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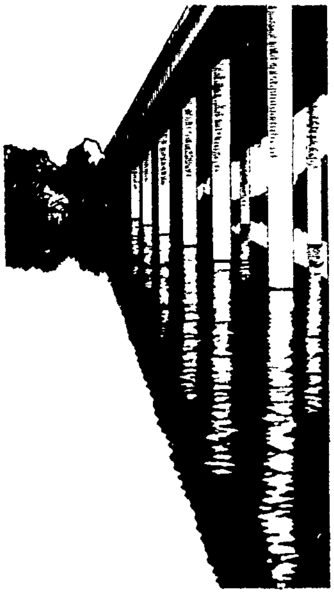

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EVALUATION OF FACTORS INFLUENCING GAS EVOLUTION BENEATH BENTHIC BARRIERS

by

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Environmental Laboratory

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Laboratory studies were conducted to determine the role of temperature, sediment type, and organic matter source and content in controlling the rate of gas evolution beneath a benthic barrier. An initial study incorporated two sediments; Brown's Lake sediment (BLS), which is predominantly clay, and washed masonry sand containing 25 percent BLS (sand). The sediments (with and without organic matter amendment) were incubated at 15° and 30° C. A second study was conducted to compare gas evolution rates from BLS amended with organic matter from different sources (coontail, water hyacinth, cattail, oak leaves, and pine needles). A third study was conducted to examine the effect of organic matter on gas evolution rate. Results revealed pronounced differences in gas release rates from sediments related to organic matter source and content, and incubation temperature. When specific gas content was monitored, the composition of the releases proved remarkably similar for all of the treatment combinations. Implications of these studies for use of barriers for control of nuisance aquatic plants are discussed.

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Benthic barrier
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Cattail
Coontail
Decomposition
Gas evolution
Gas formation
Iron oxyhydroxide
Methane
Nitrogen
Oak leaves
Organic matter
Oxygen
Pine needles
Water hyacinth

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PREFACE

The study reported herein was sponsored by the Headquarters, US Army Corps of Engineers (HQUSACE), Directorate of Civil Works (DAEN-CW), through the Aquatic Plant Control Research Program (APCRP). Funds were provided by DAEN-CW under Department of the Army Appropriation No. 96X3122, Construction General. Technical Monitor for HQUSACE was Mr. James W. Wolcott. The APCRP is managed by the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS under the Environmental Resources Research and Assistance Program (ERRAP), Mr. J. Lewis Decell, Manager. Mr. Robert C. Gunkel was Assistant Manager, ERRAP, for the APCRP. This investigation was performed under the general supervision of Dr. John Harrison, Chief, Environmental Laboratory (EL), WES, and Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division, and under the direct supervision of Dr. Thomas L. Hart, Chief, Aquatic Processes and Effects Group.

Principal investigators for this study were Drs. Douglas Gunnison and John W. Barko, EL, WES. The report was prepared by Dr. Gunnison. Ms. Dwilette G. McFarland and Mr. Harry L. Eakin assisted in the experimental design and conduct of these studies. Laboratory work was performed by Mses. Wanda Dee, Monica Humphrey, Debra Northam, and Cynthia B. Price. Ms. Gail Bird performed laboratory analyses. Reviews of this report were provided by Drs. James M. Brannon, Judith Pennington, and Craig S. Smith, of the EL. The report was edited by Ms. Janean Shirley of the WES Information Technology Laboratory.

Commander and Director of WES during the conduct of the study and preparation of this report was COL Larry B. Fulton, EN. Dr. Robert W. Whalin was Technical Director.

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CONTENTS

EVALUATION OF FACTORS INFLUENCING GAS EVOLUTION BENEATH BENTHIC BARRIERS

PART I: INTRODUCTION

1. Benthic application of barrier fabrics provides a means to physically limit nuisance growths of aquatic plants (Mayer 1978; Perkins, Boston, and Curren 1979; Lewis, Wile, and Painter 1983; Cooke 1986). Benthic barriers afford an attractive alternative to many other types of control, because they can be deployed once and left in place for several growing seasons, thus eliminating the need for repetitive treatment efforts. Moreover, because they are relatively easy to use, benthic barriers can be installed without certification or complex equipment and with very limited training of personnel (Pullman 1990). However, benthic barriers cannot be advocated for widespread field use, until their effectiveness is established.

2. A specific concern is the potentially adverse effect of gas production following placement. Existing barrier fabrics are reported to differ extensively in immediate and long-term permeabilities to gas transmission (Pullman 1990). Permeability is essential to prevent pockets of gas from buoying the barrier fabric up to the water surface, where wind and wave action can cause displacement.

3. A previous field study was conducted in 1988 at Eau Galle Reservoir, Spring Valley, WI, to evaluate the extent of gas evolution from sediment beneath benthic barriers. Benthic barrier mats (Dow Bottom Line^{TM}), equipped with systems to collect gases, were deployed in late summer at both vegetated and unvegetated sites. While barrier mats were weighted down with bricks, they were not staked in place, as is the currently recommended practice.* Barriers placed at the vegetated site billowed up noticeably within the first 3 days (Gunnison and Barko 1989, 1990). In contrast, gas collection systems at the unvegetated sites contained no visible gas after 3 days and only insignificant amounts when the barriers were finally removed at 8 weeks. These results indicated a need for the determination of specific factors controlling the rates of gas evolution beneath barrier fabrics.

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* Personal Communication, 15 March 1989, John E. Plott, Marketing Development, Dow-Corning Corporation, Midland, MI.

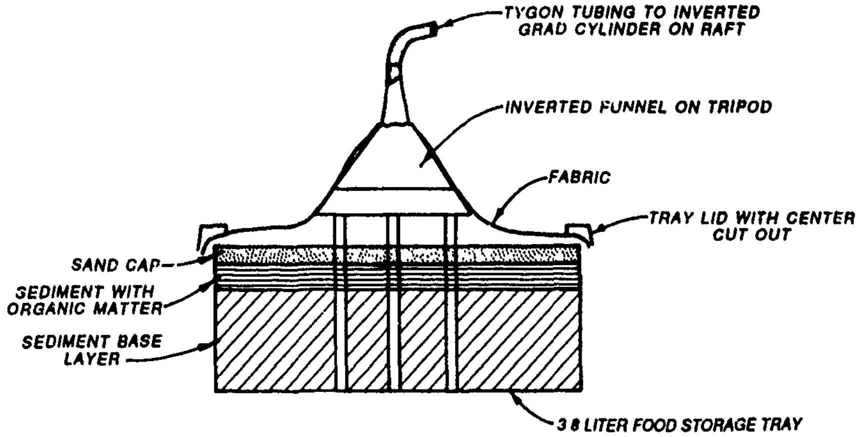
4. Since gas evolution rates from sediments are difficult to examine in the field, a series of studies were conducted to evaluate the influence of potentially important factors and their interactions in affecting gas evolution rates beneath barrier fabric under controlled laboratory conditions. These factors included concentration and source of organic matter in sediment, sediment texture, and incubation temperature. Results of these laboratory investigations and their implications for benthic barrier applications in the field are reported here.

PART II: METHODS AND MATERIALS

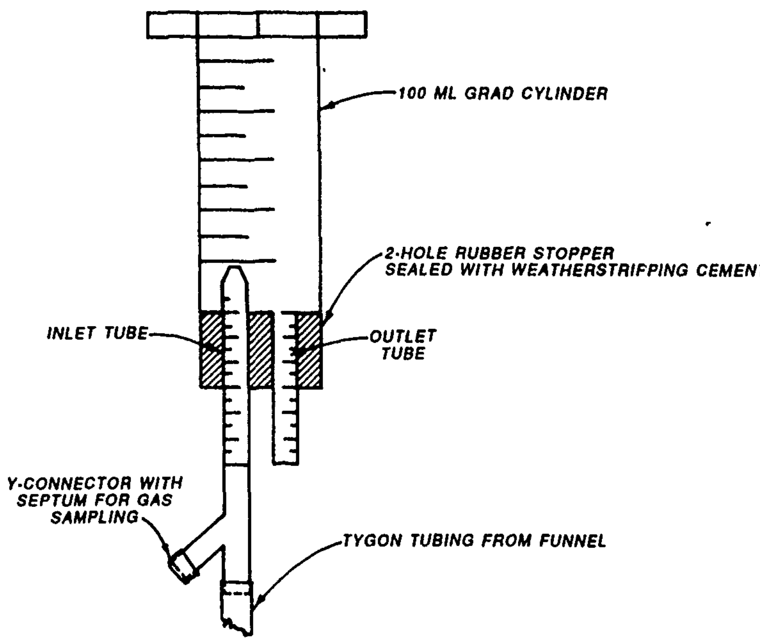
5. An initial study was conducted to determine whether sediment type alone, or in combination with added organic matter, affects gas evolution rates beneath a benthic barrier at different temperatures. Plastic containers (3.8 ℓ) were filled with either Brown's Lake sediment (BLS), which is predominantly clay, or a washed masonry sand intermixed with 25 percent (v/v) BLS (sand). Organic amendments consisted of 13 g of freeze-dried *Ceratophyllum* (coontail) intermixed with the upper 2 cm of sediment. Both amended and unamended sediments were then covered with 2 cm of washed masonry sand. Gases evolved from sediments under Bottom Line™ benthic barrier fabric (Dow Corning Corporation, Midland, MI) were captured by an inverted funnel under the fabric and held above the sediment surface on a tripod attached to the rim (Figure 1a). Containers and their fabric-and-funnel covers (collectively termed "flats") were placed on the bottom of water-filled tanks (1,200 ℓ) maintained at either 15° or 30° C. Four replicates of each sediment-organic matter treatment were prepared for incubation at each temperature. The funnel from each flat was attached to tubing that ran up to an inverted graduated cylinder designed to collect gases through water displacement (Figure 1b). Graduated cylinder traps were suspended from the water surface on a raft (Figure 1c) and monitored for gas accumulation over an 8-week period.

6. Gas evolution rates for individual treatments were determined by monitoring the volume of gas trapped in cylinders twice weekly. Once each week, gas samples were analyzed for composition on a Packard Model 419 Gas Chromatograph (Packard Instruments, Inc., Downers Grove, IL) equipped with an Alltech CRT-1 dual gas separation column (Alltech, Inc., Deerfield, IL) attached to a thermal conductivity detector. Helium was used as the carrier gas under ambient temperature conditions at a flow rate of 60 ml/min.

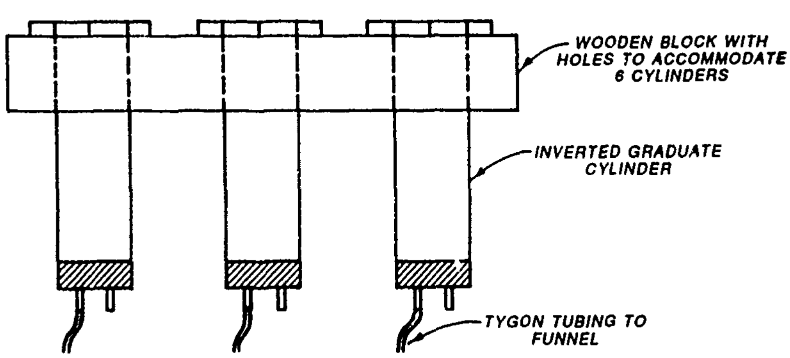
7. A second study was conducted to determine the effect of the organic matter source on the rate of gas released from sediment beneath a benthic barrier. The same procedures used in the previous study were employed, except for the following: only BLS sediment was used; the temperature was maintained at 30 °C only; and changes in gas composition were not determined. Treatments consisted of separate additions of 13.0 g of each of the following dried, ground plant materials (No. 40 micron mesh): oak leaves, pine needles, cattail leaves, coontail, or water hyacinth. Control flats (no organic matter addition) were included for comparison, and all treatments were prepared in



a. Sediment tray, funnel, and barrier fabric trap on tripod



b. Inverted graduate cylinder with inlet and outlet devices



c. Support raft

Figure 1. Diagrams depicting major components of the sediment tray and trap system

quadruplicate. Flats were incubated for 10 weeks to allow time for extensive decomposition.

8. Another investigation was conducted to determine the effect of different levels of added vegetative organic matter to sediment on gas evolution beneath a benthic barrier. The procedures used were the same as described for the second study (above), except that only coontail was used. This material was added to the sediment at each of the following levels: 0.0, 0.13, 1.3, 13.0, and 130 g. Treatment levels were replicated twice, and duration of incubation for this study was 10 weeks.

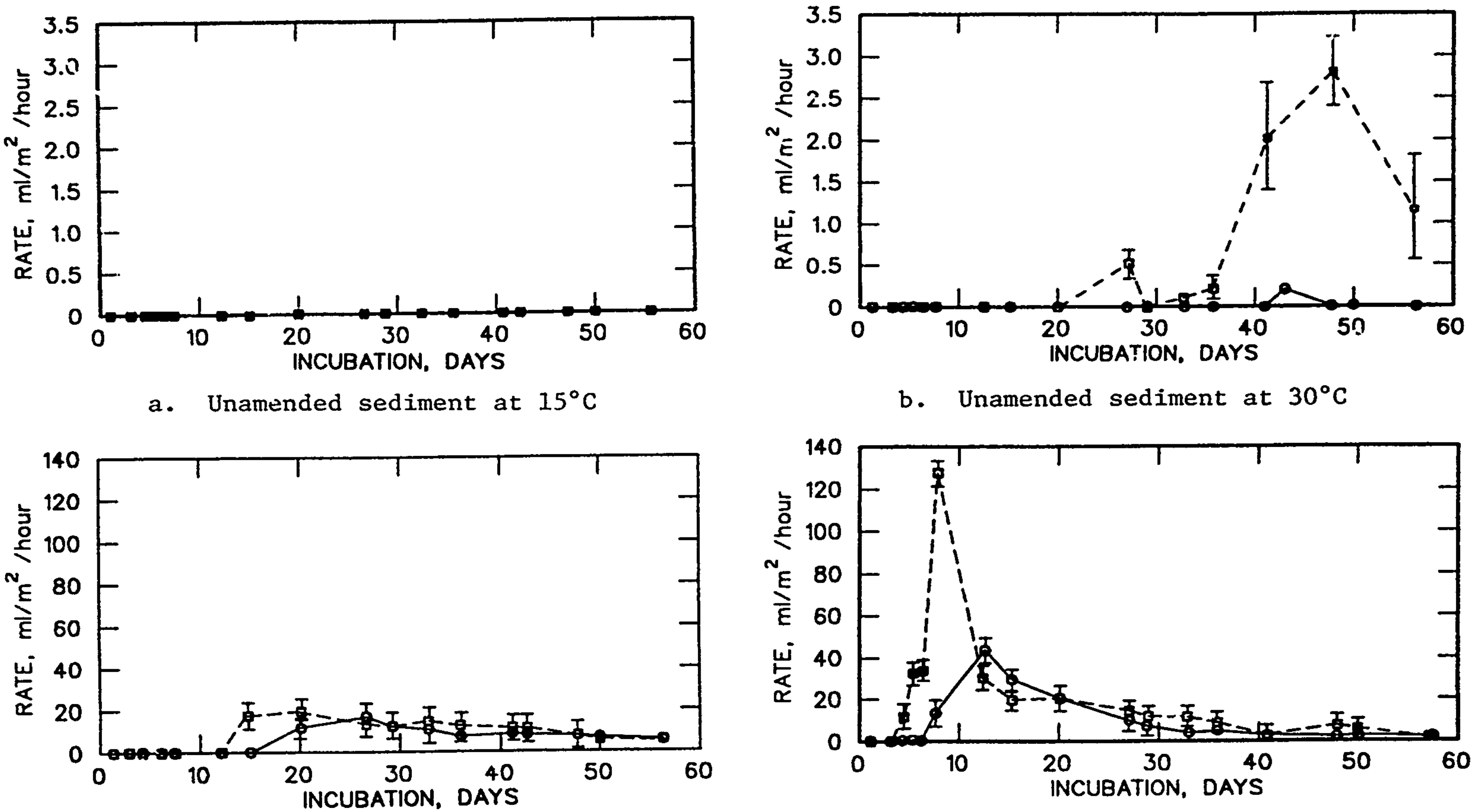
PART III: RESULTS

Effects of Sediment Type and Incubation Temperature

9. Figure 2 depicts the rates of gas release from different sediment types, with or without organic matter amendment at 15° and 30° C. Unamended sediments maintained at 15° C produced no gas (Figure 2a). Release of gas from unamended sediment consisting of sand held at 30° C was observed only at day 43 (Figure 2b). By contrast, unamended BLS sediments held at 30° C produced gas, albeit very erratically and at a low rate, from day 20 until approximately 47 days.

10. All sediments amended with plant material produced gas, but production rates differed significantly at different temperatures and with different sediment types. Amended sand incubated at 15° C had a very slow gas production rate, with the onset of gas release first becoming apparent at day 20, reaching a maximum at day 27, and then slowly declining (Figure 2c). BLS amended with plant material and held at 15° C also showed a low gas production rate, first becoming evident on day 15 and reaching a peak on day 20, then diminishing gradually thereafter (Figure 2c). Amended sand held at 30° C exhibited a moderate gas production rate, starting on the seventh day of incubation, peaking on the twelfth day, and then gradually declining to baseline levels by day 56 (Figure 2d). BLS with organic matter held at 30° C had the highest gas production rate of all combinations examined, with releases first appearing on day 3 and reaching a peak of 123 $ml/m^2/hr$ on day 7 (Figure 2d). Release rates fell markedly at first, then gradually, until the end of the incubation period.

11. Gas composition was essentially unaffected by treatments or incubation temperatures. Nitrogen made up the bulk of the gases obtained and ranged from 47.0 to 54.5 percent of the total gas production. Oxygen was even more consistent, comprising 13.3 to 15.2 percent of the total in treatments producing gas. The presence of oxygen in the flats was confirmed by the formation of an iron oxide coating observed on the sediment surface and on the inside face of the barrier fabric in those treatments containing an organic amendment. This coating forms when dissolved reduced iron, released by microbial reduction processes in sediment, oxidizes spontaneously in the presence of oxygen to form iron oxyhydroxides. Total gas was 2.8 to 3.8 percent



a. Unamended sediment at 15°C

b. Unamended sediment at 30°C

c. Amended sediment at 15°C

d. Amended sediment at 30°C

Figure 2. Gas evolution rates for BLS and sand sediments. Values given are the means of four replicates with bars showing standard error for each mean. Solid lines are sand. Dashed lines are BLS only

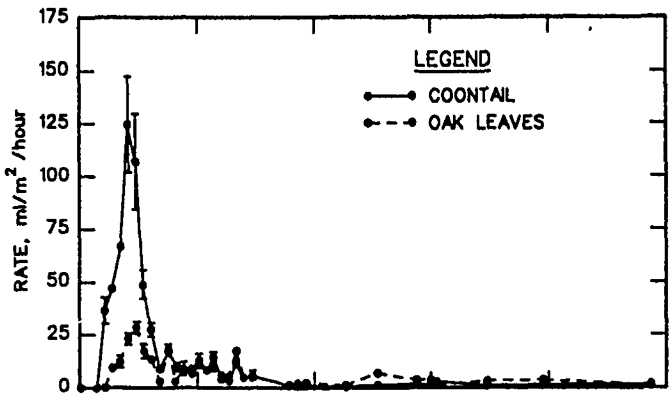
methane and 27.7 to 36.0 percent carbon dioxide. The ratio of carbon dioxide to methane was maintained at nearly 10:1 over the entire course of the incubation.

Effects of Organic Matter Source

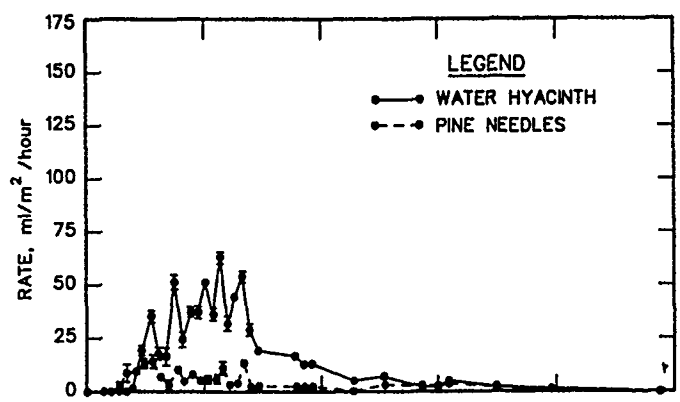
12. Gas releases were first evident in the coontail-amended sediment (Figure 3). This sediment also exhibited the highest gas production rates, reaching maximum levels in excess of 125 ml/m^2/hr (Figure 3a). The onset of gas release from coontail-amended sediment was closely followed by gas evolution from all other amended sediments (pine, hyacinth, and cattail). Hyacinth was second to coontail in gas production rate (Figure 3b). Gas release from cattail was longest of any treatment in period of gas release (about 65 days). Unamended sediment produced insignificant quantities of gas.

Effects of Organic Matter Level

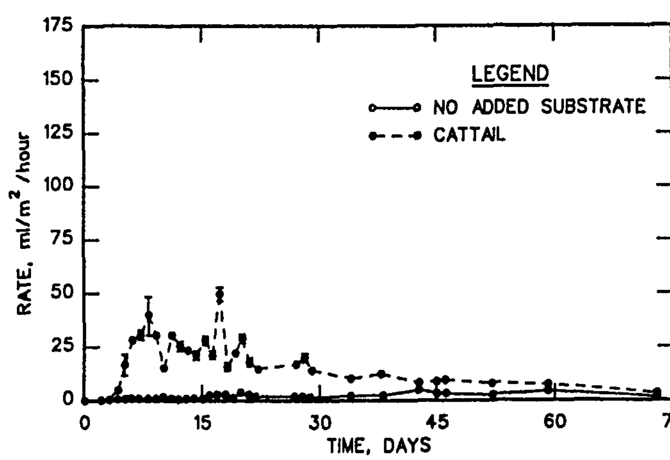
13. Control flats containing unamended BLS sediment initiated low-level gas production only after about 5 weeks of incubation; the maximum release rate achieved at 7 weeks was less than 4.0 ml/m^2/hr (Figure 4a). Flats containing sediment amended with 0.13 g of coontail demonstrated gas release rate patterns nearly identical to control flats; however, the peak release rate at 7 weeks of incubation was nearly double that of the control sediment. Sediment containing 1.3 g of coontail began releasing gas at the onset of incubation (Figure 4c). The initial peak at about 1 week was followed by a second peak at about 7 weeks. The maximum rate of gas release from sediment treated with 13.0 g occurred 1 week following initiation of incubation and then declined sharply thereafter (Figure 4d). This maximum was nearly identical to that (125 ml/m^2/hr) observed for coontail in the earlier study (Figure 3a) at the same level of organic matter amendment. The maximum rate of gas release from sediment amended with 130 g of coontail (790 ml/m^2/hr) also occurred after only 1 week of incubation. The broad-shouldered release peak showed little decrease from the initial maximum value until about the third week of incubation, after which the decline was somewhat more rapid (Figure 4e). Rates of gas release for amendments between 1.3 and 130 g increased in an approximately linear fashion with the mass of organic matter addition.



a. Coontail or oak leaves

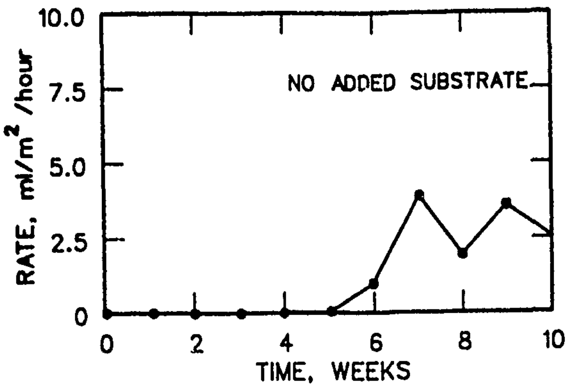


b. Water hyacinth or pine needles

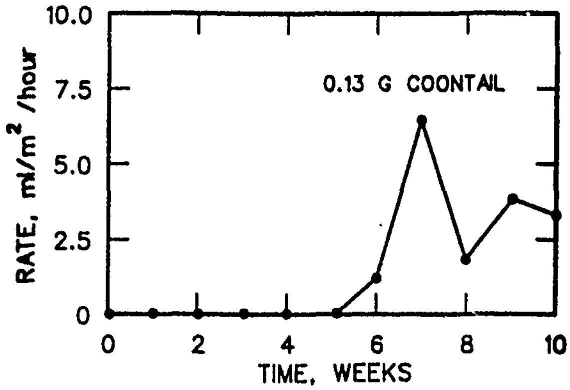


c. Cattail or no amendment

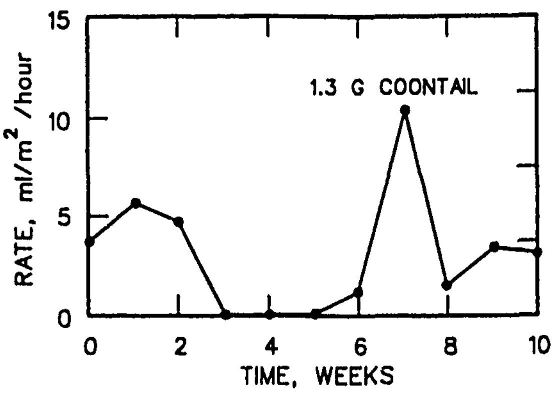
Figure 3. Gas evolution rates for BLS treated with organic matter from various sources. Sediments were incubated for 70 days at 30° C under water. Values presented are the means of four replicates with bars showing standard error for each mean



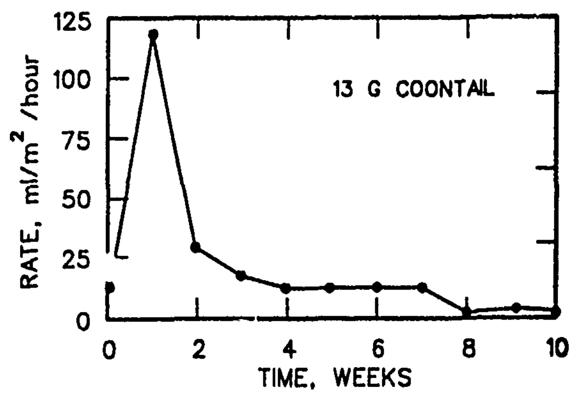
a. No added substrate



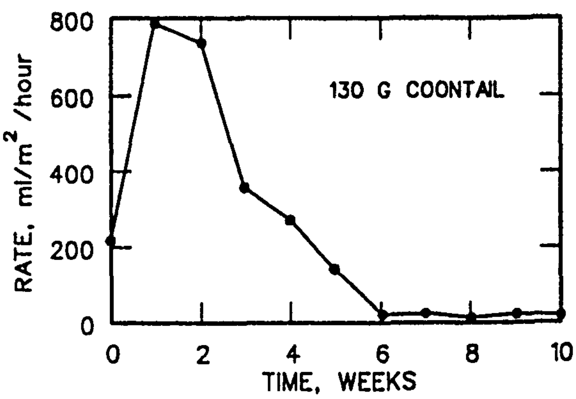
b. 0.13 g coontail



c. 1.3 g coontail



d. 13 g coontail



e. 130 g coontail

Figure 4. Gas evolution rates from BLS amended with varying levels of coontail. Sediments were incubated for 10 weeks at 30°C under water. Data points represent averaged values for two replicates over weekly intervals, with multiple determinations during each week

PART IV: DISCUSSION

14. Results obtained in these studies suggest that large volumes of gas released from organically enriched sediments can accumulate beneath benthic barriers. The rapid generation of gases apparently exceeds the diffusion rate of gases moving through the barrier fabric. Sediments amended with plant material produced gas at both 15° and 30° C. However, the incubation temperature played a crucial role in determining both the onset of gas formation and the gas production rate achieved. These results are consistent with those of Pederson and Saylor (1981) who found that temperature in combination with organic matter content accounted for 43 percent of the total variability in methane formation in freshwater sediments. Furthermore, gas formation is a reflection of degradational activity, which is temperature sensitive. Best et al. (1990) demonstrated that degradation of plant litter derived from coontail is stimulated by increasing temperatures, with degradation rates undergoing a 20-percent increase between 5° and 10° C and a 2-percent increase between 10° and 18° C. The results of this study substantiate that gas evolution begins earlier and gas production rates are higher at warmer water temperatures. However, given sufficient degradable organic matter, gas formation also occurs under cooler conditions, albeit at lower rates.

15. The absence of oxygen can normally be expected in water entrapped above a sediment containing a high oxygen demand (i.e., with added organic matter) unless there are sources of oxygen renewal. Thus, the presence of oxygen in gases trapped beneath the barrier suggests oxygen renewal, probably from overlying water through the barrier fabric. The presence of an iron oxide coating on the sediment surfaces and on the inside surface of the barrier fabric confirms the presence of oxygen in the incubation systems. The presence of oxygen beneath the barrier fabric helps to explain the low levels of methane and relatively high levels of carbon dioxide encountered in this work. Both oxygen and methane are necessary to support the growth of methanotrophic (methane-consuming) bacteria, which then form carbon dioxide as a major waste product (Gottschalk 1979). Some methane could also have been lost from the flats to the surrounding tank water by diffusion through the barrier fabric. Both the entry of dissolved oxygen and the loss of methane may have been encouraged by the "pumping" action created by rising gas bubbles causing an observed oscillation of the barrier surfaces in response to changes in internal pressure.

16. In these studies, the presence and type of degradable organic matter in sediment beneath the barrier were very important factors determining the rate and duration of gas formation. The rates of gas evolution decreased according to type of organic matter in the order coontail > water hyacinth > cattail > oak leaves > pine needles > no added organic matter. Similar results were obtained by Barko and Smart (1983), who examined gas evolution from Lake Washington sediment and found that release of carbon dioxide and methane was generally greater from sediment amended with relatively labile algae and watermilfoil than with more refractory organic materials (cattail leaves, oak leaves, pine needles).

17. Not surprisingly, the amount of an easily degraded substrate, such as coontail (or other relatively flaccid submersed plants), is important to the gas evolution process. The 13.0-g amendment level used in the studies reported here is equivalent to a moderate standing crop of about 200 g dry weight of plant material per square metre. Based on the results of this study, the maximum gas production rates from sediment containing this mass of organic material in warm water (30° C) could approach 125 ml/m^2/hr, or 3 l/m^2/day. Organic mass substantially lower or higher than this value will result in an approximately linear decrease or increase, respectively, in gas evolution rates.

PART V: CONCLUSIONS AND RECOMMENDATIONS

18. Results indicate that gas evolution beneath benthic barriers can be prodigious under some circumstances. Problems with barrier performance related to gas evolution are likely to be greatest in areas of high plant biomass, particularly among species having relatively flaccid tissues that are readily decomposed. In areas sustaining high seasonal plant production rates, it is recommended that barrier deployment be restricted to periods of the year during which the standing crop is low as this will minimize the amount of gas released. Normally, these periods will include the winter and early spring months. With perennial plant populations, the second most important factor to consider is water temperature. Barriers should be placed during cooler months of the year when microbial decomposition rates are at a low point, thus decreasing the rate of release of barrier-buoying gases.

19. Manufacturers of benthic barriers often claim that their products are fully permeable and that gas evolution should not be a problem. However, test results suggest that the permeability of the barrier tested here will be negligible. By contrast, this study suggests that secure anchoring and venting will be extremely important to insure satisfactory performance. When large areas are to be covered with benthic barriers and substantial gas evolution cannot be avoided, the authors recommend that benthic barriers be mechanically affixed to the sediment surface.

REFERENCES

Best, E. P. H., Dassen, J. H. A., Boon, J. J., and Wiegers, G. 1990. "Studies on Decomposition of *Ceratophyllum demersum* Litter Under Laboratory and Field Conditions: Losses of Dry Mass and Nutrients, Qualitative Changes in Organic Compounds, and Consequences for Ambient Water and Sediments," Hydrobiologia, Vol 94, pp 91-114.

Barko, J. W., and Smart, R. M. 1983. "Effects of Organic Matter Additions to Sediment on the Growth of Aquatic Plants," Journal of Ecology, Vol 71, pp 161-175.

Cooke, G. D. 1986. "Sediment Surface Covers for Macrophyte Control," Lake and Reservoir Restoration, G. D. Cooke, E. B. Welch, S. A. Peterson, and P. R. Newroth, eds., Butterworth Publishers, Stoneham, MA, pp 349-360.

Gottschalk, G. 1979. Bacterial Metabolism, Springer-Verlag, Inc., New York.

Gunnison, D., and Barko, J. W. 1989. "Effects of Benthic Barriers on Substratum Conditions: An Initial Report," Proceedings, 23rd Annual Meeting, Aquatic Plant Control Research Program, 14-17 November 1988, West Palm Beach, Florida, Miscellaneous Paper A-89-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS, pp 175-177.

__________. 1990. "Environmental Factors Influencing Gas Evolution Beneath a Benthic Barrier," Proceedings, 24th Annual Meeting, Aquatic Plant Control Research Program, 13-16 November 1989, Huntsville Alabama, Miscellaneous Paper A-90-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS, pp 228-233.

Lewis, D. H., Wile, I., and Painter, D. S. 1983. "Evaluation of Terratrack and Aquascreen for Control of Aquatic Macrophytes," Journal of Aquatic Plant Management, Vol 21, pp 103-104.

Mayer, J. M. 1978. "Aquatic Weed Management by Benthic Semi-Barriers," Journal of Aquatic Plant Management, Vol 16, pp 31-33.

Pederson, D., and Saylor, G. S. 1981. "Methanogenesis in Freshwater Sediments: Inherent Variability and Effects of Environmental Contaminants," Canadian Journal of Microbiology, Vol 27, pp 198-205.

Perkins, M. A., Boston, H. L., and Curren, E. F. 1979. "Aquascreen: A Bottom Covering Option for Aquatic Plant Management," Aquatic Plants, Lake Management, and Ecosystem Consequences of Lake Harvesting, Proceedings of Conferences at Madison, WI, 14-16 February 1979, J. E. Breck, R. T. Prentki, and O. L. Loucks, eds., University of Wisconsin, Madison, pp 357-366.

Pullman, G. D. 1990. "Benthic Barriers Tested," Lake Line, Vol 10, No. 4, pp 4,8.