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FACTORS LIMITING THE ACCEPTANCE AND USE OF INNOVATIVE ENVIRONMENTAL TECHNOLOGIES: A CASE STUDY OF THE SOLAR AQUATICS SYSTEM™ (SAS) TECHNOLOGY FOR WASTEWATER TREATMENT†

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ABSTRACT

This article presents the conclusions of a recent study analyzing the factors limiting the acceptance and use of an innovative environmental technology, the solar aquatic system™ (SAS), a wastewater treatment design based on artificial wetlands and aquaculture systems enclosed in a greenhouse. The conclusions of that study are applied directly to the consideration of factors limiting the acceptance and use of other innovative environmental technologies. Since environmental benefits associated with innovative environmental technologies are difficult to assess and value, increased use and acceptance of these technologies depend upon 1) explicit evidence of tangible environmental benefits, 2) standardization of innovative design, 3) increased public awareness of innovative designs through technology promotion efforts, and 4) increased ecological education to give the public the information needed to assess the value of the environmental benefits associated with innovative environmental technologies.

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INTRODUCTION

Frustrating delays and deliberate resistance to adaptation often accompany the introduction of innovative technologies that claim long-term environmental benefits as their primary advantage when compared to existing technologies. Since long-term environmental benefits are difficult to quantify, they are often not given priority over other technological considerations. One particular innovative environmental technology which has been experiencing a slow rate of acceptance and minimal use is the solar aquatic system™ (SAS), a wastewater treatment technology based on artificial wetlands and aquaculture systems enclosed in a greenhouse. Although this wastewater treatment system has consistently met permitting requirements since being patented in 1988, only seven SAS facilities are currently in operation. The identification and analysis of the major factors limiting the acceptance and use of this innovative environmental technology can be applied constructively to consideration of how, in general, the adaptation rate of innovative environmental technologies might be increased.

THE SOLAR AQUATICS SYSTEM™ (SAS)

The solar aquatics system™ (SAS) is an innovative alternative to the generally accepted conventional approach to wastewater treatment. The SAS is a water treatment technology which combines principles of ecological engineering with standard, proven wastewater treatment concepts in an attempt to provide a sustainable, economical wastewater treatment system [1]. In the SAS, wastewater is circulated through a series of aquatic environments in translucent tanks and constructed marshes. This circulation occurs inside a greenhouse to encourage year-round biological activity and to allow for the metabolization and binding of contaminants and nutrients [2]. Optimal conditions for microbial function, including oxygen availability, temperature, humidity, pH, alkalinity, habitat, light, and evapotranspiration are maintained in the greenhouse, as segments of the wastewater column are exposed to light in the translucent tanks [3]. The system's design attempts to maximize biological degradation to treat the wastewater by relying on an ecologically diverse aquatic environment.

The operating principles of the SAS are based on microbially mediated biochemical decomposition processes that convert large organic molecules to inorganic compounds. The wastewater treatment processes in the SAS can be divided into three sections: 1) the headworks, where blending and flow equalization occurs, 2) the greenhouse system, where biological processing, removal of contaminants, and UV disinfection occurs, and 3) the solids processing, where stabilization and composting of sludge and vegetative waste occurs [2].

HISTORY OF THE TECHNOLOGY'S DEVELOPMENT

The SAS was invented in the 1980s by Dr. John Todd, a specialist in natural systems technology and President of Ocean Arks International of Falmouth, Massachusetts. Todd, who appeared to be more interested in research than marketing, sold the patent in 1988 to Ecological Engineering Associates (EEA) of Marion, Massachusetts, a company established to develop and market the SAS technology to small communities and industries in need of a new wastewater treatment system. Since being patented in 1988, the technology has been marketed in communities throughout the United States, Canada, Mexico, and France. Two Canadian engineering firms, Icon Systems Limited (associated with Proctor and Redfern) in North York, Ontario and Applied Environmental Systems, in Halifax, Nova Scotia, are currently working closely with EEA to market the technology in Canada [4].

The Water Pollution Control Act Amendments passed by Congress in 1972 and the Clean Water Act Amendments of 1977 require that all publicly owned treatment works (POTW) prove that they can provide treatment of sewage that will result in a minimum average monthly effluent concentration of 30 mg/liter each of both TSS and BOD [5]. Therefore, before any publicly owned SAS facilities could be constructed, several pilot plants were built to collect data to demonstrate to the regulatory agencies that the system was effective in treating wastewater. From 1989 through 1993, these pilot plants were closely monitored by the E.P.A. and other independent scientists, and the data collected provided the necessary information for regulatory approval. In each state and Canadian province in which the system has been proposed, the SAS has been determined to be permittable [1]. Although the technology meets permitting standards, only seven SAS facilities are currently in operation in North America. The rate of acceptance of this technology has been slow, and many well-informed engineers, biologists, and environmentalists remain skeptical of the technology.

THE CLAIMED ENVIRONMENTAL BENEFIT OF THE SAS

As is common with many environmental technologies, some of the claimed environmental benefits are valid, but others have not yet been rigorously demonstrated. The most apparent environmental benefits of a SAS facility, when compared to a conventional treatment facility, are those associated with the pleasant, natural, relatively odor-free environment inside the greenhouse. These attractive features of the technology are capable of encouraging increased community awareness and understanding of wastewater treatment, natural processes, and waste reuse and recycling [6]. This increased awareness and interest in wastewater treatment has been demonstrated in two of the recently constructed facilities. Neighbors and community members often stop by at the newly opened Ashfield, Massachusetts facility to donate plants to be used in the facility, to take a tour or just to visit the pleasant, odorless greenhouse [7]. The community of Bear River, Nova Scotia is proud of its SAS facility, which has attracted visitors from other communities to tour the facility, indirectly boosting the local economy [8].

Another benefit of the SAS, also related to its pleasant, natural, odorless environment, is that these attractive characteristics of the system may allow siting of a community's wastewater treatment facility in a location that would be unacceptable for a conventional facility. Siting of wastewater treatment facilities is often controversial and difficult in a community, because nobody wants to live close to an odorous facility [9]. If a community chose a wastewater treatment system, such as the SAS, which was pleasant and odorless, the number of possible locations for siting the facility would be greater, and the cost associated with the siting process and the cost of the land chosen could be reduced because the siting process would have fewer restrictions.

Environmental benefits of the SAS that have not been proven include the estimate that SAS facilities produce 40 percent less biosolids (sludge) than conventional sewage treatment plants [6]. Also the claim that SAS facilities can harvest plants grown in the greenhouse for commercial benefits has not yet been borne out because none of the current facilities have yet attempted to do so.

FACTORS LIMITING THE ADOPTION OF THE SAS

Factors limiting the use of this technology include the larger area of land required and the higher costs, particularly design costs, associated with the SAS when compared to conventional systems. The lack of an operational history, the tendency toward conservatism in wastewater treatment technology, and the current system of government funding of wastewater treatment projects are factors that also contribute to the limited use of this technology. In addition, many wastewater engineers are unfamiliar with the SAS technology, so communities often are not presented with the option of considering alternative wastewater treatment technologies like the SAS.

Required Area of Land

For communities with fewer than 10,000 residents, the area of land required for a SAS facility is about the same as it would be for a conventional facility with the same capacity. However, the land area required for a SAS facility increases significantly for larger systems since the area required is based primarily on the size of the greenhouse, which in turn is a function of the number of tanks necessary to treat the incoming waste stream.

Costs

Although EEA claims that the SAS is an economical choice of wastewater treatment system for a small community, and although the costs of any treatment plant are dependent on various location-specific factors, the estimated current construction and operational costs of a SAS would be considerably more than the costs of a conventional system for almost any community [7]. The current overall capital cost to install a SAS is generally higher than that of a conventional system, because of the high costs of designing this innovative technology [10]. These high costs of design are a function of the innovative nature of the technology; since only a few (less than a dozen) SAS facilities have been designed and built so far, the design of every new facility requires more consideration, research, and time than does the design of a conventional system.

Lack of Operational History

Another factor limiting the acceptance of the SAS technology is the lack of an operational history. Communities about to invest in a new or upgraded wastewater treatment system do not generally want to take a chance on a new technology with little or no operational history. Concerns for the protection of their local environment from the effects of untreated sewage, as well as the threat of expensive fines levied by the state regulatory agency for violating permit specifications if the system fails, are both factors that influence communities to choose wastewater treatment technologies that come with a solid operational history [10]. This conservative component of wastewater technology decisions prevents the acceptance and widespread use of non-conventional technologies, like the SAS technology.

Engineers

Just as communities deciding on wastewater treatment technology do not want to take chances, wastewater engineers also tend to be conservative. Many wastewater engineers also are not familiar with many alternative technologies. Because engineers are often conservative and/or uninformed, when communities hire engineering consultants to assess their wastewater treatment options, they may not be presented with the options of alternative, innovative technologies.

Public Funding

The current method of public funding for wastewater treatment facilities dissuades communities from choosing alternative technologies like the SAS. Since almost all communities rely on financial assistance from their state to build municipal treatment facilities through the State Revolving Loan Fund (SRF) program, a program of state-managed loans for water treatment projects, a community's decision to choose a particular wastewater technology must be approved by someone at the state level other than the agency issuing the permit [11]. Because the federal funding for the SRF program is not sufficient to finance all projects that are proposed to the state, the state must select the specific proposals which are either the most urgent or the ones that seem the most reliable. Since the SAS has no history of proven operational reliability, a community's proposal to build a SAS may appear less worthy than a proposal endorsing a conventional system with a long history of operations. Thus, even though data show that SAS facilities will receive a permit from the state, a community proposing to build a SAS wastewater treatment facility may be less likely to get the funding necessary than if it proposed a conventional system.

RECOMMENDATIONS FOR ACCELERATING THE ADOPTION OF INNOVATIVE ENVIRONMENTAL TECHNOLOGIES

Four recommendations for accelerating technology adoption and increasing the rate of acceptance and use of the SAS technology conclude this article. These recommendations may also be applied more generally to the promotion of other innovative environmental technologies, assuming efficacy of these new technologies has been demonstrated..

The first recommendation is to emphasize the manifest, tangible, environmental aesthetic values of the technology in an effort to target promotion efforts to those customers most likely to try it. The pleasant, odorless environment inside the SAS greenhouse should be a central focus of advertising and promotion efforts. Advantages to the community of having a pleasant wastewater treatment system that people will want to visit should be demonstrated. This focused promotion will capture the attention of communities who might place a high value on the environmental aesthetics of their wastewater treatment system. By focusing promotion efforts on such tangible environmental benefits of the technology, communities and engineers will be less skeptical of the technology because the intangible, unproven environmental benefits will not be foremost in their consideration.

The second recommendation is to standardize the design of the system to reduce the costs of design. The current high cost of design for an SAS facility has significantly increased the total capital costs of construction. In most cases, a community that wants to build an SAS facility must be prepared to pay significantly more for it than they would for a conventional system. If a standardized design of the SAS could be developed, design costs may well decrease so an SAS facility could be a cost-effective for communities.

The third recommendation is to increase marketing and promotion efforts through wastewater engineering firms, and to increase efforts to make communities more aware of innovative designs. As noted, many environmental engineering consulting firms that are hired by communities to assess wastewater treatment technology options are unaware of the option of the SAS technology and other innovative alternatives.

Finally, public education efforts to encourage general interest in ecological principles would increase the perceived value of the environmental and ecological benefits associated with innovative environmental technologies. If the value of these environmental benefits were higher, the incentives for using an innovative environmental technology in a place of a conventional technology would increase correspondingly. The inherent difficulty in economically quantifying environmental benefits associated with any pollution control effort is a well-acknowledged characteristic of market systems [12] and perhaps nonmarket systems as well. In order for engineers and communities to justify the often higher costs of environmental technologies, therefore, the environmental and ecological benefits must hold a high value. An increase in general ecological education may help the public assess the value of the environmental benefits associated with innovative environmental technologies.

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REFERENCES

1. Ecological Engineering Associates (EEA), *General Informational Packet*, 13 Marconi Lane, Marion, MA 02738. 1996a.
2. Ecological Engineering Associates (EEA), *Narrative Description of the Solar Aquatic Process*, Informational Handout, 13 Marconi Lane, Marion, MA 02738. 1996b.
3. S. Peterson and B. Strong, Ecological Engineering for Wastewater Treatment, *US Water News*, p. 7, April 1993.
4. G. MacStephen, Natural Systems Specialist, Icon Systems Limited. 45 Green Belt Drive, Don Mills, Ontario, Canada M3C 3K3, personal communication, November 7, 1996.
5. K. R. Imhoff, M. Olthof, and P. A. Krenkel, *Karl Imhoff's Handbook of Drainage and Wastewater Disposal*, John Wiley & Sons, New York, 1989.
6. M. Farrell, Purifying Wastewater in Greenhouses, *BioCycle, 37*:1, p. 30, January 1996.
7. L. Leue, Facility Operator, Ashfield Solar Aquatic Sewage Treatment Facility, Ashfield, Massachusetts, personal communication, November 1, 1996.
8. C. Armstrong, Facility Operator, Bear River Solar Aquatic Wastewater Treatment Facility, Bear River, Nova Scotia, personal communication, November 20, 1996.
9. P. Levy, Adjunct Professor of Environmental Policy and Urban Planning, Department of Urban Studies and Planning, Massachusetts Institute of Technology. Cambridge, MA 02139-4307, personal communication, November 14, 1996.

10. K. J. Kornegay, Environmental Engineer, Parsons Engineering Science, Inc., 10521 Rosehaven Street, Fairhaven, VA 22030, personal communication, November 12, November 26, and December 2, 1996.
11. G. Gilmore, Municipal Assistance, Massachusetts Department of Environmental Protection, 1 Winter Street, Boston, MA 02108, personal communication, November 18, 1996.
12. Doctor R. Stavins, Professor of Environmental Economics, J.F.K. School of Government, 79 J.F. Kennedy Street, Cambridge, MA 02138, personal communication, March 17, 1997.

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