

“Two Birds, One Stone”: A New Recipe for Chemical Decontamination?

Zhaohui Wang*

College of Environmental Science and Engineering, Donghua University, Shanghai, 201620, China

*Corresponding author: Zhaohui Wang, College of Environmental Science and Engineering, Donghua University, Shanghai, 201620, China, Tel: +86-21-67792557; Fax: +86-21-67792522; E-mail: zhaohuiwang@dhu.edu.cn

Rec date: Jun 14, 2014; Acc date: Jun 17, 2014; Pub date: Jun 25, 2014

Copyright: © 2014 Wang Z. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Editorial

Since I was a schoolchild, I have frequently heard the phrase “to kill two birds with one stone” to describe successfully achieving two aims simultaneously. As an environmental researcher, I believe such a “Two Birds, One Stone” (TBOS) philosophy could be quite instructive to develop viable and cost-effective technologies to accomplish the simultaneous removal of couples of pollutants. To date, environmental scientists have concentrated their efforts on detoxification of a single pollutant using a variety of sophisticated technologies. Simultaneous conversion of pollutants by a facile treatment is being given more attention recently. Here we discuss the feasibility and real-world constrains of TBOS strategy in abiotic degradation of organic/inorganic contaminants.

Killing two birds with the same stone is virtually impossible, unless two birds pop up in the right place at the right time and are knocked out by a powerful stone. Similarly, the simultaneous removals of different pollutants in an integrated reaction are only possible under the proper conditions. A typical TBOS degradation consists of two main individual reactions: driving reaction and driven reaction. In most cases, reactive oxygen species or reducing intermediate are generated in a driving reaction. For example, excitation of dye pollutant under visible irradiation is one of most common driving reaction used in these coupled redox processes (Figure 1a and 1b). The electron injection from the excited states of the adsorbed dye into the conduction band of a semiconductor (e.g. TiO_2) can facilitate the activation of dioxygen [1]. Here the semiconductor acts as an electron mediator, ensuring rapid and efficient charge separation. In these dye-based photoredox reactions, an electron mediator is indispensable because of the rather inefficient charge transfer between dye and O_2 in a homogeneous solution. The formed organic radicals or active oxygen species can attack the other colorless pollutant (e.g. phenol) [1]. In oxygen-free systems, the trapped electrons can reduce halogenated organics (e.g. CCl_4) and toxic high-valent transitional metals (e.g. Cr(VI)). In addition to semiconductors, structural Fe(III)/Fe(II) in layered clays is recently found to mediate the simultaneous conversion of dye and Cr(VI) (Figure 1b) [2].

The simultaneous removal of organic/inorganic and inorganic/inorganic pollutants is also achievable in the homogeneous systems. How to in-situ produce highly oxidizing agents using co-existing pollutants is the key to establish an efficient coupled decontamination reaction. Recently, we reported two intriguing simultaneous conversion of pollutants based on the activation of inorganic pollutants. Sulfite, a common industrial contaminant, can be photochemically activated by cheap and nontoxic iron salts to in-situ produce highly reactive sulfate radical for degrading organic pollutants (Figure 1c) [3]. Photoredox reaction of Fe-sulfite complex is the driving reaction, whereas degradation of any organics susceptible to sulfate radicals attack, in theory, can be the driven reaction. Therefore,

considering the ubiquity of combined contamination of sulfite and organics in the industrial effluents, this so-called “photo-sulfite” reaction has a wide application prospect in wastewater treatment.

One of the best TBOS-type reactions should be the simultaneous transformation of chromium and arsenic [4]. Cr(VI) and As(III) , far more toxic and mobile than Cr(III) and As(V) , are priority pollutants associated with acid mine drainage (AMD) with great environmental impacts. To simultaneously reduce Cr(VI) to Cr(III) and oxidize As(III) to As(V) would largely lower the environmental hazard of chromium and arsenic in AMD. Although the general oxidation of As(III) with Cr(VI) is thermodynamically feasible, the direct reaction between As(III) and Cr(VI) is negligibly slow. However, once H_2O_2 , an industrially-available oxidant, was added, the simultaneous reduction of Cr(VI) and oxidation of As(III) was greatly accelerated (Figure 1d). Cr(VI) activates H_2O_2 to generate hydroxyl radicals, which is responsible for the As(III) oxidation [5].

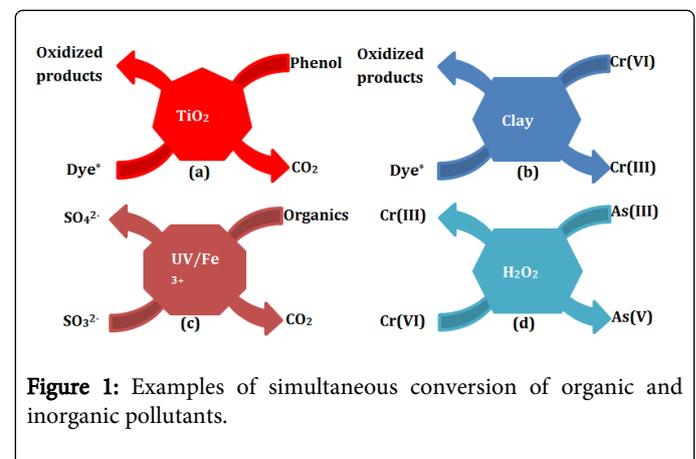


Figure 1: Examples of simultaneous conversion of organic and inorganic pollutants.

The left half reaction is a driving reaction whereas the right one is a driven reaction. Now it is evident that the coupled chemical decontamination is not only feasible but, as properly implemented, is able to provide more rapid and cost-effective treatment than the sequential degradation of each pollutant. However, most studies of the effectiveness of TBOS processes are based on laboratory scales or simulated matrices. There are several factors that cannot be underestimated due, in part to the complexity of the real wastewaters. In a dye-sensitized TOBS reaction, a full mineralization (conversion to CO_2) cannot be attained within time frames relevant to the half driven reaction (e.g. Cr(VI) reduction in Figure 1b) [2]. However, the oxidized products of dye are expected to be more biodegradable in general, and can be targeted with downstream technology. Furthermore, the driving reaction in a TBOS process is often partially inhibited by some co-existing metal ligands. For example, oxalate and citrate, typical Cr(V) ligands, would greatly diminish the efficiency of

co-conversion of Cr(VI) and As(III) [4]. In view of the fact that often the time required for wastewater treatment increases or the efficiency decreases as technologies are transferred from the laboratory to the field, a full understanding and optimization of the TBOS processes are required to ensure success in engineered application. Although we are already beginning to see some inspiring successful cases of TBOS reactions, there is a need for a universal and yet flexible framework for establishing more novel TBOS reaction. In recognition of these challenging issues, this editorial is a call for additional research to test the above-proposed TBOS hypothesis and to judge the necessity of and requirement for successful TBOS processes to ascertain the transferability of these novel technologies to the field.

Acknowledgments

This work was financially supported by National Natural Science Foundation of China (NSFC) (Grant Nos. 21007009, 41273108 and 21377023) and Fundamental Research funds for Central Universities (2232013A3-08).

References

1. Chen C, Ma W, Zhao J (2010) Semiconductor-mediated photodegradation of pollutants under visible-light irradiation. *Chem Soc Rev* 39: 4206-4219.
2. Liu R, Guo Y, Wang Z, Liu J (2014) Iron species in layered clay: Efficient electron shuttles for simultaneous conversion of dyes and Cr(VI). *Chemosphere* 95: 643-646.
3. Guo Y, Lou X, Fang C, Wang Z, Liu J (2013) Novel photo-sulfite system: towards simultaneous transformations of inorganic and organic pollutants. *Environ Sci Technol* 47: 11174-11181.
4. Wang Z, Bush RT, Sullivan LA, Liu J (2013) Simultaneous redox conversion of chromium(VI) and arsenic(III) under acidic conditions. *Environ Sci Technol* 47, 6486-6492.
5. Bokare AD, Choi W (2010) Chromate-induced activation of hydrogen peroxide for oxidative degradation of aqueous organic pollutants. *Environ. Sci Technol* 44: 7232-7237.