The Small Flows Journal

A collection of professional papers on the study of onsite and small community wastewater issues.

NATIONAL SMALL FLOWS CLEARINGHOUSE

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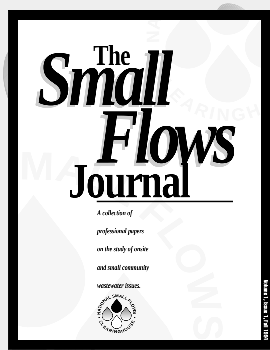

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From the Editor

In answer to the interest expressed by readers of the *Small Flows* newsletter and a general demand for technical information about cost-effective wastewater treatment systems for small communities, the staff of the National Small Flows Clearinghouse (NSFC) is pleased to present our first issue of ***The Small Flows Journal*.** We hope that ***The Small Flows Journal*** will help to satisfy the demand for this information by providing a forum for the exchange of ideas and methodologies for solving small flows issues.

The papers presented in this first issue cover a variety of problems that may be encountered by small communities searching for ways to improve their wastewater treatment systems. *"Save The Bay's 'Toxic Diet' Project"* and *"A Small Community Success Story: How Pressure Sewers and a Community Septic System are Protecting the Environment at Cuyler, New York"* both present case studies of communities that successfully implemented programs to improve the quality of life for their citizens. In *"Save The Bay's 'Toxic Diet' Project,"* methods for identifying and reducing nonindustrial toxics to the influent stream are offered. *"A Small Community Success Story"* describes, step-by-step, a community's decision to upgrade its sewage disposal system, and how it accomplished this goal in the face of severe budget constraints. In *"A Study of Scum Control in Septic Tanks,"* the results of the author's study could be applied by a small community facing similar problems maintaining septic tank systems. All of these articles deal with issues that are commonly faced by small communities.

To ensure the quality of the material published in ***The Small Flows Journal***, each manuscript is juried by the journal's Editorial Review Board. Board members (listed on this page) were chosen based on their distinguished accomplishments and contributions to this field. All manuscripts submitted are reviewed by three members of the Editorial Review Board. Furthermore, the process is completely anonymous, meaning that the identity of the author is not revealed to the reviewers during the review process, and the identities of the reviewers also remain confidential. This procedure ensures that authors feel free to submit their work and that the process remains fair.

We hope you will enjoy reading this issue of ***The Small Flows Journal*** as much as we enjoyed preparing it, and that you will wish to continue receiving it. To sign up for a free subscription, please fill out and return the subscription information card on the back cover (no postage is necessary). Also, we'd very much appreciate you passing the extra card along to a colleague.

Finally, we'd love to hear your comments on the journal. Please call or write to let us know what you think. If you wish to submit a manuscript for consideration for publication in ***The Small Flows Journal***, see the call for papers on page 24.

Sincerely,

Jill A. Ross
Editor-in-Chief
The Small Flows Journal

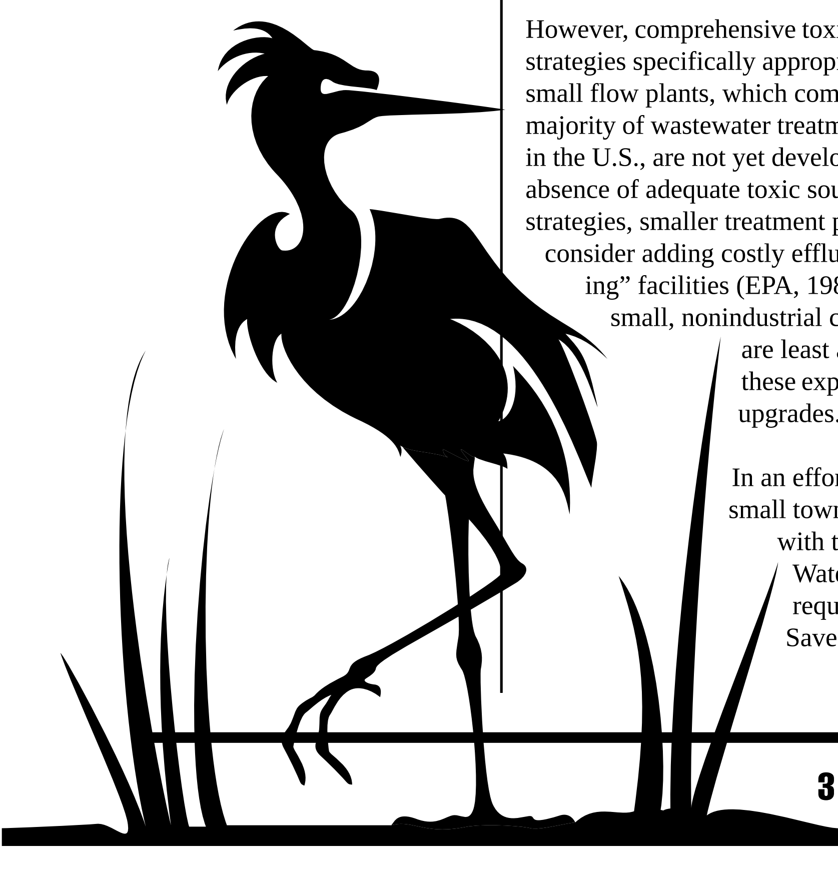
Save The Bay's "Toxic Diet" Project

by Diana Wilder

Preventing water pollution is easier and more cost-effective than cleaning it up, and although progress has been made in curbing industrial pollutants in larger communities, small, nonindustrial communities lack strategies for reducing unregulated toxics sources to the influent stream. This article outlines one environmental organization's model for reducing these toxics sources that can be used to help small communities nationwide.

Under the Clean Water Act's 1987 toxic discharge requirements, wastewater treatment facilities face increasingly strict limits for heavy metals and other nonconventional pollutants. While industrial discharges are the primary targets of most toxic reduction strategies and pretreatment efforts, most minor (and a number of major) wastewater treatment facilities have no significant industrial inflows. In nonindustrial communities, pipe corrosion, households, and small businesses are the likely sources of toxics to the influent stream. Reducing toxics loadings from these unregulated sources is now a critical issue for small, nonindustrial wastewater treatment facilities nationwide.

However, comprehensive toxic reduction strategies specifically appropriate for these small flow plants, which comprise the majority of wastewater treatment facilities in the U.S., are not yet developed. In the absence of adequate toxic source reduction strategies, smaller treatment plants must consider adding costly effluent "polishing" facilities (EPA, 1989), and small, nonindustrial communities are least able to afford these expensive upgrades.



In an effort to help one small town to comply with the Clean Water Act requirements, Save The Bay, a local environmental organization, developed a cost-efficient methodology for identifying and reducing the community's nonindustrial toxic sources.

The Toxic Diet Project

Save The Bay is a private, member-supported nonprofit environmental organization based in Providence, Rhode Island, and is dedicated to the restoration and protection of Narragansett Bay and its watershed. For the past eleven years, Save The Bay has compiled and published a report titled "The Good, The Bad, and The Ugly" (GBU), an evaluation of the National Pollutant Discharge Elimination System (NPDES) permit compliance for publicly-owned treatment works discharging to the watershed.

The 1993 GBU report revealed a disturbing trend: publicly-owned small flow treatment facilities have a difficult time meeting NPDES limits for metals (Save The Bay, 1993). The town of Northbridge, Massachusetts, on the Blackstone River is one of the publicly-owned treatment works in noncompliance for metals (Camp, Dresser, & McKee, 1994). To help Northbridge and other small-flow wastewater treatment facilities meet their permit limits, Save The Bay initiated the Toxic Diet project. The goal of the Toxic Diet is to develop a national model designed to improve the quality of the nation's waters by reducing nonconventional pollutant loadings to small, nonindustrial wastewater treatment facilities.

The Control of Toxics through NPDES

Even with full NPDES implementation and compliance, a watershed might still be impaired due to the cumulative impact of multiple pollution sources and long-term chronic impacts. In response to this possibility, the U.S. Congress included Section 303(d) of the Clean Water Act. This section directs states to identify impaired waters in which water quality standards cannot be met through technological controls.

The Blackstone River is currently identified as an impaired body of water. In 1991, the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (MADEP) organized the Blackstone River Initiative to translate water quality standards into more stringent controls (EPA and MADEP, 1992). The Clean Water Act requires states to establish total maximum daily loadings (TMDLs) for each pollutant of concern affecting impaired waters. A TMDL is an estimate of a body of water's assimilative capacity. Assimilative capacity is the assumed property of a body of water's that enables it to accommodate a certain amount of pollution without damage (EPA, 1993).

There are several problems with the use of assimilative capacity. First, if we attempt to estimate a level of pollution below which there are no harmful effects, we have fallen prey to the "null hypothesis"—the logical impossibility of universal negative proof. Second, the causal relationships between specific pollutants and specific environmental effects are not well understood (Jackson, 1993). This scientific uncertainty severely limits our ability to determine threshold capacities for specific pollutants in specific ecosystems. Lastly, actual translation of a TMDL into permit limits for individual dischargers under NPDES is politically challenging. Definitions of "acceptable levels of impact" and "harm" or "damage to the environment"—all necessary elements of a TMDL's "scientific" approach to water pollution control—cannot be derived without human value judgments. The use of mixing zones and dilution factors, also often politically influenced, further complicates the process (GAO, 1994b).

In response to the growing uncertainty of toxicity assessment and the ambiguity of federal and state mandates, some national and international organizations, including the International Joint Commission on the Great Lakes, favor pollution prevention and "zero discharge" of toxic substances (Jackson, 1993). The precautionary approach rejects the current regulatory emphasis on pollution "control" rather than elimination (Wilder, 1994). Source reduction, rather than elimination, is a less threatening and more politically acceptable incarnation of the precautionary principle in the U.S.

. . . reducing the total amount of toxics in use is the cheapest, easiest, and cleanest way for a community to maintain and improve its environmental quality.

An Emphasis on Prevention

The Toxic Diet is based on the idea that reducing the total amount of toxics in use is the cheapest, easiest, and cleanest way for a community to maintain and improve its environmental quality. As a nation, we spend far more on cleaning up our pollution problems than on preventing them. The U.S. spends $115 billion per year on pollution control; this figure is expected to rise to $170 billion annually by the year 2000. At the same time, less than one percent of the EPA's annual budget is dedicated to source reduction (GAO, 1994a). At this time, if a small community wishes to pursue the pollution prevention approach, it must do so largely on its own initiative. The Toxic Diet will provide communities with a workable model for achieving toxic source reduction.

Northbridge's current NPDES permit contains strict effluent limits for three metals: copper, lead, and zinc. The limits are strict in part because the publicly-owned treatment works discharges to a small tributary of the Blackstone River. Faced with a choice between dilution (relocating the treatment facility's outfall pipe to discharge directly to the Blackstone River) or pollution prevention (reducing metals levels to meet the new permit limits), the town decided to pursue source reduction as the best long-term solution.

Average concentrations of copper and lead in Northbridge's treated effluent (0.07 mg/l Cu, 0.04 mg/l Pb) exceed the average monthly limits by a factor of ten (permit limits are 0.008 mg/l Cu, 0.002 mg/l Pb). These concentrations have the potential to cause lethal and sublethal (reproductive and/or developmental) impacts to the aquatic life in the receiving water. Zinc is less problematic, but still worrisome (treated effluent averages 0.27 mg/l, with the permit limit set at 0.068 mg/l). The challenge lies in identifying the sources of metals loadings, determining the percent of contribution for each identified source to total loadings, assessing the feasibility of source reduction for each source identified, and successfully implementing pollution prevention strategies to attain the desired permit limits.

According to existing toxic reduction models, industrial sources and specific industry types (such as drycleaners or photographic studios) are the easiest targets for source reduction. However, Northbridge and many other small wastewater treatment facilities do not have this luxury. Two of the town's three industrial sources have already implemented pollution prevention procedures and discharge very little to the sewage treatment plant (only seven percent of the treatment facility's influent is industrial).

SAVE THE BAY

In communities like Northbridge, and in municipalities where industries are moving toward closed-loop systems, more attention must be focused on other sources. Since the majority of wastewater treatment plant influent in Northbridge comes from households and small businesses, the Toxic Diet will serve as a model for source reduction of toxics in small communities, and it will help larger urban publicly-owned treatment works that have reached the limit of industrial pretreatment.

Project Phase I

The first phase of the Toxic Diet is currently underway in Northbridge and is expected to be completed in 1995. The project involves a source assessment of four discharger types: industrial, residential, small business, and the drinking water conveyance system. A preliminary mass balance will be derived from data obtained by ongoing sampling of residential, commercial, and isolated industrial trunk lines. The following steps outline the Phase I source assessment methodology:

1. Identify categories of dischargers to the Northbridge sewer system and evaluate the loading of copper, lead, and zinc (pollutants of concern) through waste audits, mass balances, and trunk line sampling prior to and following discharge connections.

2. Identify small quantity generators discharging to the sewer system and evaluate loadings of copper, lead, and zinc through waste audits, mass balances, and sampling prior to and following discharge connections.

3. Assess and quantify the loading of copper, lead, and zinc from the drinking water conveyance system and identify the local water supplier's schedule for implementation of corrosion control facilities and the expected reduction in loading associated with those improvements.

4 Assess base-line residential contributions of copper, lead, and zinc through a program of sampling in isolated residential trunk lines and survey consumer behavior to identify home product usage and behaviors that may significantly affect loading of the pollutants of concern.

In Northbridge, the problem of isolating each categorical discharger's contribution to the waste stream is simplified by the town's physical layout. There are purely residential areas with sewer access points that guarantee isolation. Town industries and small businesses are also well-placed to provide information before and after discharge points. Monthly sampling of source waters, wastewater treatment facility influent and effluent, and household tap water (first flush) are also under way.

Residential Assessment

Everyday household products, such as laundry detergent, shampoo, soap, and general cleaners, contain trace amounts of metals and other toxics. A single household's contribution is insignificant, but the cumulative impact of thousands of individual households can add up to a significant percentage of a wastewater treatment facility's total metals loadings (Dickey, 1991).

As a first step, we evaluated the methodologies available for determining per capita contribution for the toxics of concern. The procedure commonly used is to collect purchasing data on consumer goods from local grocery and supply stores and use a series of mathematical formulas to arrive at a per capita loading (Dickey, 1991). In Northbridge, many residents work outside of town and do their shopping elsewhere. The integrity of loadings derived from this type of calculation and data sources are therefore questionable.

To solve this problem, we designed a household product use survey for spreadsheet and statistical analysis. The survey will identify consumer products used, and the amount and frequency of use by residents. Residential loadings for the metals of concern will be calculated using a database of consumer product metals loadings developed by Phillip Dickey of the Washington Toxics Coalition.

A door-to-door survey effort was initiated in October 1993 and a "project thermometer" was installed on the town common to help increase awareness of the survey effort (see photo 1 on page 8). To

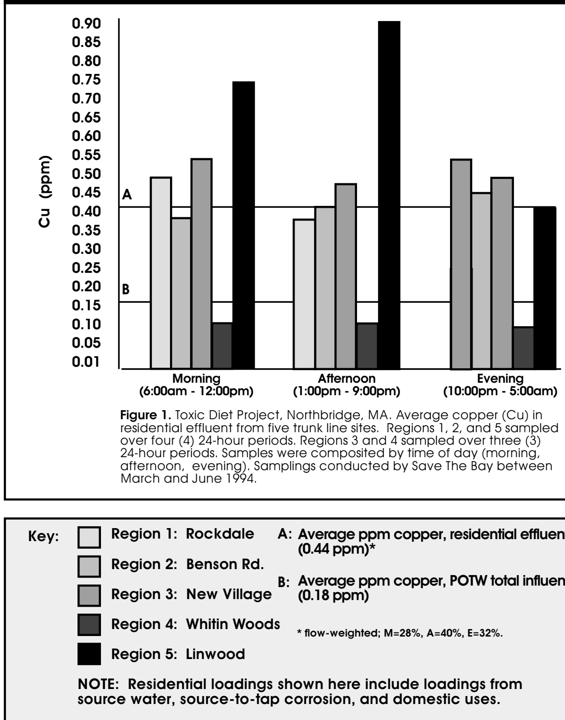


Figure 1. Toxic Diet Project, Northbridge, MA. Average copper (Cu) in residential effluent from five trunk line sites. Regions 1, 2, and 5 sampled over four (4) 24-hour periods. Regions 3 and 4 sampled over three (3) 24-hour periods. Samples were composited by time of day (morning, afternoon, evening). Samplings conducted by Save The Bay between March and June 1994.

FIGURE 1
Average Cu (ppm) in Residential Effluent in Northbridge, MA

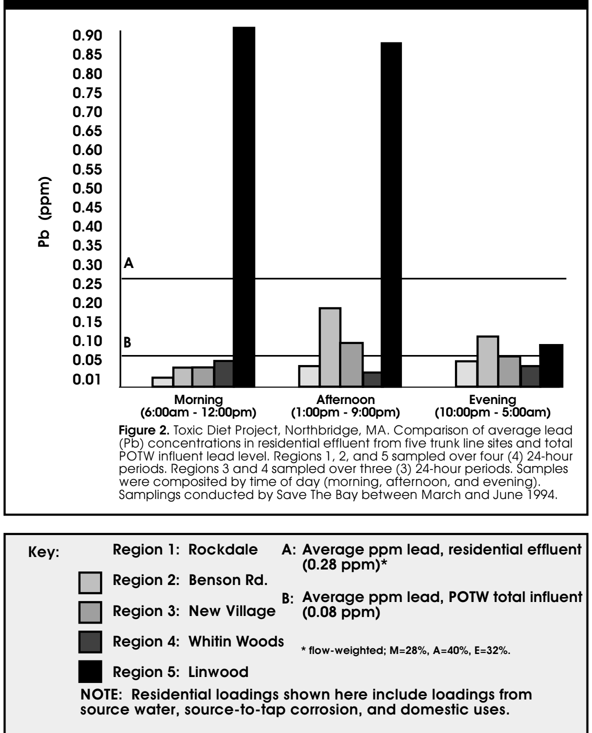


Figure 2. Toxic Diet Project, Northbridge, MA. Comparison of average lead (Pb) concentrations in residential effluent from five trunk line sites and total POTW influent lead level. Regions 1, 2, and 5 sampled over four (4) 24-hour periods. Regions 3 and 4 sampled over three (3) 24-hour periods. Samples were composited by time of day (morning, afternoon, and evening). Samplings conducted by Save The Bay between March and June 1994.

FIGURE 2
Average Pb (ppm) in Residential Effluent in Northbridge, MA

date, 250 surveys have been completed—enough to begin analysis.

In conjunction with the survey, residential wastewater was sampled over a four-month period, from March to June 1993 (see photo 2 on page 9). Samples were collected in five isolated residential regions over three to four days using an Isco model #1680 automatic sampler. One 250 ml. sample was taken per hour over each 24-hour period. Samples were preserved to < 2 pH with HNO_3 according to standard procedure. Each day's round of 24 samples was composited manually into three time-specific categories (morning, afternoon, and evening) corresponding to periods of high and low water use. This time-specific data will be compared to survey questions, which measure the time and frequency of certain household cleaning chores, water consumption patterns associated with these activities, and product metals loadings to help determine specific activities that contribute significant amounts of metals to the influent stream.

FIGURE 3
Average Zn (ppm) in Residential Effluent in Northbridge, MA

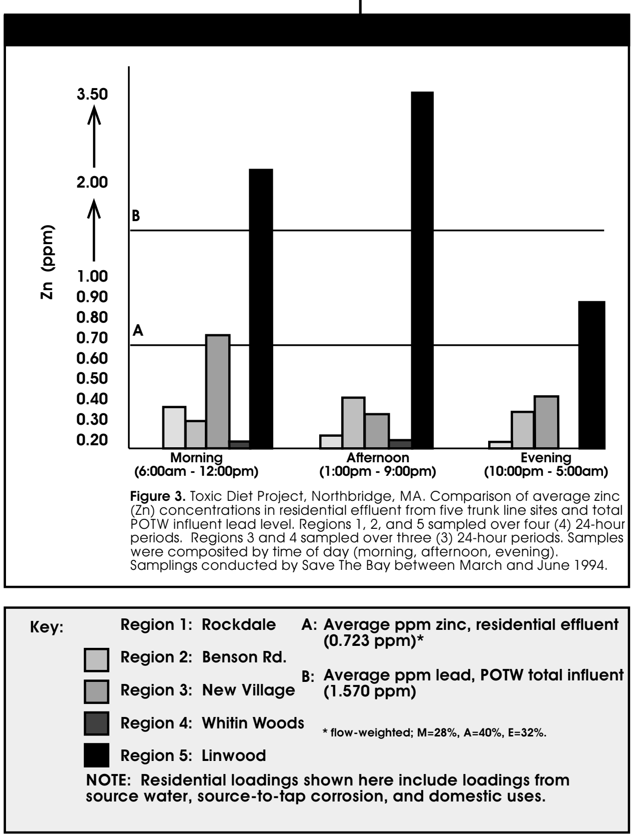


Figure 3. Toxic Diet Project, Northbridge, MA. Comparison of average zinc (Zn) concentrations in residential effluent from five trunk line sites and total POTW influent lead level. Regions 1, 2, and 5 sampled over four (4) 24-hour periods. Regions 3 and 4 sampled over three (3) 24-hour periods. Samples were composited by time of day (morning, afternoon, evening). Samplings conducted by Save The Bay between March and June 1994.

The four-month residential sampling phase was completed in June 1994. During the sampling phase, residential effluent comprised roughly one third (30 percent) of total wastewater treatment facility inflow. Preliminary analyses indicate that copper, lead, and zinc levels fluctuate according to the time of day and from region to region (fig. 1-3). A comparison of average residential and total treatment facility influent metals levels show that residential concentrations of copper (fig. 1) and lead (fig. 2) are diluted by nonresidential inflows containing lower levels of these metals, while zinc levels increase dramatically: a residential average of 0.701 mg/l compared to 1.57 mg/l Zn in publicly-owned treatment facility influent (fig. 3). This indicates significant zinc loadings from nonresidential sources. Subsequent analyses of drinking water and first-flush samples will determine the percentage of metals loadings in residential effluent attributable to source water and corrosion.

Small Business Assessment

INFORM, a nonprofit research organization, found that many businesses do not pursue pollution prevention because they do not believe such practices will improve their operations or save them money (INFORM, 1985). Such perceptions exist because business owners and managers are largely unaware of inefficiencies in their operations. Therefore, the best approach for small business and industry is based on business owner/operator education.

To accomplish this goal, Save The Bay, in cooperation with the Massachusetts Office of Technical Assistance (MOTA) and the Town of Northbridge, organized two workshops to inform small businesses of the free technical advisory services available through MOTA's outreach program. Upon invitation, MOTA personnel or volunteers trained in pollution prevention assessment conduct free audits of business operations. These audits are confidential, which should allay the fears and concerns of business owners. Following the audits, technical advisors assess the information and recommend alternative processes. The information provided by waste audits indicate estimated source reduction potentials for each business type. This information will be combined with trunk line sampling prior to and after sewer tie-ins. From this base line data, Save The Bay will develop a pollution prevention strategy specifically designed for each business shown to be of significance.

For the businesses requiring capital outlay to improve their processes, Save The Bay will assist in obtaining low- or no-interest loans. Community involvement, fostered by citizen participation in the survey and concerns that stem from a rate-supported facility, will help in implementing pollution prevention strategies.

Drinking Water Conveyance Systems

A major study of residential service lines in Sacramento, California, revealed that water distribution systems can significantly increase metals concentrations before the water is used by residents (Burnham, 1994). According to the study, the composition of conveyance pipes determines what type of metals leach into the passing water; newer systems tend to show increased levels of copper and zinc, while older systems show higher levels of lead, mercury, and zinc. Therefore, the ages of the houses, businesses, and water conveyance systems in the region are significant factors in estimating loadings sources for these specific metals.

To estimate metals loadings from drinking water pipe corrosion, first-flush samples of standing tap water were taken at ten residential sites over a period of eight months in conjunction with an ongoing corrosion control study. Metals concentrations from these sites will be averaged based on the distance of the sample sites from the source wells and the ages of residences taken from the household surveys to estimate total corrosion loadings from the drinking water conveyance system.

Project Phase II

In Phase II of the Toxic Diet project, potential source reduction for the pollutants of concern will be evaluated through the application of both pollution prevention technologies currently available and best management procedures. In the case of the drinking water conveyance system, the potential for further reduction of loadings from enhanced corrosion control methods will be assessed.

Other Source Reduction Options

In the course of this study, several additional areas of concern emerged. These concerns arose as we expanded our scope to assess all significant additives to the wastewater stream. Additives to drinking water for corrosion control and disinfection additives at the treatment plant itself can significantly impact the publicly-owned treatment work's ability to meet permit limits. Consequently, these factors were included for evaluation.

Wastewater Treatment Operations

Wastewater treatment facilities are themselves sources of several nonconventional pollutants, primarily chlorine and dechlorinating substances. Several options are available to reduce the use of toxics at the treatment plant.

As a nonchemical process, ultraviolet (UV) light has emerged as a viable, feasible, and cost-effective disinfection method for small- to medium-flow publicly-owned treatment works (EPA, 1991a). EPA studies show that UV light is an effective germicidal agent. UV light leaves no residual, does not interact with chemicals in wastewater, and will not result in the formation of toxic compounds. UV light can be produced onsite and has no adverse safety concerns for plant staff or nearby communities. However, UV light does have its limitations. In particular, it requires effluent

PHOTO 1
A "project thermometer" is installed on Northbridge's town common to publicize Save The Bay's survey effort.

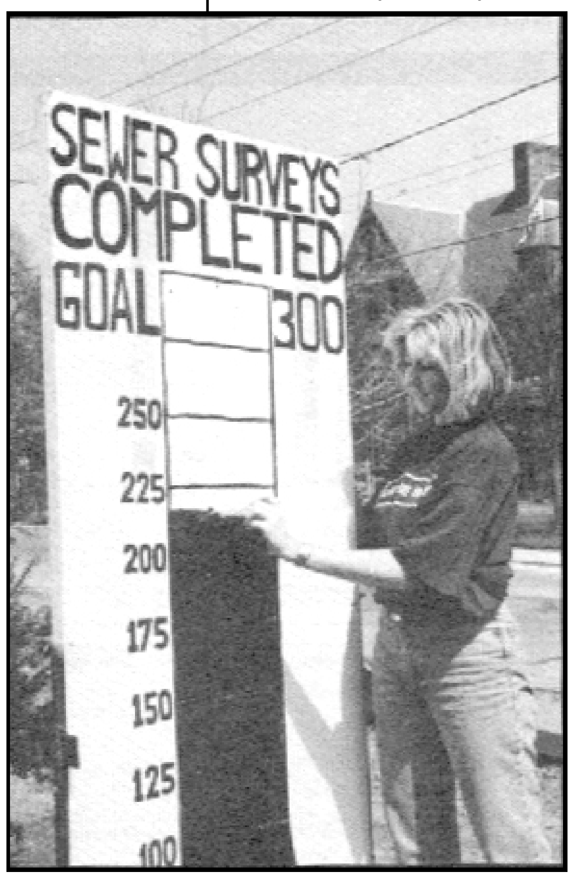


PHOTO 2
Northbridge residential wastewater is sampled in conjunction with the Save The Bay survey.

with relatively low total suspended solids (TSS) to ensure effectiveness.

The benign nature of UV light contrasts strongly with chlorine, a highly toxic chemical. Chlorine is dangerous to transport, leaves a toxic residual, and can combine with other wastewater elements to create trihalomethanes (THMs), potential cancer-causing agents.

Cost is most likely the reason that chlorine is used by publicly-owned treatment facilities. Compared to UV, ozone, and other disinfection alternatives, chlorination/dechlorination appears to be relatively inexpensive. But when the human health and safety concerns of chlorination and the negative side effects of dechlorinating chemicals (sulphur dioxide and sodium sulfites or sulfite salts) are taken into account (the creation of sulfates and subsequent reduction in dissolved oxygen; and equipment corrosion), they may outweigh any immediate cost savings. In addition, dechlorination may not remove 100 percent of the chlorine residue, THMs, and halogenated organics remaining after chlorination.

Corrosion Control

Although drinking water utilities can have significant impacts on the environmental and operational goals of wastewater treatment facilities, they are regulated under a separate set of federal and state requirements using human health criteria. Because humans are at the top of the food chain, safe drinking water standards for metals and other bioaccumulative toxics are often less strict than aquatic life criteria under NPDES. The lower standards for drinking water creates problems for the publicly-owned wastewater treatment facility, especially when the drinking water utility is privately owned.

Drinking water corrosion control programs may result in additional long-term costs to municipal treatment facilities (Elmund et al., 1986). Specifically, the use of sodium hexametaphosphate and other precipitating agents will increase the amount of solids in the wastewater stream, resulting in additional sludge treatment and removal costs for wastewater treatment plants.

In 1986, the public water utility in Fort Collins, Colorado, considered the effects of drinking water corrosion control on wastewater treatment. This holistic approach resulted in the elimination of certain phosphate-based corrosion control compounds from consideration.

According to the Fort Collins study, the addition of sodium bicarbonate and lime can significantly reduce copper and lead corrosion without imposing additional treatment costs on the wastewater treatment facility. A five- to six-fold copper and lead reduction was achieved in Fort Collins by adding sodium bicarbonate and lime to the drinking water supply. By 1992, 90th percentile concentrations for copper were down to .002 mg/l and .166 mg/l for lead. The utility is now considering the use of carbon dioxide (CO_2) in place of sodium bicarbonate as an even cheaper alternative (Elmund et al., 1986).

In communities where the drinking water supply system is privately owned, as it is in Northbridge, publicly-owned treatment works will need to find some means, legal or otherwise, to influence decisions on additives and treatment methods. Options for exerting control include the outright purchase of the utility, strict enforcement of sewer use ordinances (treating the water company as an indirect discharger), and/or cost-sharing arrangements for improved corrosion control.

Conclusions

When Phase I is completed in 1995, it will be the town's responsibility to institutionalize recommended source reduction strategies. These may include mandates on piping for drinking water and wastewater, water conservation, product or chemical bans (such as the Palo Alto, California, ban on copper sulfate), or local limits. Measured reductions in the loadings of metals to the Northbridge publicly-owned wastewater treatment facility will determine the project's success. It is our hope that the Toxic Diet will provide a way for nonindustrial communities across the country to adopt pollution prevention as a proactive, common-sense strategy for NPDES permit compliance.

Acknowledgements

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For more information on the Toxic Diet, contact Diana Wilder at Save The Bay, 434 Smith Street, Providence, RI 02908. (401) 272-3540

A Small Community Success Story:

How Pressure Sewers and a Community Septic System are Protecting the Environment at Cuyler, New York

by James V. Feuss, P.E.; R. Paul Farrell, P.E.; and Peter W. Rynkiewicz

A low pressure sewer system using grinder pumps was installed, mainly by volunteers and town residents, to upgrade a small town's sewage disposal system. Performance of the system has consistently met or exceeded expectations. The case study presented in this article proves that a small community with severe budget constraints can work together to provide a healthier environment for its residents.

Cuyler is an unincorporated hamlet of about 130 people located in the Township of Cuyler, a rural area of upstate New York approximately 40 miles south of Syracuse. Cuyler is literally a crossroads community, being situated at the junction of New York State Route 13, several county routes, and a former major railroad route. It is economically depressed, agriculturally oriented, and has many homes well over a century old.

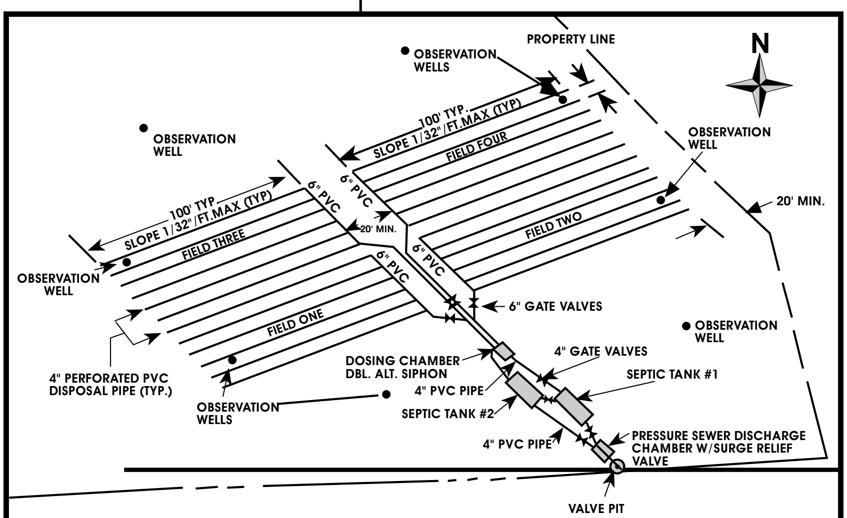

FIGURE 1
Overall Plan of Cuyler Treatment System

In the early 1970s, the Cortland County Health Department and Cuyler citizens became concerned over the aesthetic and public health consequences of individual septic systems, which failed seasonally, and of numerous surreptitious "straight pipes" into drainage ditches. The county health department was presented with the dilemma of finding a way to solve this serious problem within their very limited resources. The county board of health modified the public health engineer's job to include the title of town engineer for the town of Cuyler. Thus was born one of the earliest "self-help" projects in New York State (NYS), though that term was not yet in general use (Feuss and Farrell, 1994).

Wastewater Treatment

The county health department evaluated many options to abate the public health hazard in Cuyler. Surface discharge options were eliminated by a New York State Department of Environmental Conservation (NYDEC) study that determined that none of the streams within a reasonable distance had the required assimilative capacity. In response to the town's need for a "minimum maintenance" and "zero discharge" treatment plant, a system containing two, 5000-gallon septic tanks, dosing siphons, and soil absorption systems was chosen.

The system was designed so that the tanks can be operated individually, in series, or in parallel. To compensate for a high natural water table, the soil absorption system was constructed by bringing in 1605 m^3 (2100 yd^3) of fill, which was placed over existing pasture land. The soil absorption system consisted of 730 m (2400 ft) of trench, divided into four equal sections. The overall plan of the treatment system is shown in figure 1, and the profile is shown in figure 2.

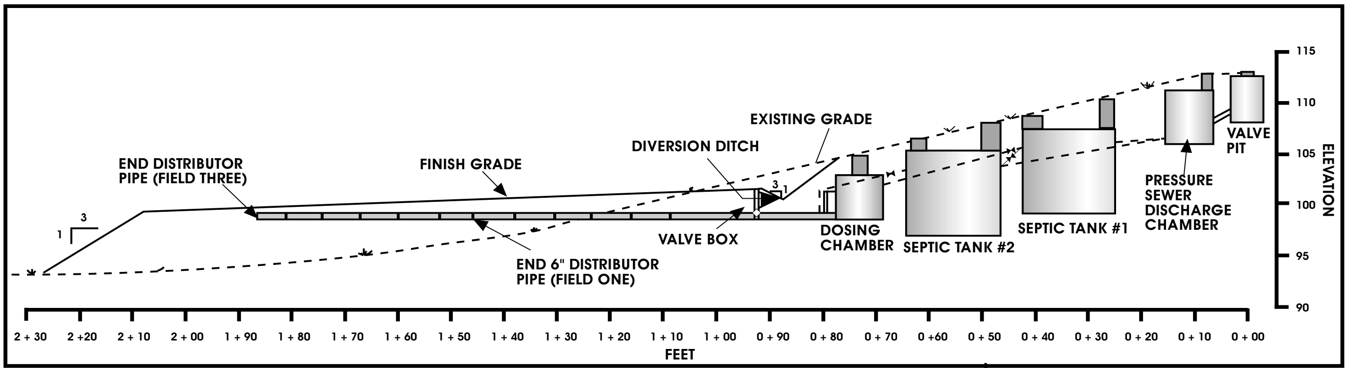

FIGURE 2
Treatment System Profile

Normal operation calls for using one section on each side with alternate dosing. These sections are in operation for 12 to 24 months while the other two sections "rest" to permit them to restore their absorption capacity biologically. Eight monitoring wells were strategically placed to ensure that no downstream plume went beyond permissible boundaries. The groundwater gradient is toward a wetland on the north side of NYS Route 13.

Design of Pressure Sewers

Many options were considered for the proposed wastewater collection system. Conventional gravity sewers would have been extremely expensive due to the depth of cuts required to retrofit service connections to existing homes. In addition, two pumping stations and a major road cut would have been necessary. On the basis of information gathered from technical reading and attendance at an occasional seminar, the county public health engineer decided that low pressure sewers using grinder pumps warranted further investigation. This interest was reinforced by the favorable results of a pressure sewer demonstration project that had been recently completed in Albany, New York (Carcich, Hetling, and Farrell, 1972). This work had been done jointly by the research unit of the NYDEC and the Environment/One Corporation. The project was supported by a research grant from the U.S. Environmental Protection Agency (EPA), and the report has become a classic on pressure sewers.

Environ-ment/One, a leading manufacturer of grinder pumps based in Schenectady, was contacted for product information and application engineering inputs to a preliminary piping system design. The original collection system design specified an H-shaped layout with two main branches and one main connecting the two branches, serving the 41 buildings (mostly single family residences with a few multi-family homes) in the village. Piping was sized to minimize friction loss, while achieving adequate velocities to assure a self-cleansing system. The maximum pump site elevation difference is 12.8 m (42 ft) and the maximum total dynamic head is calculated to be 20.25 m (66.5 ft)

PVC Pipe -- Type SDR-21		
Nominal Size	**Length-m**	**Length-ft**
32 mm (1 1/4 in.) service laterals	1100	3600
50 mm (2 in.) main	850	2800
75 mm (3 in.) main	275	900

TABLE 1
Total Length of Pipeline by Size

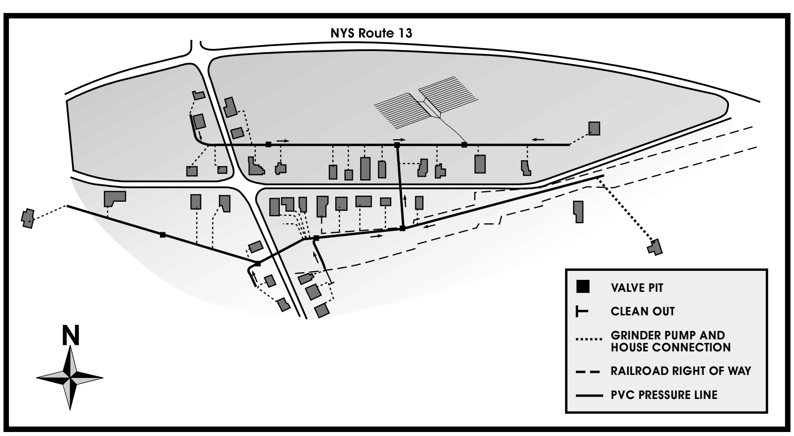

FIGURE 3
Detailed Plans of Cuyler Sewer System

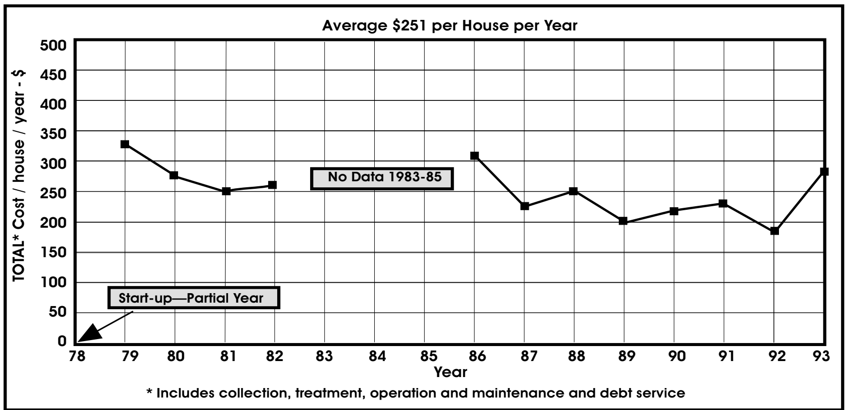

FIGURE 4
Total System Cost Per House Per Year (1992 dollars)

(Weston, 1983). As shown in figure 3, the chosen piping layout is without loops. House connections are 32 mm ($1^1/_4$ in.) PVC, and the mains are 50 mm (2 in.) and 75 mm (3 in.) SDR-21 PVC. Fire hose connections were installed in the valve pits so that sections of the piping could be bypassed if repairs were needed. To conform to the anticipated frost penetration depth in Cortland County, the mains were buried 1.2 m (48 in.) below grade. Total length of pipeline by size is shown in table 1, and a plan view of the collection system is provided in figure 3.

Economic Factors

An available land area suitable for the community septic system was found, albeit with some difficulty. The originally proposed site had good soil characteristics, but its proximity to a historic cemetery led to vehement objection by Cuyler residents.

TABLE 2
Operating Cost and Reliablility Data

		ANNUAL COSTS ('92=1)								├ Costs per House ┤			
		DEBT SVC.	OP REPAIR	TREATMENT	OP PARTS	OTHER	TOTAL	#PUM CALLS	CUM. MTBSC	TOTAL*	PUMP O&M	3 YR AVG.	(REF 6)
YEAR	78	(startup this year-data incomplete)											
	79	5250	1500	160	375	555	7840	6	6.67	$196	$47	-	1.67
	80	5150	980	525	140	525	7320	7	6.15	$183	$28	-	1.50
	81	5100	1000	125	240	670	7135	7	6.00	$178	$31	$35	1.39
	82	5000	1380	400	660	500	7940	14	4.56	$194	$50	$36	1.32
		(data not available from Town Clerk)											
	84		-										
	85		-										
	86	4750	1771	1030	2390	529	10470	13	4.18	$255	$101	$61	1.29
	87	4650	1514	831	571	500	8066	12	4.03	$197	$51	$67	1.17
	88	4550	1212	500	2422	500	9184	10	4.04	$224	$89	$80	1.13
	89	4620	761	1344	95	595	7415	5	4.32	$181	$21	$53	1.09
	90	4575	993	2475	50	514	8607	10	4.29	$210	$25	$45	1.05
	91	4475	659	746	2627	633	9140	4	4.56	$223	$80	$42	1.02
	92	4375	406	2080	0	671	7532	7	4.65	$184	$10	$39	1.00
	93	4350	3507	2784	622	696	11959	10	4.60	$292	$101	$64	0.98
	Avg	****	$1,120	****	$849	$574	$8,551	8.92	4.6year	$210	$53		

Although the current site required more engineering, it was much more agreeable to all. Patient but persistent negotiations eventually led to the acquisition of this site and a right-of-way for much of the pressure pipeline along an abandoned railway track bed (Rechlin, 1986).

The project was truly a self-help venture. The county assistant public health engineer supervised construction and served as clerk of the works. A local engineering firm prepared the final plans and specifications for a minimal fee. A civic-minded local attorney provided, at no cost, legal services to include permit filing, bond applications, and one condemnation. The fill was hauled by the town and county highway departments, and the final grading was done by volunteers.

Total construction costs at the time of installation (1978) amounted to $166,100, or $4,153 per house, which is less than one third of the estimate of $574,300 ($14,357 per house) for a gravity sewer and conventional treatment option. The construction cost also included the upgrading of the electrical service to 220 volts for most of the houses, which was not included in the original estimate. This cost savings plus a partial grant and a long-term low-interest loan from the Farmer's Home Administration were the keys to economic feasibility.
The debt is being retired systematically, and the annual cost per home has been declining each year. In 1994, the annual debt service was $105 per household.

Operating cost and reliability data from start up in 1978 to the present are summarized in table 2. Numbers for the first five years were taken directly from the Roy F. Weston evaluation (1983) funded by the EPA. Data for 1986 through 1993 are courtesy of Cuyler's town clerk, who in April 1994 searched the town records and made copies for the authors of all sewer system invoices (Jackson, 1994). These recent data have been analyzed and presented in the same format as in the Weston report. The result is an accurate and detailed history (except for missing records from 1983–85) spanning the 17-year life of the system. The total annual system costs (collection, treatment, operation, maintenance, and debt service) are shown in figure 4. These do not include individual electric expenditures, which typically amount to 200 kwhr or less per year.

Grinder pump operation and maintenance costs on a per house basis, excluding the individual electric bills, are shown in figure 5. These annual costs have been adjusted to 1992 dollars using the Consumer Price Index to compensate for inflation (Department of Commerce, 1993). Annual costs as expressed in constant ('92) dollars, have averaged $63 per pump per year for the 17 years since operation began. Because the system is so small and parts are quantity purchased at irregular intervals, the annual costs exhibit a noticeably cyclic tendency. The per pump cost for operation and maintenance is also plotted on figure 5 as a moving three-year average, which smooths out the peaks and valleys and gives a more useful long-term figure for budgeting purposes. These pumps have static-type level sensors with no moving parts in contact with sewage; consequently, there are no additional hidden preventative maintenance expenses.

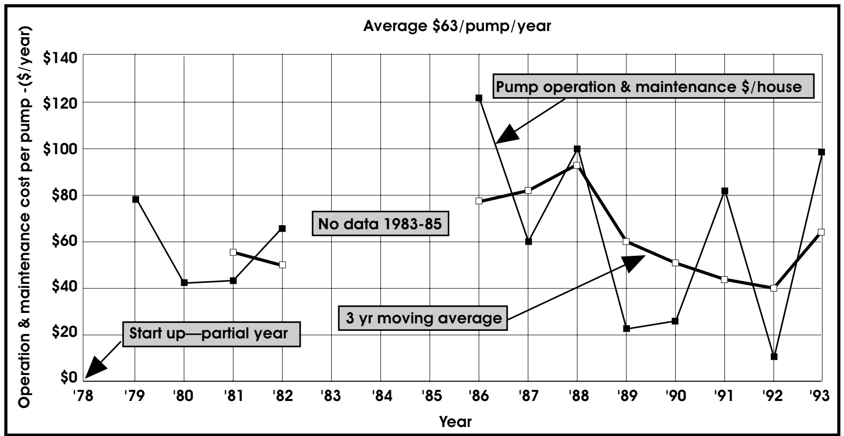

FIGURE 5
Operation and Maintenance Costs Per Pump (1992 dollars)

Operation and Maintenance

The system went into full-time operation in 1978. Performance has consistently met or exceeded expectations since that time. Cuyler is too small to have a formal public works department, so the occasional repairs are done part time by local residents. Three spare cores (the pump, grinder, and motor—all in a single unit that is easily pulled out and replaced) purchased as part of the original capital investment are used whenever onsite repair is not convenient. Service training, replacement parts, and an occasional core or motor overhaul are readily available from a nearby distributor or direct from the factory.

The cumulative mean time between service calls (MTBSC) for the project is 4.6 years over the total project life as shown in figure 6. MTBSC is calculated by dividing the total number of pumps by the cumulative average to date service calls per year. This record is impressive, especially in light of the fact that the average age of this pump population is now greater than 15 years. Grinder pump design has been subject to continuous improvement since 1978, but the Cuyler pumps contain none of these refinements.

A few years ago, former town supervisor Bob Randall estimated that nearly one-fourth of the 41 positive displacement grinder pumps had "not been touched since they were originally installed." Detailed review of the data furnished by the town clerk shows Randall's rough guess was

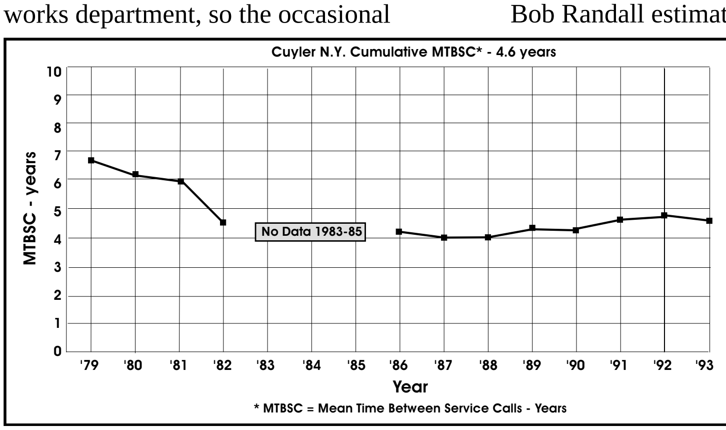

FIGURE 6
Grinder Pump Reliability

pretty accurate. During the past eight years, there were eight homes (one fifth) with zero service calls and 16 homes that required one call. Several of the homes with multiple calls experienced "short-term callbacks," indicating a lack of training or knowledge needed to fix a problem correctly the first time. The poorest reliability record was at a house that has averaged one call per year. The complete distribution of calls per house is plotted as figure 7.

A post-construction evaluation of Cuyler's alternative approach was made for the EPA in 1983 by the consulting firm, Roy F. Weston, Inc. (1983). The report indicated that after five years of operation, all three objectives of the project (i.e., low cost, zero discharge, and low maintenance) had been achieved and the system was operating entirely within expectations. Following are three important findings from that Weston report:

PHOTO 1
Cortland County Public Health Director, Jim Feuss points out the site of community septic tank and soil absorption system.

1. . . . although the total cost actually expended exceeds the $150,000 town-imposed limit, it came very close to the original estimate, and does substantiate the fact that the benefit of lowest possible capital cost was achieved. This is especially true when the cost estimates are adjusted to 1978 dollars.

2. The benefit of discharge elimination would appear to be completely achieved.

3. Overall, the operational responsibilities associated with this system have been easily managed by the small rural community of Cuyler. The benefits of minimizing operating costs and operational requirements, and maximizing system reliability has been achieved (Weston, 1983, 2-6).

Effluent grab samples taken from the dosing siphon chamber over a four-week period during the spring of 1994 averaged 85 mg/l suspended solids. If the influent is assumed to be 310 mg/l, which is typical of the Albany Pressure Sewer Demonstration, then the suspended solids removal efficiency is 73 percent. These results further substantiate the conclusion from earlier research that the pre-grinding of sewage by a grinder pump has no adverse effect on its ability to settle (Carcich, Hetling, and Farrell, 1972).

Although the treatment system is designed for low maintenance, some maintenance is still required. The septic tanks must be pumped at least once every two years, and the operation of the valves and dosing siphon should be checked monthly. Maintenance of the system has been inconsistent in the past; valves have frozen, the dosing counter has become inoperable, and solids have entered the leachfield. The Cortland County Health Department is currently working with the

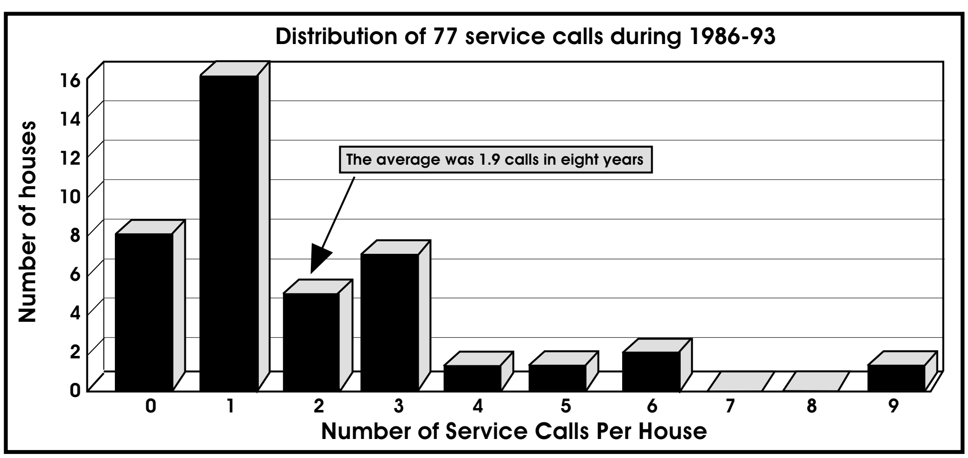

FIGURE 7
Service Call Frequency Distribution

town to improve routine and preventative maintenance.

Conclusions

The Cuyler experience illustrates that a tiny community with limited resources can, within severe construction and operating cost constraints, provide itself with effective low-maintenance sewage disposal and a healthy, more pleasant environment. To date, the Cuyler grinder pump pressure sewer and community septic system have been performing well above initial expectations for 17 years with affordable operating and debt service costs.

While replacing some of the original steel gate valves with PVC ball valves in the summer of 1994, an accumulation of sludge was found in most of the tile field lines. The town has embarked upon a program to clean all of the treatment system lines and to ensure proper operation of the alternate dosing system. The original design of the leachfield facilitates repair because it allows the isolation of each of the four fields. Once again the county board of health has amended the senior author's job duties to include serving as the town's engineer to oversee repairs and the operation and maintenance of the treatment system. These recent repairs exemplify the on-going cooperative relationship between Cuyler residents and the health department. Both are pleased and very proud of their joint accomplishments.

Acknowledgements

We would like to thank John S. MacNeill Jr., P.E., P.C., who provided engineering plans and specifications for the project; Lynn Jackson, Cuyler's town clerk, who provided information from the town records; and John T. Ryan Jr., Esq., who provided legal assistance to the Town of Cuyler during the project.

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Peter W. Rynkiewicz

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A Study of Scum Control in Septic Tanks

by Frank Pearson, Ph.D., P.E.

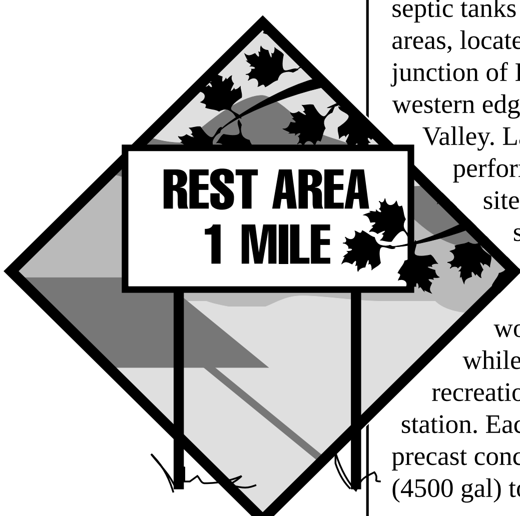
A roadside rest area using septic tanks can serve as a laboratory for the study of scum control. The author had the unique opportunity to test and observe several approaches, the results of which are reported in this article. Ideas for improving septic tank designs to help prevent scum accumulation are also offered.

Roadside rest areas contribute to the comfort and safety of highways all across the U.S. More than half of the rest areas operated by the California Department of Transportation (CADOT) use septic tanks to dispose of wastewater from toilet facilities.

At some well-frequented roadside rest areas in California, scum accumulates rapidly in the inlet compartments of the septic tanks, largely from toilet paper used in the restrooms. Occasionally, scum blocks the septic tank inlet lines, and frequently, septage needs pumping more than once a year. Substituting toilet paper rated for septic tanks reportedly failed to control the scum, so other control methods were investigated. This article describes the study and its results, and offers some solutions for scum control.

Scope of the Tests

Scum control tests were conducted in septic tanks at the Westley roadside rest areas, located in an isolated area near the junction of Interstates 5 and 580 at the western edge of California's Central Valley. Laboratory tests were also performed for this site. The Westley site has separate northbound and southbound rest areas, each with three septic tanks. Two such tanks each serve both women's and men's restrooms, while the third tank serves the recreational vehicle (RV) dump station. Each Westley septic tank has four precast concrete cells in series, of 17 m^3 (4500 gal) total capacity.



Septage pumping had emptied the tanks six weeks before the tests began. Two of the northbound septic tanks were less heavily loaded and accumulated insufficient scum to study scum control. The four remaining Westley septic tanks were studied. Three such tanks have conventional tee inlets, and one tank has a drop inlet in which inflow enters above the water level in the septic tank.

Field evaluations also considered two septic tanks at a roadside rest area near the town of Turlock, located toward the east side of the Central Valley. The Turlock septic tanks both have drop inlets, which formed plunge pools through the scum at the inlet manholes. So broad were these plunge pools that attempts to measure the scum depth by probing at the manholes were abandoned.

Biological Additives

Initial testing focused on enzymatic additives, which CADOT had selected. The additive doses and application methods reflected the respective manufacturers' general recommendations. However, no waste-specific additive dose versus response characteristics were available. Each supplier suggested trials to determine the requisite dose, but no standardized additive evaluation protocols and criteria were available for such trials and neither were the necessary time or funding.

Early field tests and laboratory tests delivered the specified additive dose in one initial application. Later, in consultation with suppliers, doses were split into two or three applications through the field test runs. The test septic tanks differed according to inlet type, waste type, and loading. To help distinguish the effects of additives and tanks on scum, additives were rotated among the tanks in later runs.

Field Methods

Field tests monitored how treatments and conditions affected the depth of scum exposed at manholes at either end of the inlet compartments of the four Westley test septic tanks. Field test runs initiated by pulverizing the scum at each manhole using a paddle plunger. Then additive was blended into the scum at the inlet manholes of the three treated septic tanks, while the fourth control tank received no additive.

After pulverizing the scum and dosing additive-treated scum, the depth of scum was measured at each manhole. The measurement device was a calibrated rod hinged at one end to a 200-mm (8-in.) diameter sheet metal plate. Initially, the plate set to the vertical was sliced through the scum. Then the plate was rotated to the horizontal and pulled up until resistance was felt as the plate contacted the underside of the scum layer. This permitted reading the scum depth as the rod calibration mark opposite the upper surface of the scum. As many as four depth measurements were obtained over the exposed scum surface, with fewer readings from shallow or fluid scum layers.

The field tests comprised five runs over the three months available. Early runs lasted up to four weeks but later runs were briefer. Over the course of each run, fresh waste entering the tanks replenished the scum removed (sunken) by the control measures tested. Scum depth measurements were nominally timed on the first, fourth, and tenth days after initially pulverizing the scum. The following plotted and tabulated results show the actual timings and

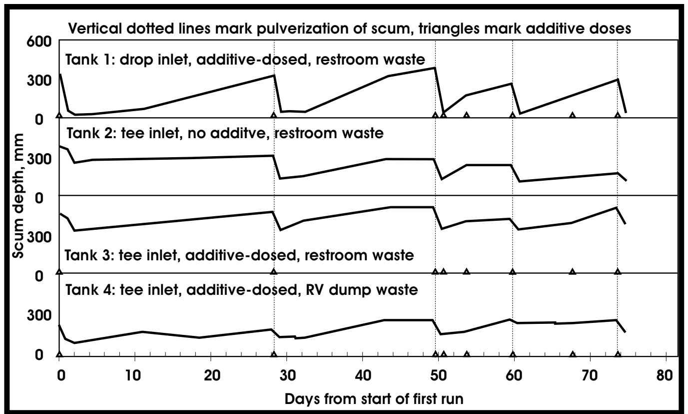


FIGURE 1
Scum Depth Histories for Four Westley Septic Tanks

		Drop Inlet		Tee Inlet					
		Septic Tank 1 Restroom Waste		Septic Tank 2 Restroom Waste		Septic Tank 3 Restroom Waste		Septic Tank 4 RV Dump Waste	
NO. OF DAYS	RUN NO.	ADDITIVE	DECREASE	ADDITIVE	DECREASE	ADDITIVE	DECREASE	ADDITIVE	DECREASE
1	1	B3¾	**280**	none	26	C2¾	**126**	A3¼	38
	2	B3¾	**286**	none	**178**	C2¾	**50**	A3¼	**140**
	3	B3¾	**352**	none	**160**	C1¾	**114**	A1¾	**172**
	4	A3¼	**264**	none	**126**	B3¾	**98**	A1¾	**90**
	5	C2¾	**236**	none	**58**	B ¼	—	A1	**58**
Mean		—	**284**	none	**110**	—	**97**	—	**100**
4	1	none	**304**	none	102	none	**136**	none	**122**
	2	none	**278**	none	**150**	none	**58**	none	**72**
	3	B1	**212**	none	**160**	C1	**96**	A1	**108**
	4	none	—	none	—	B1	—	A1	—
Mean		—	**265**	none	**137**	—	**97**	—	**101**
10 to 15	1	none	**262**	none	76	none	66	none	**76**
	2	none	0	none	18	none	**-88**	none	-38
	3	none	**112**	none	46	none	-8	none	**84**
	4	none	**50**	none	**50**	none	—	none	**-88**
Mean		—	**106**	none	48	—	-10	—	9

E.g., a decrease of 250 denotes a scum layer some 250 mm less deep than at the start of the run. Depth decrease values shown in **boldface** differ from zero at the 95% level of statistical significance, by Student's t - test. Additive designation A3¾ signifies some 3¾ kg of Additive **A**. Additve doses listed for day 1 include the dose at the start of the run.

TABLE 1 —
Decreases (in Millimeters) from Initial Scum Depth During Field Runs

magnitudes of additive doses and depth measurements.

Field Results

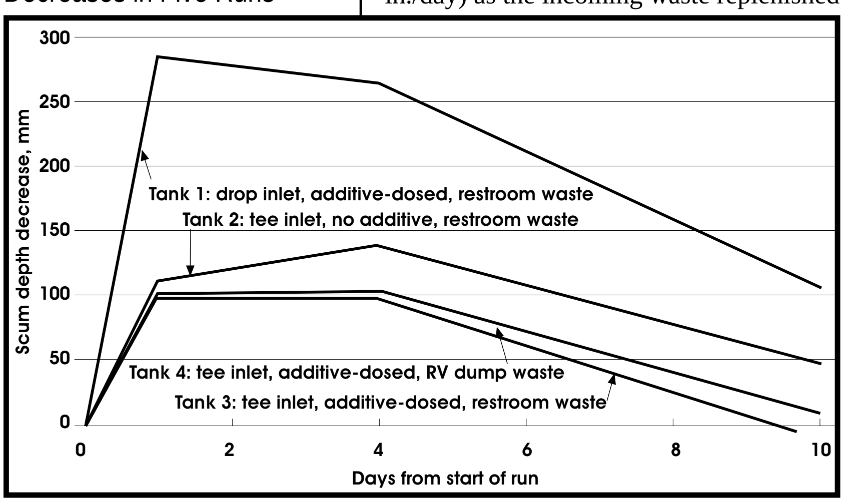
In the text to follow, septic tanks numbered 1 through 4 serve, respectively, the northbound-east, southbound-east, and southbound-west restrooms, as well as the southbound RV dump. The letters A, B, and C distinguish the additives. In the inlet manholes of tanks 1 through 4, initial scum depths were 330, 280, 510, and 250 mm (13, 11, 20 and 10 in.) respectively, averaged over the five runs. Corresponding initial depths in the second manholes averaged 75, 25, 75, and 25 mm (3, 1, 3 and 1 in.), so shallow that effects of treatment were minor. All scum depths mentioned below refer to measurements made in the inlet manholes.

Figure 1 presents scum depth histories for the four septic tanks, showing when the scum was pulverized at the start of the runs and when additive was dosed. Table 1 lists the additive doses, with decreases from the initial scum depth on the first, fourth, and tenth days of the runs, and figure 2 shows the mean decrease from the initial scum depth during the five runs.

Invariably, the scum mat became shallower during the first day after pulverizing the scum. From the first to the fourth day, the scum depth usually fell slightly. After the fourth day, the scum depth increased at a rate of some 15 to 25 mm/day (0.6 to 1.0 in./day) as the incoming waste replenished the scum. Figure 2 reveals the effects of certain conditions on the decrease in scum depth after pulverization; namely, the effects of septic tank inlet type, additive versus no additive, and restroom waste versus RV dump waste. Consider the mean scum depth decreases on the first day of the runs.

During the first day of the runs, scum depths declined more in the drop inlet tank; i.e., by 280 mm (11 in.) in tank 1 with a drop inlet, compared with a mean of 100 mm (4 in.) in tanks 2 through 4 with tee inlets. Among tee inlet septic tanks, the scum depth declined about the same in additive-treated tanks as in the additive-free tank, and the same in tanks receiving restroom waste scum as in the RV dump station tank.

FIGURE 2
Average Scum Depth Decreases in Five Runs



Statistical Analysis of Field Scum Depth Decreases

The field data suggest a statistical hypothesis for testing; i.e., that decreases in scum depth were primarily associated with the type of septic tank inlet rather than with the presence or choice of additive. The switching of additives B and C between tank 1 (drop inlet tank) and tank 3 (a tee inlet tank) after run 3 of the field tests permits testing of that hypothesis. For that purpose, regression analysis of day 1 scum depth decrease data yield the coefficients d, e, and f in the following equation:

$$F = dD + eE + f \qquad (1)$$

in which:

F = day 1 scum depth decrease, in millimeters;

d, e, and f = numerical coefficients, in millimeters; and

D and E = Boolean variables identifying the additive type and inlet type, thus:

D = 0 for additive C,
D = 1 for additive B,
E = 0 for a tee inlet,
E = 1 for a drop inlet.

Regression analysis of the scum depth decrease data in table 1 yields the solution:

$$F = 5D + 185E + 120 \pm 56 \quad (2)$$

The coefficient of the inlet parameter, e = 185 mm (7.3 in.), exceeds the coefficient of the additive parameter, d = 5 mm (0.2 in.). The respective partial correlation coefficients are 0.85 and 0.04. Thus, day 1 scum depth decreases relate more strongly to the tank inlet type than to the choice between additives B and C.

Substituting appropriate values for D and E in equation 2 describes the trend of day 1 scum depth decreases. For example, with drop inlets ($E = 1$) and Additive B (D=1), the scum depth decrease according to the regression is $F = 5\text{x}1 + 185 \text{ x } 1 + 120 \pm 56 = 310 \pm 56$ mm (12.2 ± 2.2 in.).

In case the strong effect of inlet type may have obscured any effect of additive on scum depth decrease, day 1 mean scum depth decreases were compared among tee inlet tanks. However, Student's *t*-test showed no difference between those means at the 95 percent significance level. Nor did depth decreases differ significantly between the restroom waste tanks and the RV dump station waste tank.

Laboratory Tests

Laboratory tests can complement field tests by permitting generally closer scrutiny of processes, better control of conditions, and greater replication than field tests can provide. Laboratory column and batch reactors loaded with septic tank scum from the Westley southbound rest area simulated the operation of septic tanks. Column reactors simulated the disintegration of a scum mat in a septic tank, while batch reactors characterized the drainage and density of scum.

The Westley scum was homogenized, screened, and divided. Additive-treated portions received measured doses of the additives A, B, or C, and the prepared scum was loaded into the reactors. Preliminary tests showed that the batch reactors worked poorly in daylight, so the batch reactors were kept in darkened cabinets, and the column reactors were covered.

Column Reactor Tests

Each column was a vertically-mounted 1320-mm (52-in.) length of 73-mm (2.9-in.) bore clear Plexiglas tubing, stoppered at the bottom, and piped to maintain a constant, but adjustable, level of municipal wastewater.

Two liters (0.53 gal) of Westley scum floated

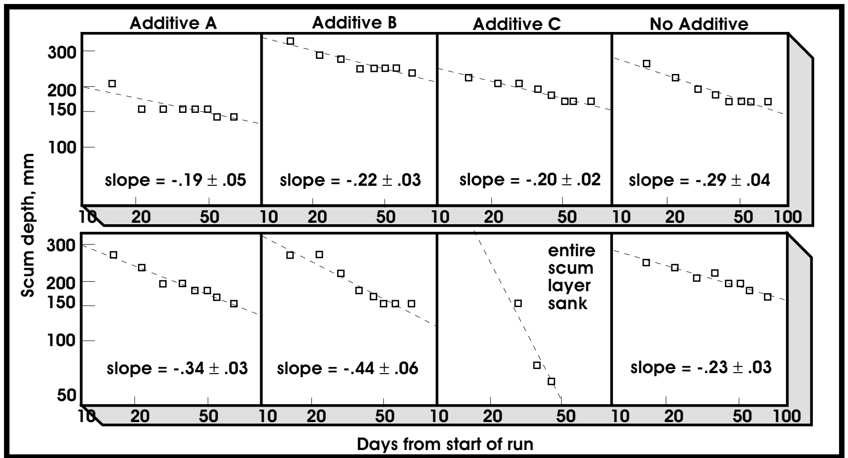


FIGURE 3
Scum Disintegration in Eight Laboratory Test Columns

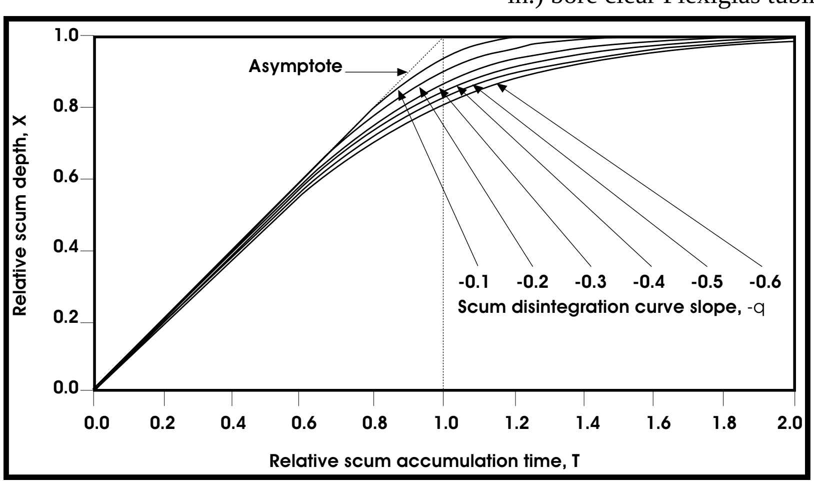


FIGURE 4
Septic Tank Scum Layer Growth Characteristics

on the wastewater. Wastewater was replaced approximately every week. Additive-dosed scum received 1 kg/m^3 (1 g/L) of additive A, B, or C. The eight columns gave two columns for each additive and two additive-free columns.

During the 72 days of column operation, the floating layers of scum progressively disintegrated into the wastewater. Total solids levels in the wastewater increased through the columns. Grab samples of wastewater displaced weekly from beneath the scum layers in the columns showed an average of 0.67 kg/m^3 (670 mg/L) total solids, compared with 0.37 kg/m^3 (370 mg/L) in column influent. Figure 3 shows scum depth versus time in the columns, as log-log plots. The frames show regression lines and numerical slopes with standard errors. In one column with the steepest slope, the entire layer of scum sank during the test. The slopes were significant at 95 percent for all columns.

Line slopes were more consistent among the additive-free columns than among treated columns. For each additive, the slopes of lines for the treated columns bracketed the slopes for additive-free columns. The regression slopes were compared between additive-treated columns and untreated controls. For that purpose, a Boolean additive variable was incorporated into the regression, as described previously for field data. In no case was the Boolean variable significantly correlated with scum depth. So no additive was shown to significantly affect scum disintegration in the columns.

Figure 3 shows that disintegration kinetics of a scum layer obey $x = pt^{-q}$, in which x = scum depth, t = time, and p and q are constants, with q values shown as the slopes of the regression lines.

For the additive-free control columns, the slopes are -0.23 and -0.29, or approximately -0.25. Also for illustration, the depth of scum at unit time, p, may have approximated the calculated depth of each initial two-liter charge of scum in a 73 mm (2.9-in.) diameter column, which amounts to 478 mm (18.8 in.). Substituting these p and q with t = 15 days in $x = pt^{-q}$ yields a calculated scum depth of x = 244 mm (9.6 in.). At 15 days, the observed depths in the additive-free columns were some 240 and 255 mm (9.5 and 10 in.).

For a septic tank in the field, the rate of change of scum depth may be the scum supply rate minus the disintegration rate. Functionally, $x' = r - qpt^{-q-1}$, where r = scum supply rate, mm/day. Substituting for t, the differential equation governing scum depth reduces to $x' = r - qp^{-1/q}x^{1+1/q}$. Then the scum layer would grow to a limiting depth at which $x' = 0$, which is $(rq^{-1}p^{1/q})^{q/(1+q)}$.

For simplicity, normalize scum depth to X, the fraction of the limiting scum depth. The normalized limiting scum depth is unity. Also, normalize time to T, the ratio of actual time to characteristic time, $T = t_1/t_2$. Here, t_1 is the actual scum accumulation time since the tank was emptied. Characteristic time, t_2 , is the time taken to attain the limiting scum depth at the prevailing scum supply rate without any disintegration of scum.

When normalized, the scum supply rate becomes unity. The normalized differential equation governing scum depth is $dX/dT = 1 - X^{1+1/q}$. Figure 4 shows the relative scum depth and accumulation time as fractions of maximum depth and characteristic time. In practice, the asymptote might be considered to approximate the growth of a scum layer, with a uniform increase in depth until a steady-state depth is attained. The steady-state depth and the time to attain it depend on the scum supply rate and scum disintegration test results as described above.

It becomes possible to compare the steady-state scum depth as estimated from column test results with field observations of limiting scum depth at a particular scum supply rate. One estimator of the scum supply rate is the rate of recovery of scum depth at the end of the field runs, which was quite similar among tanks, as figure 2 shows. Table 1 (or figure 2) shows this rate of recovery as $r = 25$ mm/day (1 in./day) in the septic tank with the most well-defined recovery, tank 1.

For a scum accumulation rate of 25 mm/day (1 in./day), the limiting scum depth estimated from column test results would be $(rq^{-1}p^{1/q})^{q/(1+q)} = 350$ mm (13.8 in.), based on $q = 0.25$ and $p = 478$ mm (18.8 in.) as imputed for additive-free columns. Accumulation of scum at 25 mm/day (1 in./day) would take 14 days to attain the 350-mm (13.8-in.) limiting depth. For comparison, when the field tests began, the actual depth of scum in tank 1 was 380 mm (15 in.), six weeks after pumping the septic tanks. Furthermore, in field tests the scum layer in tank 1 recovered most of that initial depth in about two weeks, as figure 1 shows. Thus, an estimate of steady state scum depth based on column test results matched the observed scum depth in the field. However, column tests do not address whether or how certain field conditions such as septic tank hydraulics or sludge gasification may affect scum disintegration kinetics.

Batch Reactor Tests

The batch reactors were 500 mL Erlenmeyer (conical) flasks. Duplicate reactors received 500 mL of scum treated with additives A, B and C, at doses of 0.1, 0.1 and 10 kg/m^3 (1 kg/m^3 = 1 g/L). Quadruplicate control batch reactors received 500 mL of additive-free scum. The reactors were weighed before and after filling. In another identical set of reactors, the scum was dosed with slaked lime from pH 5.8 to pH 8.4, because neutralizing the acidity of the scum might have promoted biodegradation.

After 28 days in storage, any free water was poured off. The reactors were weighed and scum volumes were measured approximately against the flask calibrations. Scum densities were computed. Figure 5 shows the resulting relative volume and density of the scum in the unlimed and limed reactors. Relative volume is the residual scum volume as a fraction of its initial 500 mL volume, being less than unity because water drains from the scum. Relative density is the density ratio of scum to water, which must be less than unity in order for the scum to float.

For unlimed scum, the drainage of water during the test approximately halved the scum volume. Relative volumes averaged 0.52, varying little with additive dose. Relative densities averaged 0.96. At all doses of additive B, and at the highest dose of additive A, the dosed scum was denser than the additive-free scum, though such dosed scum was still generally less dense than water.

Liming evidently weighted the scum, because most aliquots of

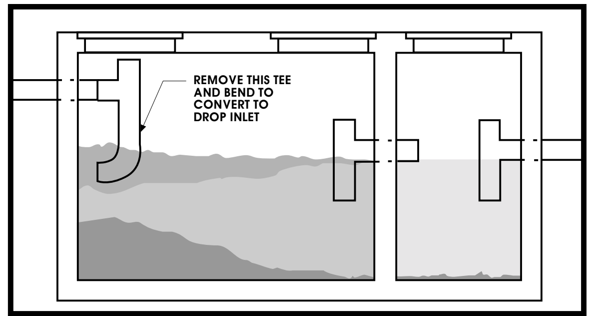


FIGURE 6
Schematic Diagram of Septic Tank Tee Inlet and Drop Inlet

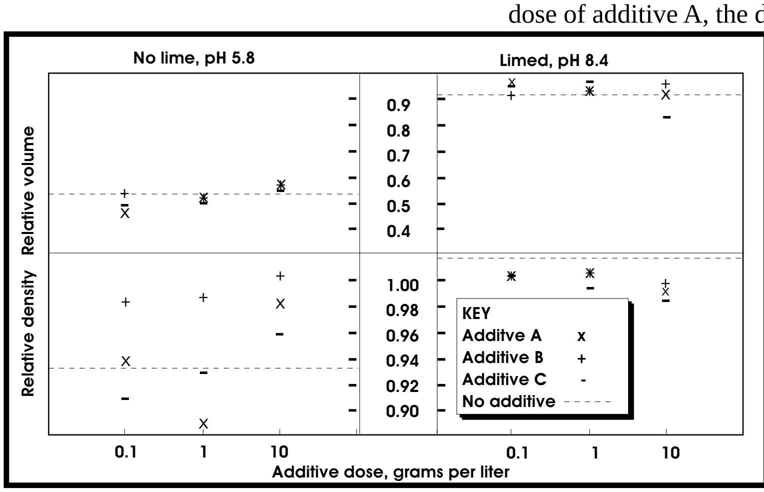
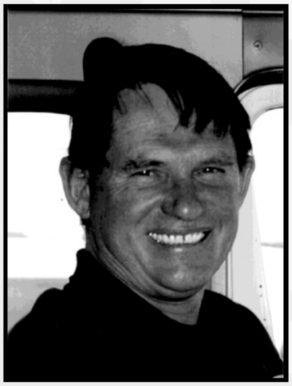


FIGURE 5 —
Scum Volume and Densities in Batch Reactors



Frank Pearson

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limed scum sank; relative densities at the end of the tests averaged 1.01. Relative volumes averaged 0.93, varying little with additive dose.

Conclusions

Scum exists only because it is buoyant. Lighter-than-water wastes such as fat and oil always float and should be removed from the waste if significant. Test column results show that the toilet paper-derived scum would sink, possibly by disentraining gas bubbles from the heavier-than-water paper solids. Field results emphasize agitation as a scum control measure in septic tanks, particularly in conjunction with a drop inlet. Sinking the scum could prolong septage pumping intervals by exposing the solids to the degrading sludge. Field results showed that a drop inlet controlled scum better than conventional tee inlets did—based on scum thickness measurements at the inlet manholes—and that no biological additive used significantly controlled the scum.

Various methods of mechanical agitation could help reduce the contribution to septic tank scum from heavier-than-water materials such as paper. The simplest method would be hand plunging at intervals of perhaps one-half the time taken for excessive scum to accumulate. Other mechanized agitation methods include mechanical paddling, hydraulic jetting, and pneumatic sparging.

Agitation for scum control would appear mostly suited to septic tanks larger than domestic size. Whatever the septic tank size, agitation should only be used in a tank with multiple compartments. In a single compartment septic tank, a drop inlet or any other agitation would tend to disrupt settlement and risk the discharge of excessive solids to the leach field. In any case, multiple compartment septic tanks are advisable to avoid high levels of solids in the effluent, due to agitation of the tank contents by gas released from the degrading sludge, particularly in summer.

Alternatively, to lessen or avoid a need for external agitation, a septic tank might be designed to safely retain a depth of scum that disintegrates as fast as it accumulates. Field observations and laboratory column test results suggest that for toilet paper scum mats in septic tanks, deeper mats disintegrate faster. Deeper scum mats submerge more, where hydrostatics tends to dislodge bubbles. For any given rate of scum supply to the septic tank, the scum mat will tend to deepen until its rate of disintegration (plus the rate of any loss of scum to the septic tank outlet) equals the scum supply rate.

Septic tank designers might provide sufficient freeboard in a tank to retain the limiting depth of scum corresponding to the prevailing scum supply rate and disintegration kinetics.

The septic tank inlet should enter at a level above the limiting scum surface. Provision for easy conversion between a conventional tee inlet and a drop inlet could be advantageous in a multiple-compartment septic tank subject to scum mat formation. Figure 6 illustrates a possible arrangement which permits simple modification to raise the water level so as to increase scum storage volume if needed.

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