Semiconductor photocatalysis for life-support systems on the moon

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Abstract

Over the past decade, photocatalysis with semiconductor dispersions has received much attention and practical applications have been realized in the decontamination of water, sacrificial hydrogen production and extraction of metals. As the lunar surface has abundant UV radiation (necessary to sensitize high-band-gap, stable semiconductor catalysts), it is suggested that photocatalytic processes could be conveniently adopted on a lunar base. A specific example of detoxification of water in a photosynthetic culture medium is discussed. When the aquatic plant *Lemna major* is grown repeatedly in the same culture medium (nutrient concentration kept constant), the standing biomass progressively decreases. However, if the culture medium used is exposed to sunlight in the presence of TiO_2, a standing biomass close to the first cycle is maintained.

1. Introduction

Recently photocatalysis with semiconductor powder dispersions has attracted a great deal of attention as a means of harnessing solar power [1–5]. Although the original aim of these studies was the photocleavage of water, the achievable quantum efficiencies are much lower than the level required for a practical system [1–5]. However, photocatalysis with semiconductor particles may find practical applications in the decontamination of water [4, 6–8], the sacrificial production of hydrogen [3–5] and the extraction of metals [4–6]. In this paper we demonstrate that semiconductor photocatalysis is perhaps the most ideal method for carrying out some of these processes on a lunar base. The stable photocatalysts are high-band-gap materials sensitive only to UV radiation (*e.g.* TiO_2) and light in this wavelength region is abundant on the surface of the moon.

A specific example is the decontamination of water in a life-support system containing green plants (*i.e.* a culture of submerged or floating photosynthetic organisms). The accumulation of excreted toxins prevents the recycling of water in the medium. Distillation is energy expensive and in some cases does not remove all organic wastes. It is known that organic wastes can be completely mineralized photocatalytically using semiconductor powders [4, 6–8] in the presence of oxygen, *i.e.*

$$\text{organic matter} + O_2 \xrightarrow{h\nu/TiO_2} H_2O + CO_2$$

2. Results

To test the feasibility of adoption of the above method for the decontamination of water in a culture, we carried out the following experiment. The floating aquatic plant *Lemna major* was grown in a glass vessel (cross-sectional area, 90 cm^2; volume of the liquid, 1350 cm^3) containing sterilized water supplemented with mineral nutrients (nitrate nitrogen, approximately 0.02 g l^{-1}; ammoniacal nitrogen, approximately 0.02 g l^{-1}; K_2O, approximately 0.1 g l^{-1}; P_2O_5, 0.1 g l^{-1}). The concentration of nutrients was kept constant throughout the entire period of growth. In about 60 days, the growth of the community approached an equilibrium and a nearly stationary biomass was obtained. The growth curve is shown in Fig. 1(a). The crop was then removed and the culture solution was filtered and replenished with water and nutrients to the original concentration. When the process was repeated, it was noted that the rate of growth and the optimum standing weight of biomass decreased progressively as a result of the accumulation of waste products. The growth curve after four cycles is shown in Fig. 1(b). After completion of four cycles, the plants were harvested and the culture medium was filtered; TiO_2 (Aldrich 99%, 10 mg l^{-1}) was added to the filtrate, agitated by

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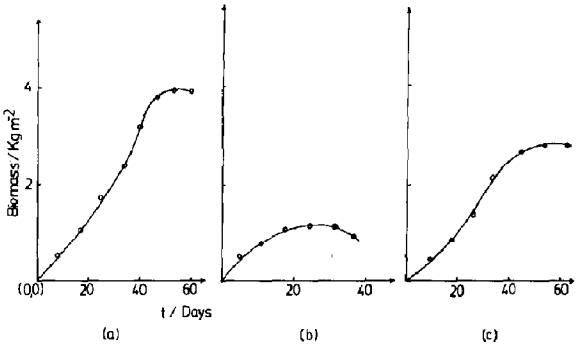

Fig. 1. Plot of the weight of biomass per unit area *vs.* time: (a) initial culture; (b) culture at the fourth cycle; (c) culture at the end of the fourth cycle detoxified by photocatalysis.

passing air and exposed to the sun for 8 h (average intensity, 1.4×10^4 kJ day^{-1}). The catalyst was separated by centrifuging, the nutrient concentration was adjusted to the former value and the experiment was repeated. Figure 1(c) shows the growth curve for this case. It is seen that the initial rate of growth and the standing biomass are comparable with that of the first cycle, indicating that efficient detoxification has taken place. A permanganate decolouration test showed increasing accumulation of soluble organic matter when growth cycles were repeated. The same test revealed that 8 h exposure to sunlight in the presence of TiO_2 was sufficient for nearly complete destruction of the organic compounds. When one growth cycle was completed, acidified permanganate added to a concentration of approximately 10^{-4} M faded to 50% absorbance in about 2 min; after photocatalytic treatment, this time was prolonged to more than 30 min. We conclude that replenished growth after photocatalytic treatment of the culture solution is due to the removal of accumulated toxins.

References

1 G. Porter, in J. D. Coyle, R. R. Hill and D. R. Roberts (eds.), *Light, Chemical Change and Life*, Open University Press, Milton Keynes, 1988.
2 A. Harriman, *J. Photochem., 25* (1984) 33.
3 H. Gratzel, in M. Gratzel (ed.), *Energy Resources through Photochemistry and Catalysis*, Academic Press, New York, 1983.
4 A. Heller, *Nouv. J. Chim., 11* (1987) 177.
5 A. J. Bard, *J. Phys. Chem., 86* (1986) A2.
6 E. Borgarello, N. Serpone, M. Bardeen, C. Minero, E. Pelizzetti and E. Pramauro, in E. Pelizzetti and N. Serpone (eds.), *Homogeneous and Heterogeneous Photocatalysis*, Reidel, New York, 1986.
7 R. W. Matthews, *Water Res., 20* (1986) 569.
8 D. Dulin, H. Drooesman and T. Mill, *Environ. Sci. Technol., 20* (1986) 72.