella enterica*, *Shigella boydii, Shigella sonnei, Enterobacter cloacae* and *Escherichia coli* (Cabral, 2010). Infact acute microbial diarrheal diseases caused by *E. coli* are among the major public health problem in developing countries (Cabral, 2010). An estimated deaths of 1.5 million children have been reported, each year from diarrheal diseases (Fenwick, 2006). Children under five years are usually the most affected by waterborne diseases in Asian and African countries (Seas et al., 2000). Hence, there is need for an effective and environmentally friendly water disinfectant, in order to prevent waterborne diseases.

Chlorination which is the process of adding chlorine to water, is one of the methods used to disinfect water and to prevent waterborne disease caused by pathogens in water. Pathogens are harmful microorganisms that may cause diseases in humans. The use of free

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chlorine had found a wide application over the years, as a disinfectant for water treatment, but suffers a drawback because it reacts with natural organic matter (NOM) to form disinfection by-products (DBPs) which are mostly chlorinated organic compounds such as trichloroethylene (TCE), carbon tetrachloride (CT), chlorophenols, polychlorinated biphenyls and other halogenated organics (Westrick et al., 1984). The DBPs are said to be endocrine disruptors as they are highly toxic and persist in the environment (Vogel et al., 1987). Their direct exposure to humans can lead to cancer, miscarriages and nervous system complications (Vogel et al., 1987). Therefore it is very crucial to develop new methods that are able to remove bacteria in water without causing toxin effects.

Over the year the synthesis of compounds based on ferrocene compounds such as ferrocenylimines, have gained wide interest because of the unique properties and applications associated with it (Ikhile et al., 2013). The chemical stability, biological activities and non-toxicity properties of ferrocene has made it to be molecule of interest to incorporate into an organic compound (Ornelas, 2011). Recently, Qin et al. (2013) reviewed the application of imines also known as Schiff bases, in organic synthesis especially their biological activities. Studies by Zaheer et al. (2011) on some ferrocenyl Schiff bases showed that they exhibit antioxidant, antibacterial, antifungal, DNA protection and low cytotoxicity activities. Therefore reacting ferrocene with imines might enhance their biological activities.

As part of an ongoing search to develop an environmentally friendly water disinfectants, novel ferrocenylimines compounds (Fig. 1) were easily synthesized (Ikhile and Ngila, 2015), according to a modified procedure (Zaheer et al., 2011; Ping et al., 2001). Their potential application for the elimination of bacteria in water was investigated by evaluating their antibacterial properties against twelve test bacterial strains. The antibacterial activity of ferrocenylimines compounds **1**–**3** were also compared with the antimicrobial activity of ferrocene (Fig. 1), which is one of the starting materials towards the synthesis of ferrocenylimines compounds. However, to our knowledge, their use in biological water treatment has not been explored.

2. Materials and methods

2.1. Bacterial strains

The microorganisms selected in this study have been implicated in transmission of waterborne diseases, which is a global major concern (Craun, 1986; Gauthier and Archibald, 2001). The twelve bacterial strains used for the experiments were obtained from the American Type Culture Collection (ATCC) as shown in Table 1 below.

2.2. Maintenance and growth of bacterial strains

All the bacterial strains were plated and maintained on Muller-Hinton agar (Oxoid) during the experiments. The plates were incubated at 37 °C overnight and stored at 4 °C when not in use. Bacterial strains were grown in liquid culture by inoculating Mueller-Hinton broth (HI Media) with a colony from a freshly grown plate. All strains were grown at 37 °C with mild agitation (100 RPM) until an optical density of 600 nm (OD600) was reached. These cell suspensions, in media, were used for the anti-bacterial testing.

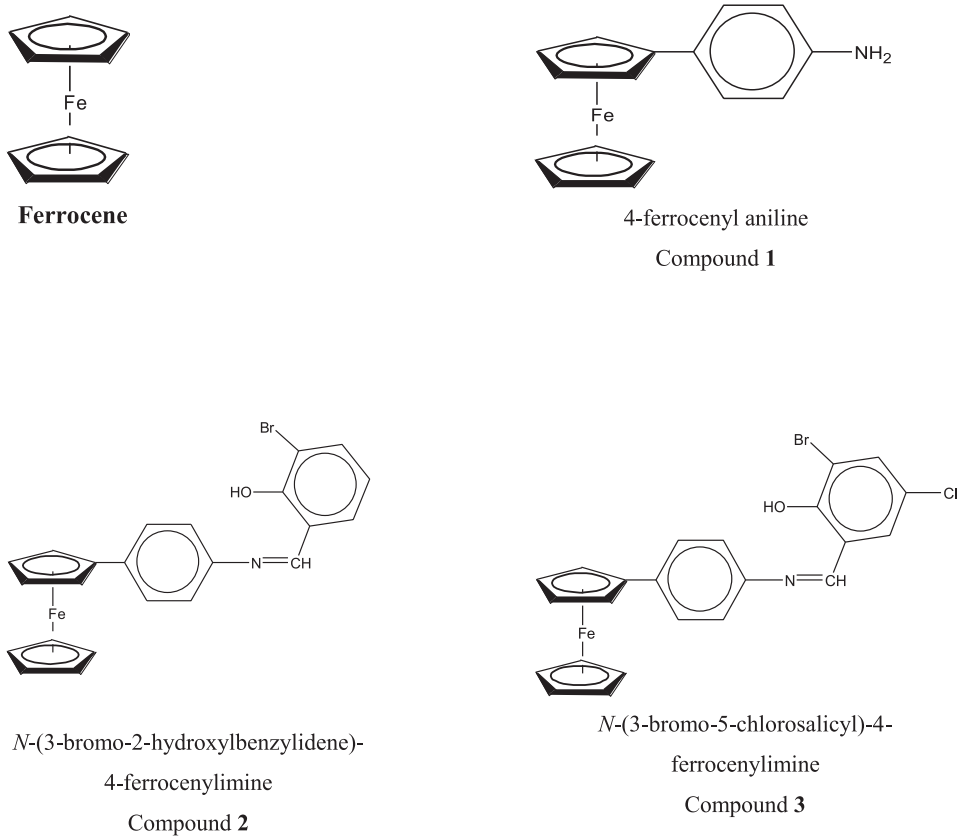

Fig. 1. Chemical structure of ferrocene and ferrocenylimines compounds **1**–**3**.

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