Promising Technologies for Remediation of warfare Nerve Agents and Pesticides: Biodegradation and Non-Biological Applications

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Abstract

The importance of chemical weapons as a current overall threat in possession of terrorist groups, along with a constant increase of pesticides usage, leading to intoxications frames and contaminations into the environment around the world, have kept the attention of researchers in order to develop new technologies for a rapid and complete detoxification of the poisoning caused by these organophosphorus compounds (OP). The standard treatment includes the usage of reactivator compounds, such as the so-called oximes. Other important remediation processes involve the employment of bioremediation techniques using different degrading enzymes, such as Phosphotriesterase, Human Serum Paraoxonase 1, Diisopropyl fluorophosphatase, among others. In addition to these promising treatments, there is also the possibility of using non-biological materials in the degradation process, such as some metal oxides clusters.

Keywords: Neurotoxic agents; Reactivators; AChE; Remediation processes

Introduction

In the period of the First World War, several nations gave rise to chemical warfare programs in order to get advantages in their fighting performance. Posteriorly, these activities were intensified during the Second Big War, mostly due to the discovery of organophosphorus nerve agents [1]. According to Jang et al. [2] the nerve agents are supposed to be the most dangerous compounds ever used. These substances are known for actively act on Acetylcholinesterase (AChE) enzyme. The OP chemical structures involve the high toxicity in mammals regarding similar species. OPs are chemical compounds that have several applications, but these substances are generally employed as pesticides and chemical weapons [2,3]. Currently in the agricultural field, pesticides such as Diazoxon, Parathion and Paraoxon are widely employed to provide protection to crops from pests and insects that cause damages to theses cultures. However, these products are quite toxic, causing adverse and harmful effects to human health, acting directly on the central and peripheral nervous system, thus giving rise to neuromuscular abnormalities that can lead to death [4].

Neuroscience researches aim to comprehend the impacts caused by these agents and how they can affect humans [5], being these efforts necessary to get new remediation techniques [6,7].

Figure 1: Chemical structure of OP compounds. The leaving group of each agent is highlighted in red.
OP insecticides and chemical warfare agents were developed to act as irreversible AChE inhibitors [8]. The general OP structure is constituted by a phosphoryl group (P=O) or a thiophosphoryl group (P=S), two lipophilic R groups, and the characteristic leaving group of each compound. The structures of one of the major pesticide (Ethyl paraaxon) and some main chemical warfare agents (Tabun, Soman, Sarin, Cyclosarin, VX) are shown in Figure 1[9,10]. OPs are highly lipophilic compounds and rapidly move to the nervous system, with the subsequent initiation of the intoxication through the binding and posterior inactivation of AChE [8].

Toxicology and Remediation perspectives

After AChE inhibition by OP, two processes can take place: (a) aging of AChE and (b) spontaneous reactivation of the enzyme, which happen at an insignificant rate. The reactivation process can be sped up by adding a nucleophilic, such as oximes. Other promising techniques, which aim to provide an efficient detoxification the enzymatic biodegradation treatments [11-13]. It is well-known that traditional techniques for OP detoxification are commonly expensive; in this context, bioremediation processes are recently a good alternative for this purpose, along with the use of specific antidotes. The enzymes Human Serum Paraoxonase 1 (HssPON1), Disopropyl fluorophosphatase (DFPase) and Phosphotriesterase (PTE) have been shown to be appropriate for high performance decontamination applications [14,15]. These enzymes usually present a binuclear metal center which is directly related to the hydrolysis reaction mechanism, being responsible for maintaining the structural integrity and also for the catalytic activity [16]. In this context, metal clusters have been designed in order to efficiently mimic an enzyme active site in the catalysis; as an example of application, there is the collaboration from Katz et al., wherein it was employed a zirconium (IV)-cluster-containing metal–organic framework as an active biomimetic catalyst, presenting a great activity and selectivity for the hydrolysis of paraaxon. This good performance is believed to be related to the set Zr-OH-Zr, which interestingly mimic the binuclear metal center (a couple of Zn2+ ions) of the PTE enzyme [17].

Conclusion

Chemical weapons represent a major concern to the society due to their devastating effects. Equally important, the misuse of OP pesticides can cause serious damages to public health and the environment, leading to death thousands of victims annually. Therefore, the search for more efficient tools capable of providing rapid and complete detoxification has been quite important nowadays. Thus, the purpose of this collaboration is to bring about promising possibilities, such as the employment of degrading enzymes (bioremediation) and non-biological systems, which can provide great contributions to the medicinal chemistry, and also stimulate more and more researches in this field, which is undoubtedly of significant importance and interest.

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