ALGAL TURF SCRUBBER TECHNOLOGY AND PILOT PROJECTS IN THE REGION

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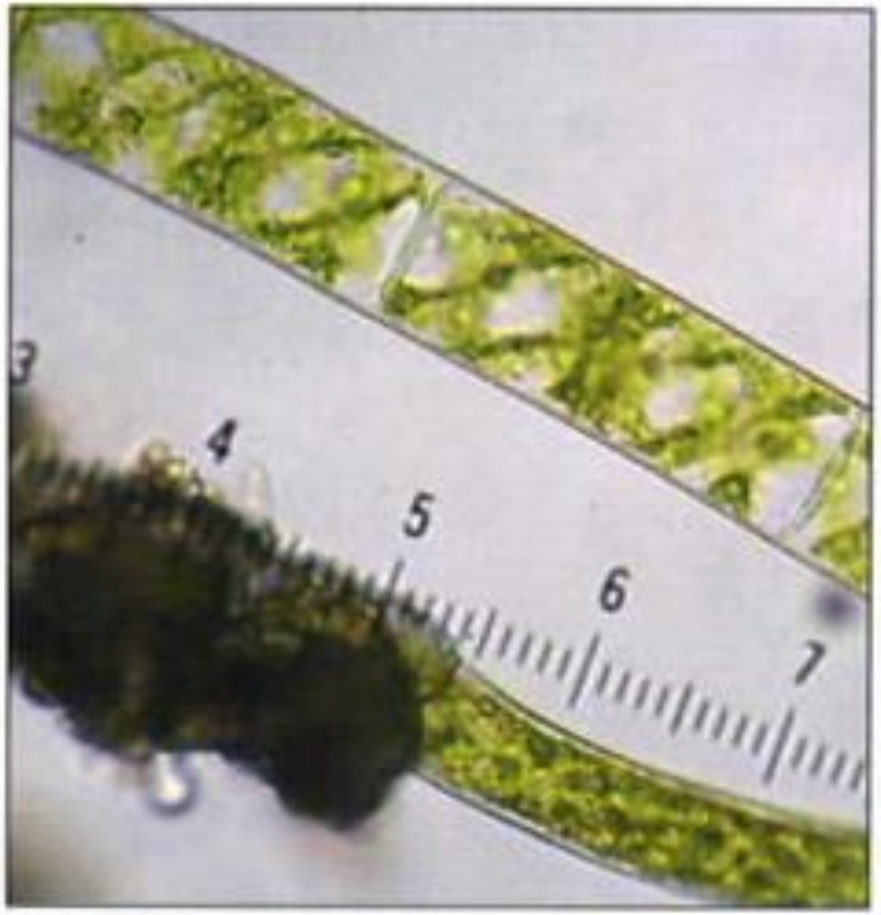
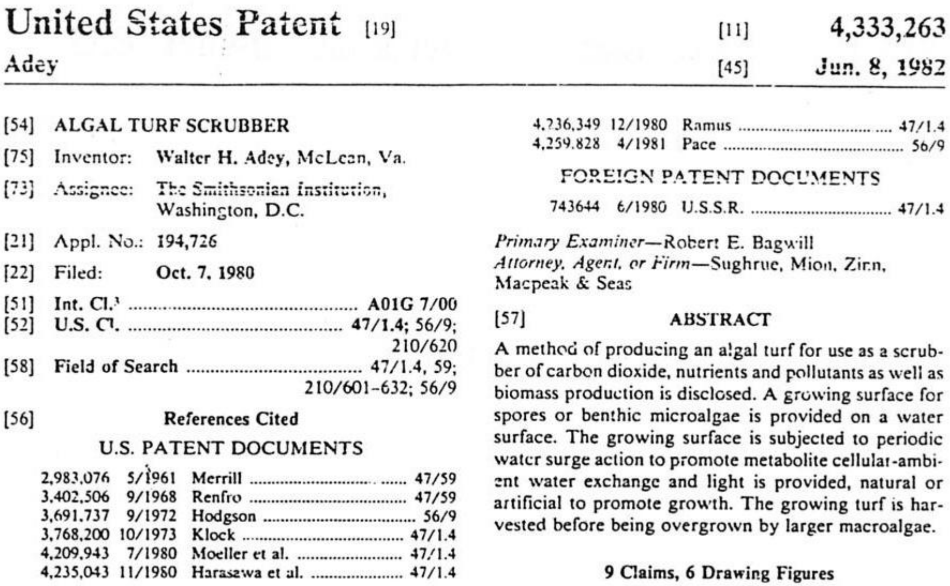
Algae are fast-growing, photosynthetic microorganisms that absorb nutrients and produce valuable biochemical byproducts. . .



In this presentation a technology is described that utilizes the controlled growth of algae as the driving force for a best management practice…



United States Patent [19]
Adey
[11] 4,333,263
[45] Jun. 8, 1982

[54] ALGAL TURF SCRUBBER
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[73] Assignee: The Smithsonian Institution, Washington, D.C.
[21] Appl. No.: 194,726
[22] Filed: Oct. 7, 1980
[51] Int. Cl.^{3} A01G 7/00
[52] U.S. Cl. 47/1.4; 56/9; 210/620
[58] Field of Search 47/1.4, 59; 210/601–632; 56/9

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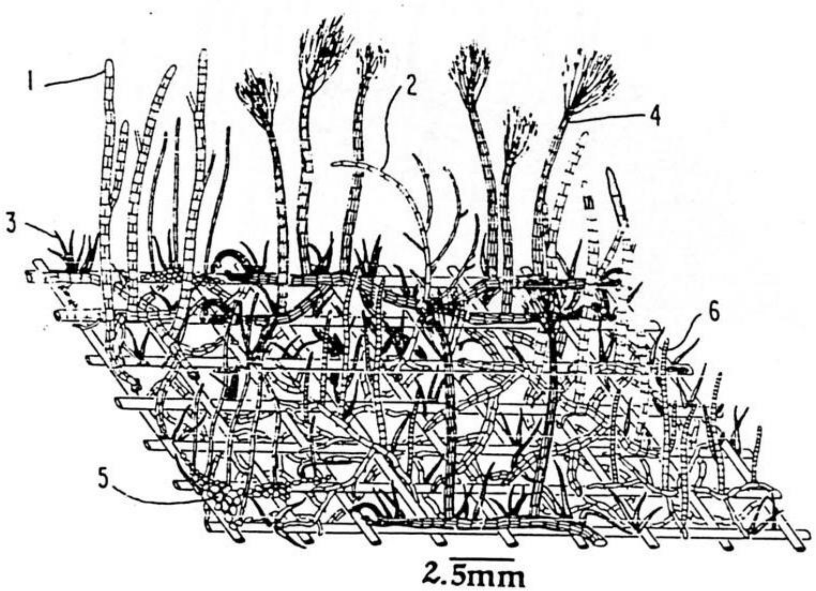
Primary Examiner—Robert E. Bagwill
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas

[57] ABSTRACT

A method of producing an algal turf for use as a scrubber of carbon dioxide, nutrients and pollutants as well as biomass production is disclosed. A growing surface for spores or benthic microalgae is provided on a water surface. The growing surface is subjected to periodic water surge action to promote metabolite cellular-ambient water exchange and light is provided, natural or artificial to promote growth. The growing turf is harvested before being overgrown by larger macroalgae.

9 Claims, 6 Drawing Figures

Our work focuses on a patented technology, the algal turf scrubber, that has proven to be reliable and effective as a tool for nutrient removal from a waterbody.



The algal turf scrubber (ATS) utilizes native algae that grow attached to a screen in a shallow, flowing water system.

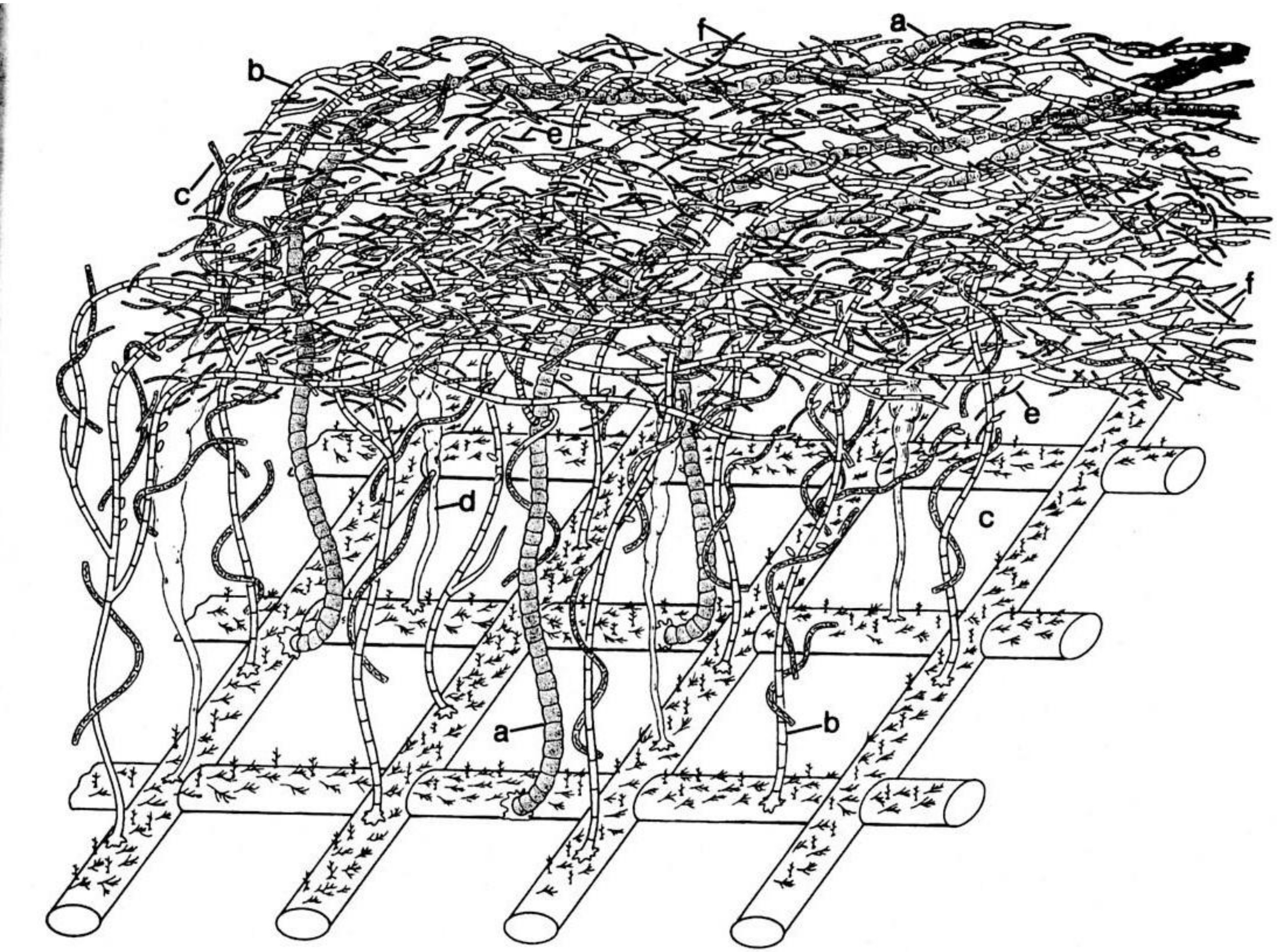


FIGURE 25.7 Schematic drawing of primary algal turf species growing on the ATS screen of the Florida Everglades study: (a) *Compsopogon coeruleus*, (b) *Cladophora crispata*, (c) *Spirogyra rivularis*, (d) *Enteromorpha microocca*, (e) *Eunotia pectinalis*, (f) *Melosira varians*. The very small branched alga attached directly to the screen is *Stigeoclonium tenue*, while the numerous small ovoid shapes in the algal canopy represent several species of small pennate diatoms, particularly *Amphora* and *Cocconeis* spp. Drawing by Alice Tangerini, Department of Botany, National Museum of Natural History. From Adey *et al.* (1993).

This technology contrasts with most algal growth systems that utilize suspended algae instead of attached algae. One advantage of the ATS is that attached algae are easier to harvest than suspended algae.

Eutrophication in the Chesapeake Bay is associated with out-of-control algal growth. However, the algal turf scrubber technology relies on controlled algal growth!

FROM OUR WEB SITE

Algae blooms in the Inner Harbor and beyond

B'MORE GREEN

Timothy B. Wheeler

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It isn't just Baltimore's Inner Harbor that's been plagued lately with fish-killing algae blooms. Scientists with the Department of Natural Resources say they've been seeing "extensive algal blooms" this month across Maryland's portion of the Chesapeake Bay.

The scientists say they've detected high concentrations of *Prorocentrum minimum*, a type of algae with little whiplike arms that enable it to move in the water.

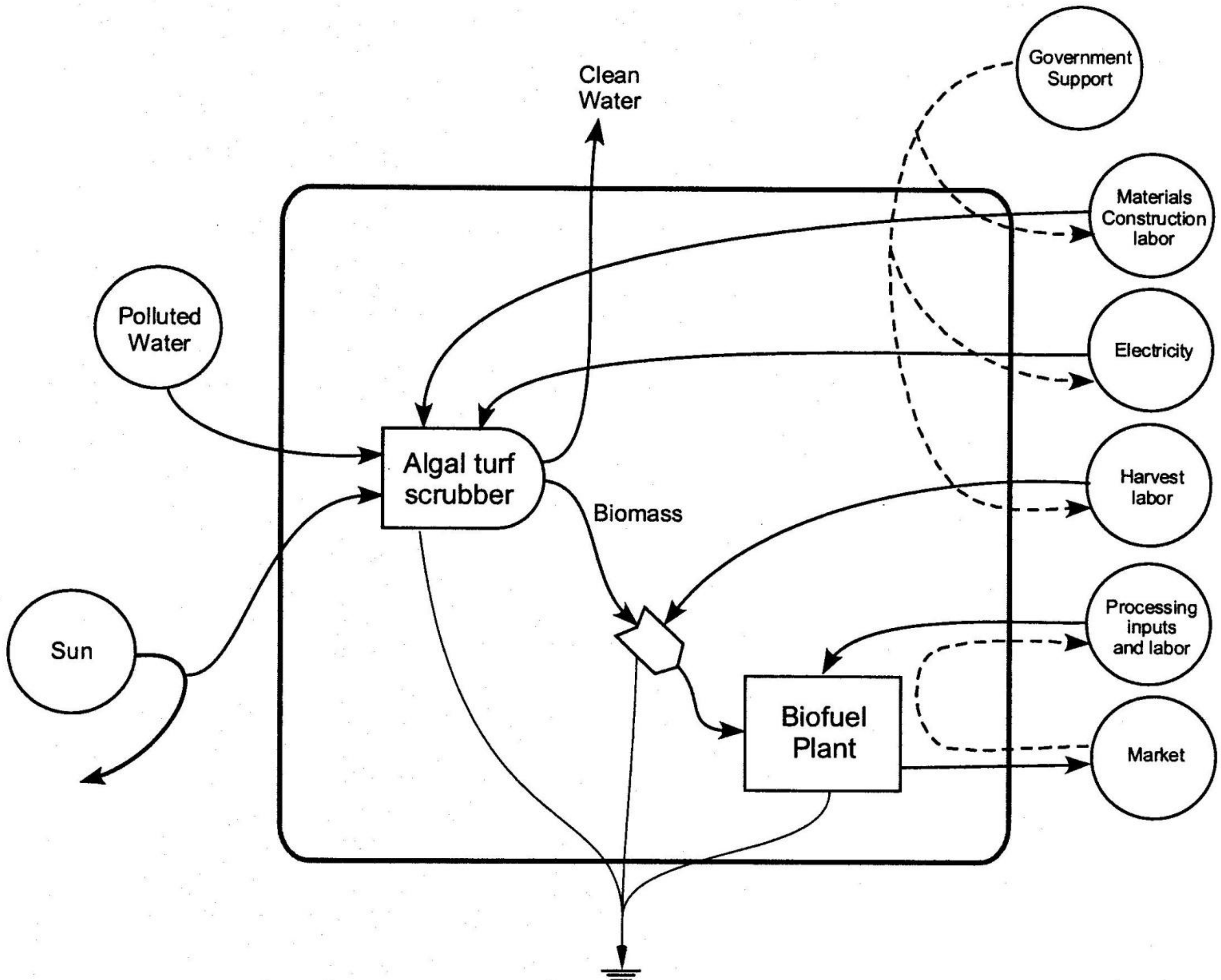
Scientists say this year's big blooms, covering vast stretches of the bay, likely have been sparked by unusually heavy runoff of fertilizer and other nutrients during the wet spring. Though generally considered not toxic, these blooms can kill fish by consuming all the oxygen in the water when they die and decay. It's the same type of algae found in the harbor recently, along with more than 3,000 dead fish, mostly menhaden.

Such blooms also can stunt the growth of beneficial bay grasses, discoloring the water and blocking out sunlight needed by vegetation. A similar surge in 2000 led to a die-back of bay grasses in the mid-bay, according to the DNR. The grasses are important shelter for crabs and fish, and they're considered a basic indicator of the bay's health.

Prorecentrum blooms tend to dissipate after May, so DNR scientists say. A map showing where algal blooms have been spotted so far this year around the bay can be found at http://mddnr.chesapeakebay.net/hab/HAB_maps.cfm.

The ATS technology has been implemented at the large scale in Florida and Texas and we are now hoping to scale-up from experimental studies that have been conducted throughout the Chesapeake Bay watershed…

We envision the algal turf scrubber as the basis of a green economy that cleans polluted water and provides a valuable byproduct that can be used as a feedstock for biofuels or for other useful products.



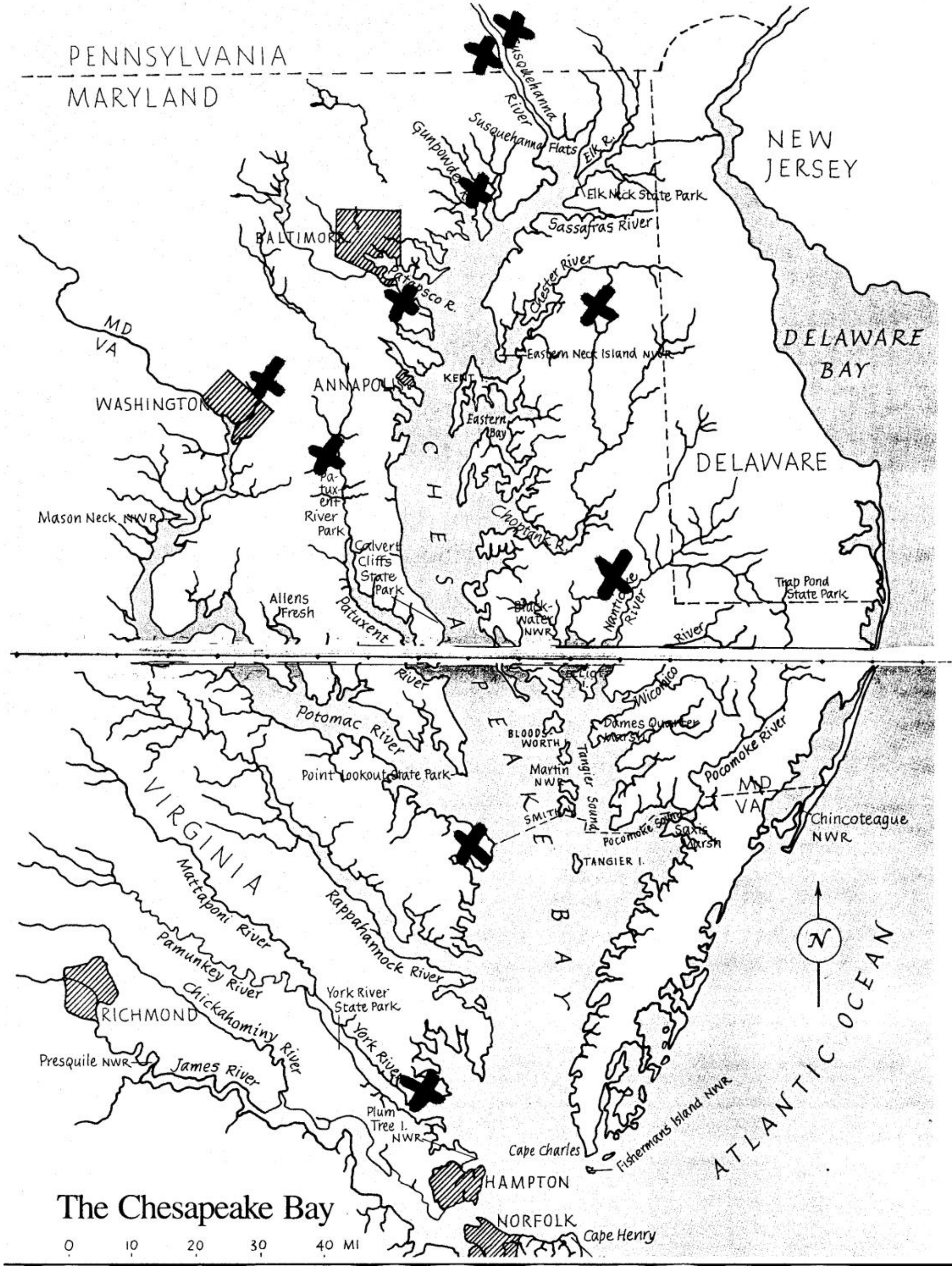
Nutrient removal by the algal turf scrubber is calculated as follows:

Nutrient removal rate = biomass production rate x nutrient content of biomass

grams nutrient/m2/day   grams dry weight/m2/day   grams nutrient/grams dry weight

Typical biomass production rates range from 5 – 30 grams dry weight/m2/day and typical nutrient contents are 3-5% nitrogen and 0.3-0.5% phosphorus.

We’ve operated experimental algal turf scrubbers all around the bay as noted on the map to the right. Data has been gathered at least over an annual cycle at each of these sites.



Walter Mulbry of USDA has operated scrubbers for more than a decade…

Walter's original work focused on dairy wastewaters.

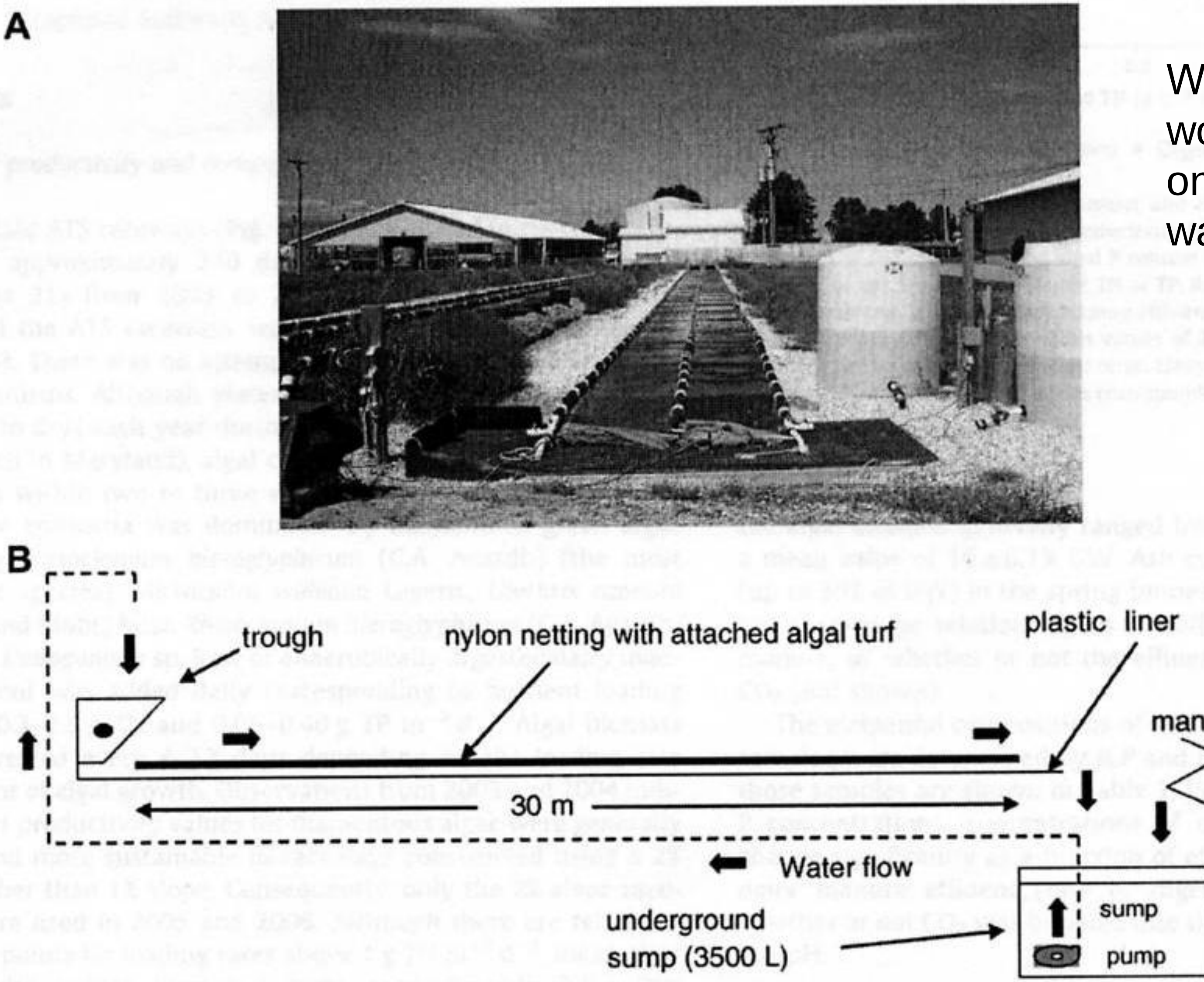


Fig. 1. Photograph (panel A) and schematic drawing (panel B) of pilot-scale raceways at the Dairy Research Unit in Beltsville, Maryland. Each raceway is 1 m in width, 30 m in length, and has a water depth of 1–3 cm. Two raceways (left of center in panel A) were constructed at a 1% slope and two raceways (center in panel A) were constructed at a 2% slope. Raceway effluents (approximately 3500 L for each raceway) are contained in four separate underground concrete tanks covered by plastic grating (foreground in panel A) and are continuously recycled from the sumps to the top of the raceways using four separate sump pumps at a flow rate of 93 L min^{-1}. A trough at the top of each raceway fills and tips over, releasing pulses of effluent that wash over the attached algal turf every 8–15 s before draining into the concrete sump at the base of the raceway. Raw or anaerobically digested dairy manure effluent (20–60 L d^{-1}) is added daily to the recirculating scrubber effluent of each raceway. Water from adjacent storage tanks is added only when rainwater is inadequate to replenish water lost to evaporation.

Variation in algal biomass productivity running on dairy wastewater…

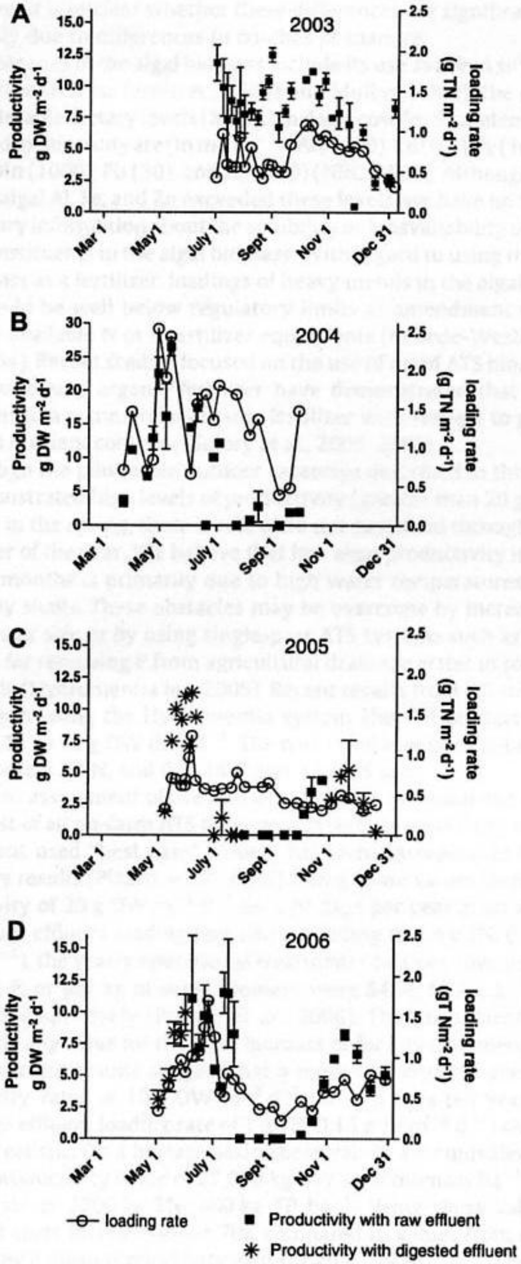


Fig. 4. Algal productivity and manure effluent loading rates from 2003 to 2006. Algal productivity values (g DW m^{-2} d^{-1}) are averages for 2–4 raceways using raw or anaerobically digested dairy manure effluents. Note that the scale of the right side *y*-axis in panel B is different than in panels A, C, and D. Error bars are standard error.

Some of the experimental ATS were small scale. This system was located on the Patuxent River.

The small scale systems were one square meter in area…

Data from the small scale systems was similar to the larger systems.

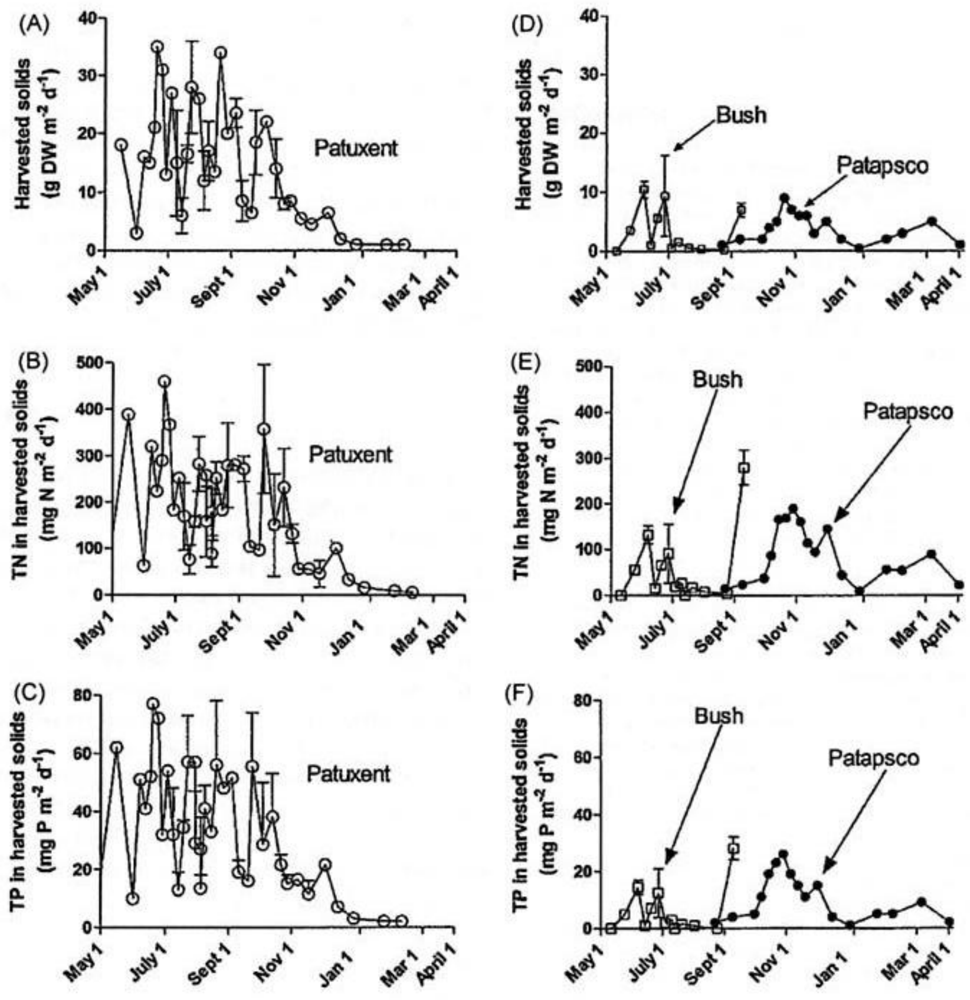


Fig. 4. Harvested solids and nutrient removal rates from ATS units at three river sites during May 2006 to April 2007. Values are from a single ATS unit (Patapsco site) or are average values from two units (Patuxent and Bush River sites). Error bars are standard error.

From the spring of 2008 to the fall of 2009 the algal turf scrubber technology was tested at Exelon's Muddy Run hydroelectric facility.

Two experimental ATS were constructed and operated at Muddy Run. Each raceway was 300 feet long and 1 foot wide. One raceway had a 2% slope and the other had a 1% slope. These systems were operated from 2008 to 2009.

The algal growth in these raceways was studied to gather information for optimizing the design of large scale ATS.

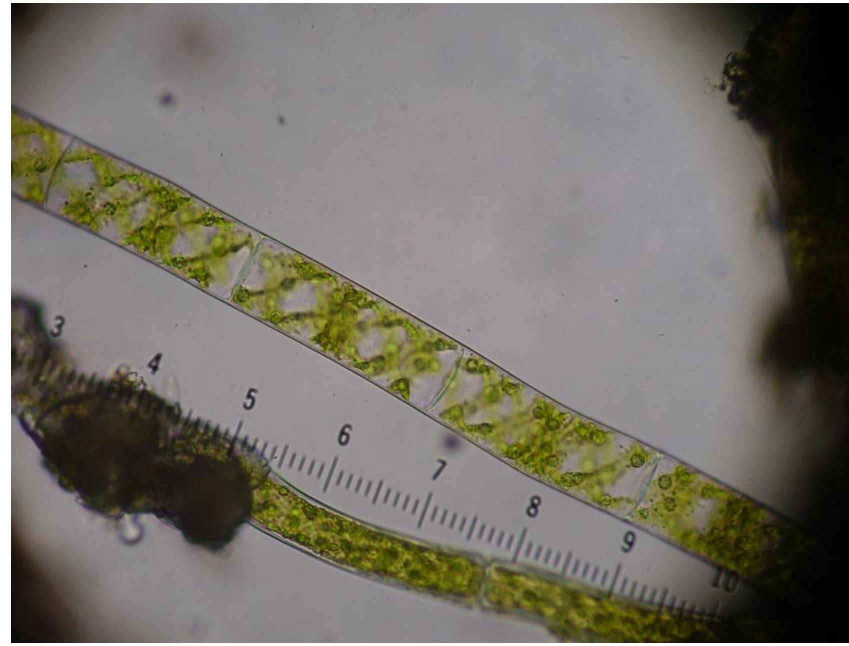
To harvest algae, the water flow was stopped and the system was allowed to drain. Then algae was harvested with a shop vac.

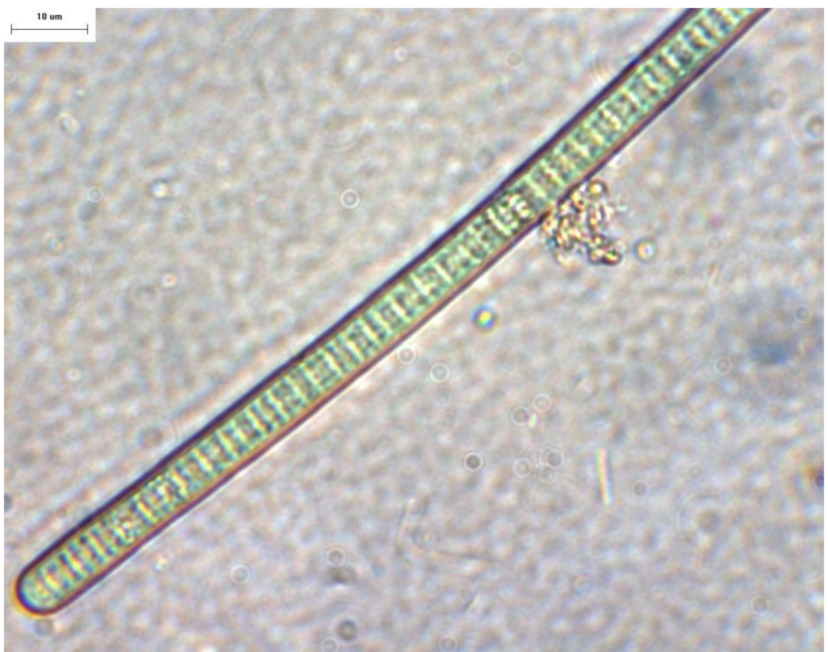
Table 2a. Biomass production of the Aluminum ATS at 2% slope. Data are grams dry weight/m2/day. Numbers in parentheses are the months included in the seasons.

Season	vacuum harvest	greenwater	slough	total
Summer 2008 (6-8)	14.2	2.4	1.4	18.0
Fall 2008 (9-11)	6.2	4.2	0.5	10.9
Winter 2008-2009 (12-3)	---	---	---	---
Spring 2009 (4-5)	4.0	8.6	0.7	13.3
Summer 2009 (6-7)	11.6	4.6	1.4	17.6
Fall 2009* (8-10)	6.6	6.3	0.7	13.6
Growing Season Averages (fall 08-summer 09)	7.3 (52%)	5.8 (42%)	0.9 (6%)	14.0

* at 0.5% slope

The productivity of the ATS raceways at Muddy Run was high, compared to natural ecosystems, but algal growth was limited by low temperatures in the winter months.





Common algae from Muddy Run, PA

Table . Comparison of growing season productivities for the ATS systems at Muddy Run and various natural aquatic plant communities of the Chesapeake Bay. Data for natural communities have been converted from various units to grams dry weight/m2/day, according to the footnotes given at the bottom of the table.

Plant community type	Net productivity	Reference
Aluminum ATS at Muddy Run	14.0	this study
Wooden ATS at Muddy Run	11.7	this study
Submerged aquatic vegetation*	2– 8	Stevenson 1988
Emergent marshes**	11.3	Wass and Wright 1969
	8.8	Johnson 1970
	4.9	Cahoon 1975
	3.1	Turner 1976
Phytoplankton***	2.5	Selner and Kachur 1987
	2.0	Boynton et al. 1982
	1.5	Harding et al. 1999

* calculated assuming dry weight is 50% carbon.

** calculated assuming that annual belowground net production equals annual aboveground net production and assuming a 9 month growing season.

*** calculated assuming dry weight is 50% carbon.

A number of recent studies have been conducted at the Virginia Institute of Marine Science in the lower Bay…

Data from the VIMS ATS systems indicates higher productivities than found in the more northern portions of the Bay…

Algal species composition varies along the salinity gradient of the Bay. This species of diatom is common in brackish water but absent in freshwaters.

Our largest experimental system is located on Maryland's Eastern Shore in a farm setting. Our challenge here has been to run the pumps on solar power…

Work on the Eastern Shore has demonstrated harvest techniques at a larger scale than most of our experimental systems…

We hope the algal turf scrubber represents a new BMP that can compliment the existing conservation tools available to farmers for nutrient removal…

MARYLAND

Research, Education, Outreach *May-June 1997*

MARINE NOTES

SPOTLIGHT ON RESEARCH

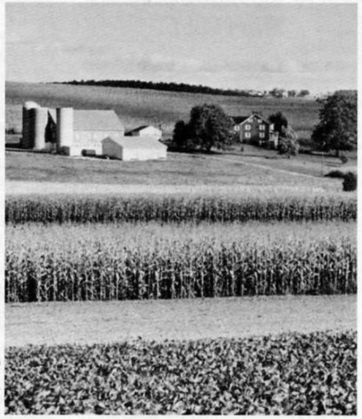
Smart Farming for a Cleaner Bay

By Merrill Leffler

Researchers have been trying to determine the most effective practices for keeping fertilizers on farms and out of surface and groundwater

"With cover crops and no-till farming, the Chesapeake Bay Program could meet its goal of reducing nitrogen 40 percent by the year 2000," says Russ Brinsfield.

A bold assertion from the director of the University System of Maryland's Wye Research and Education Center but one that is based on nearly a decade of research on test plots and demonstration farms.



Kathy Gugulis

While nutrient runoff from suburban development of once-rural areas is on the rise and presents an increasing challenge, farming still accounts for the largest use of land in Maryland. Farm acreage in the state dropped nearly 40 percent between 1965 and 1996 — nevertheless, more than two million acres, over 3,000 square miles, are still in agriculture.

Because the application of fertilizers and manure in regions of intensive farming threaten nitrate contamination in groundwater and phosphorus build-up in soils, researchers at the Wye have been trying to determine the most effective practices for keeping fertilizers on farms and out of surface and groundwater.

Though nitrogen and phosphorus are key to the Bay's rich productivity — they stimulate algal growth at the base of a bountiful estuarine food chain — their massive runoff from the land has also been key to the Bay's decline.

In a pattern that has become common to many coastal waters, nutrient overloading leads to algal growth far greater than a more balanced food web can assimilate. In early spring and summer, blooms of algae will blanket surface waters, choking off light below. As unconsumed algae decompose and rain down onto sediments below, they deplete oxygen in bottom waters — the observable effects can become evident in the loss of underwater vegetation, in fish kills and in the death of bottom-dwelling organisms such as oysters and mussels.

While some farms drain directly into the Bay's main stem, many more border the river and stream systems that eventually empty into the Bay.

To reach the Bay Program's 40 percent reduction goal and maintain it at those levels in the years ahead means stemming nutrient runoff from these systems — for example, from the Potomac and Patuxent watersheds on the western shore, and the Choptank and Nanticoke watersheds on the Eastern Shore. Stemming nutrient flow into the rivers depends on curbing runoff to hundreds of feeder creeks and streams.