Old Solutions to New Problems?

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The environmental costs of industrial expansion fall disproportionately on people who have benefitted the least from that expansion. The aim of this paper is to show how some small part of this inequity might be redressed by adapting established technology to meet the needs of less advanced societies.

Probably the most serious threat facing mankind is the worldwide shortage of potable water. For example, an estimated 60 million low income people in South Asia are affected by chronic exposure to naturally occurring arsenic in groundwater. They cannot afford large-scale treatment systems and available small-scale methods of remediation have proven ineffective or unreliable.

Research at UC Berkeley[1] showed the necessary remediation might be achievable by electrocoagulation (EC). EC has been used in large water treatment plants for over a century but significant effort was required to adapt it to meet the needs of this application. The modified process, named ECAR (Electrochemical Arsenic Remediation) is based on the production of Fe(II) through the electrolytic dissolution of an Fe(0) anode. The cathode reaction is normally the reduction of H^+ ions to H_2 gas.

Small-scale tests of ECAR in 2008 yielded promising results and subsequent field trials of 100L[2] and 600L[3] batch reactors demonstrated that the process could consistently lower arsenic levels from over 300 μg/L to under 5 μg/L: half the limit recommended by the World Health Organization. Over several months of operation, the equipment proved robust, inexpensive to operate and easy to maintain.

Electrochemical processes are particularly well suited to water purification on a small scale because of their size-independent efficiency, low land area demand, and ease of handling[4]. An increasing number of publications deal with the destruction of toxic and refractory organic pollutants in acid waters by the electro-Fenton method[5], a process based on the cogeneration of ferrous ion and hydrogen peroxide on the same electrode. The hydroxyl free radical •OH produced by the reaction between the ferrous ion and hydrogen peroxide is a powerful and non-selective oxidant, capable of converting many organic compounds directly to carbon dioxide.

Photoelectrochemical processes have also been proposed for the remediation of contaminated water. In an early example, Frank and Bard suggested that cyanide in aqueous solution might be oxidized to cyanate by exposing the solution to sunlight in the presence of metal-oxide semiconductors[6]. Results of their tests with a xenon arc lamp are reproduced in Table 1.

Table 1: Removal of CN^- Under Irradiation in the Presence of Several Semiconductor Powders[a]

μM CN^- reacted	Initial $[CN^-]$, mM	Illumination time, min	Semiconductor powder
7.7	1	60	TiO_2 (anatase)
6.3	1	45	TiO_2 (anatase)
5.5	1	30	TiO_2 (anatase)
9.5	1	60	ZnO
7.8	1	30	ZnO
<0.1	1	30	Fe_2O_3
<0.3	1	45	WO_3
0.6	3	60	CdS
<0.1	3	60	Fe_2O_3
15.8	3	60	TiO_2
22.5	3	60	ZnO

[a] The solution was 10 mL of 0.1 M KOH containing the indicated amount of KCN and 0.1 g of semiconductors contained in a quartz tube, illuminated with a 450-W Xe lamp with continuous O_2 bubbling.

Rough calculations by Frank and Bard suggested that the photochemical process might compete favorably with oxidation processes using more conventional electrochemical reactors.

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