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United States
Environmental Protection
Agency

Office of Water
(WH-546)

832R89001

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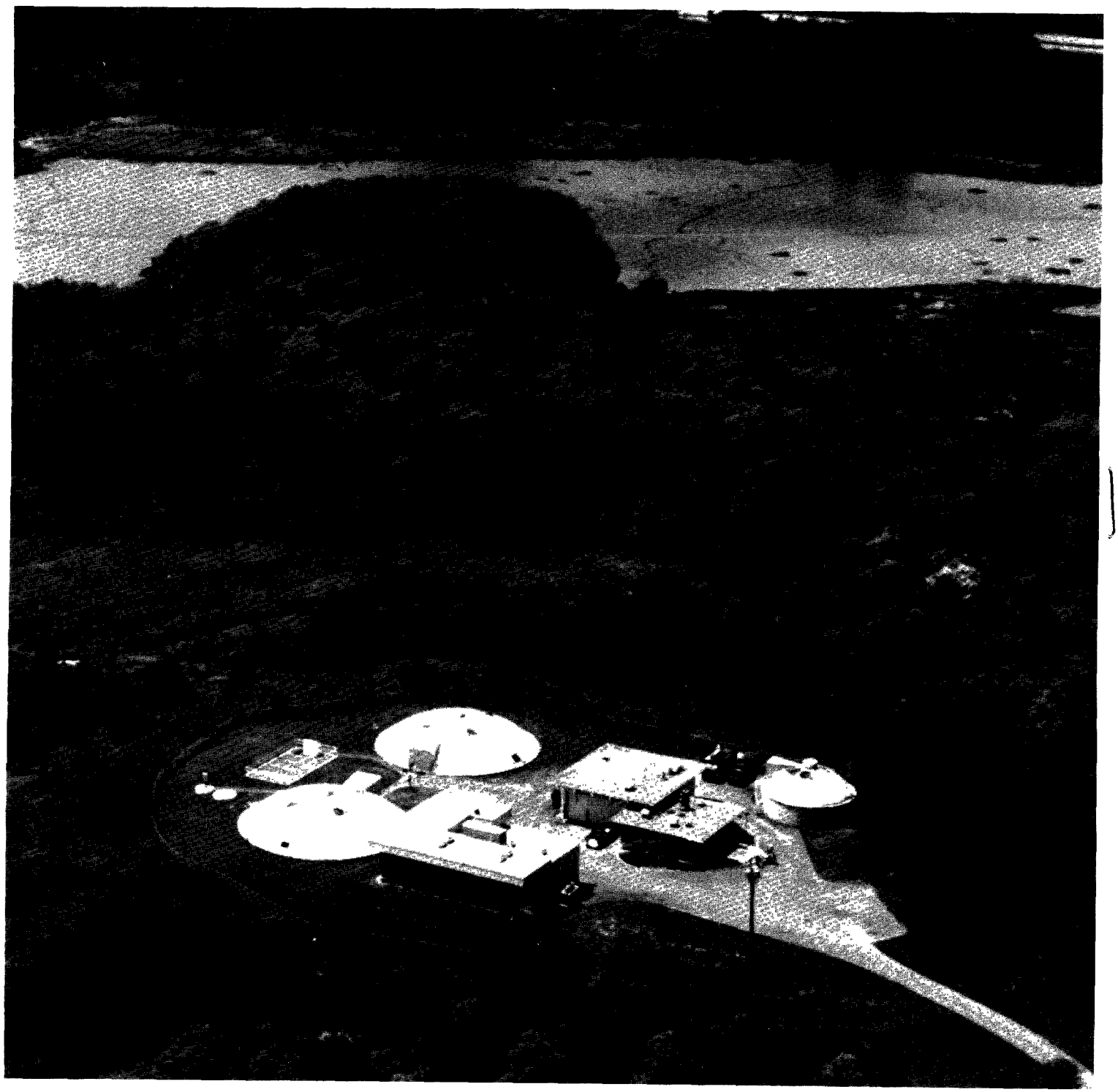
Analysis of Performance Limiting Factors (PLFs) at Small Sewage Treatment Plants



This brochure was prepared by EPA's Office of Municipal Pollution Control, Planning and Analysis Division. EPA was assisted in the preparation of this brochure by the staff of Roy F. Weston, Inc.

Analysis of Performance Limiting Factors (PLFs) at Small Sewage Treatment Plants

March 1989

Office of Municipal Pollution Control
Office of Water
U.S. Environmental Protection Agency
Washington, D.C. 20460

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EPA IS TRANSFORMING DATA INTO SOLUTIONS

The Environmental Protection Agency has long been gathering data on the successes and problems of federally funded wastewater treatment systems. Operational difficulties have been carefully scrutinized, especially those leading to permit violations. Small systems often suffer most from frustrating operational problems. Plants sized between 0.1 and 1.0 mgd are more likely than larger plants to be underfunded, understaffed, and not always reached by the professional networks that can offer troubleshooting advice.

Since 1982, the On-Site Operator Assistance Program, created under Section 104(g) (1) of the Clean Water Act, has been sending technical experts to small POTWs to help operators and managers solve debilitating problems. The program is hands-on, interactive, and very successful. Its approaches are briefly described in the accompanying sidebar.

Since the program's beginning, the *"104"* troubleshooters have compiled operation and maintenance evaluations (OMEs) for the plants they have visited. Each of these describes recommendations and solutions prescribed for the plant. It also records the plant's problems using a checklist of 21 performance limiting factors (PLFs). The PLFs are described in Table 1.1 on page 4. PLFs offer a consistent way to categorize the factors that are frustrating good performance at the treatment works.

This wealth of technical information has recently been analyzed to discover what generalized practical advice it can offer about solving operational problems at small POTWs.

THE STUDY APPROACH WAS SHORT AND CLEAN

Analysts examined a cross-sample of small plants that received *"104"* assistance, looking closely at problems and solutions. This sample of 150 POTWs was selected to be representative of all plants in the data base, not just nationally, but within Regions. A checklist was devised to assure that all participants would compile data consistently when reviewing OMEs.

Pilot reviews in two of the EPA Regions proved the quality of the data in the OMEs and helped refine the checklist. OMEs in the remaining eight EPA Regions were then reviewed. The information was analyzed, and the preliminary results discussed in a series of workshops involving project staff. These discussions helped reveal the root causes underlying each PLF, as well as some creative solutions to the problem. Recommendations and conclusions were distilled in the same way.

In what follows you will find extracted the main points from a technical report written for EPA's Office of Municipal Pollution Control. This brochure is primarily for the following audiences:

- Local officials and treatment plant staff ultimately responsible for facility design, construction, and operation;
- State regulatory officials responsible for approving design and assuring compliance of individual treatment plants; and
- The design engineering community.

ABOUT THE SECTION 104 ON-SITE OPERATOR ASSISTANCE PROGRAM

States receive federal grants that support troubleshooting at small plants experiencing performance problems.

These technical experts typically:

- **Visit the POTW.** They perform a diagnostic evaluation by examining the plant; reviewing performance records and monitoring data; and talking over problems with plant managers and staff, as well as community decisionmakers.
- **Develop a training and assistance program.** This program is based on the preliminary visit and may range from recommendations only to an over-the-shoulder assistance and training course.
- **Complete an OME for each facility.** This Operations and Maintenance Evaluation records everything the troubleshooter observed and did: the diagnosis, the problems, the training/troubleshooting approaches applied, and the outcome of activities.
- **Conduct Follow-up for Six Months.** Troubleshooters keep checking in with plant staff for half a year to see that agreed-upon activities are being continued.

To keep records consistent and cross-comparable, each trouble shooter categorizes plant problems using 21 standardized PLFs—"performance limiting factors."

While the *"104"* program is managed by EPA's Office of Municipal Pollution Control in Washington, D.C., and coordinated by the Agency's Regional Offices, the States direct the grants. Some States choose to operate the program themselves, but most conduct the *"104"* assistance program through State Training Centers established under Section 109(b) of the Clean Water Act. These centers are frequently associated with community colleges.

THE FINDINGS: EIGHT PLFS TOPPED THE LIST

The eight PLFs described below are those most frequently cited in the *"104"* data base. Although they often overlap categories, these PLFs can be organized into three main areas:

- Factors Affecting Plant Operation;
- Factors Related to the Design of Small Wastewater Treatment Plants;
- Factors Related to Plant Administration.

Many of the OMEs filed by *"104"* troubleshooters contained excellent solutions or constituted effective case studies. Such information is included here to add dimension to the study findings and conclusions.

Because the formal titles used to identify PLFs are not readily recognizable, PLF's will be italicized in subsequent discussions to make them easier to identify.

❑ *Operator's Understanding & Application of Process Control*

The operator either doesn't understand process control theory, or is unable to apply practical concepts related to it, or both. This PLF was the one most frequently cited. Because it was so broadly defined, it has been difficult to isolate as a discrete issue. Indeed, it is often cited in conjunction with other more specific factors affecting plant performance, such as *plant staffing* and process *design errors*.

❑ *Facility Staffing*

Staffing problems most frequently identified in the OME reports were: too few staff, staff with many competing duties, or no staff at all. Excessive turnover and lack of experienced staff were also mentioned.

❑ *Support from the Municipality*

This PLF covers unproductive municipal policies and actions concerning the day-to-day operation of the treatment plant. Poor support is often synonymous with inadequate funding. *"104"* troubleshooters cited some specific problems:

- Plant staff were not empowered to make decisions on operations, maintenance, and administration;
- Administrative procedures were restrictive;
- Administrators were unfamiliar with plant needs;
- There wasn't enough money to hire and keep good staff and to perform basic O&M.

❑ *Infiltration/Inflow (I/I)*

Excessive flows overwhelm the plant and/or its operator. I/I is short- hand for the two main extraneous flows entering the wastewater collection system. Infiltration is groundwater leaking into the system through cracks or breaks

in pipes or structures. Inflow enters via sewer system connections like roof leaders, basement drains, land drains, and manhole covers.

❑ *Process Design Errors*

These are mistakes made in the plant design. Examples include improper sizing of process units or selection of equipment and lack of operational flexibility.

❑ *Solids Handling and Disposal*

This PLF was the second most frequently cited. It indicates that the plant's performance problems are due to faulty solids handling procedures inside the treatment works and/or the lack of an adequate sludge disposal system. This PLF is often associated with *operator's understanding of and ability to apply process control.*

❑ *Preventive Maintenance Program*

Preventive maintenance problems are logged under this PLF. Plant staff are not regularly inspecting, cleaning, and maintaining mechanical hydraulic, electrical, and process equipment. The result can be reduced service life of the equipment and facilities, unexpected breakdowns, and higher operating costs.

❑ *Laboratory Capability for Process Control and Discharge Permit Monitoring*

Either staff have not been trained in the correct use of existing laboratory equipment, or the proper hardware is lacking with which to collect data for process control and discharge permit compliance reporting. In half the cases where it appeared, this PLF was the only one cited.

Table 1.1 Performance Limiting Factors (PLFs)

PLF Code	Description of Performance Limiting Factor
A	Poor Understanding and application of process control by operator
B	Staffing (too few staff, low pay, turnover, etc.)
C	Support from municipality (administrative and technical)
D	Operating budget and user charge system
E	Operability and maintainability considerations (process flexibility, automation, standby units, etc.)
F	Infiltration/Inflow
G	Construction problems
H	Process design errors (clarifiers, aerators, disinfection, etc.)
I	Over design
J	Under design
K	Solids handling and sludge disposal
L	Pretreatment, industrial discharges, and toxics
M	Operation and maintenance manual
N	Preventive maintenance program
O	Spare parts inventory
P	Chemical inventory
Q	Laboratory capability for process/NPDES testing
R	NPDES reporting
S	Equipment/Unit process broken down/inoperable
T	Hydraulic overload
U	Poor aeration system

1. SOME FACTORS MAINLY AFFECT PLANT OPERATION

Solid Operation is Built on Staff Expertise

Successful day-to-day operation of a treatment plant is perhaps most critically dependent on the *operator's understanding and ability to control the treatment process.* Troubleshooters cited deficiencies in this area more frequently than in any other.

Operators experienced difficulties in two main areas: solids management and process monitoring (i.e., poor sampling protocol, analysis, and/or data interpretation). While *solids handling* and *process monitoring* are separate PLFs in their own right, they overlap substantially with the *operator understanding and application* issue.

Proper Solids Handling is Vital

Overall operation was limited at many plants where solids handling equipment was not properly operated. The incorrect use of sand drying beds was particularly prevalent. Failure to clean beds of dried sludge and reload them with sludge from the clarifiers boosts the solids inventory and undermines plant operations. Inappropriate operation and poor maintenance of solids handling equipment were cited in several OME reports as the primary cause of poor plant operation.

Savvy Lab Control Keeps Operations on an Even Keel

The operation of a treatment plant is dependent on complex biological and chemical reactions. Data from process control monitoring provide a type of "biofeedback" on the whole system, identifying needs for adjustment and control. If the process test results are incorrect or no testing is being done, it becomes virtually impossible for the operator to run the plant as designed. Some specific process control-related problems were:

- The operator lacks the knowledge of how to run basic laboratory procedures necessary for process control and NPDES reporting.
- The operator is conducting the required tests, but lacks the knowledge to interpret the data and apply them to the operation of the plant.
- The plant was constructed with a well-equipped laboratory, but it is not being used.
- The operator is using inadequate sampling techniques and/or is miscalculating process control set points. The incorrect results

Solutions

Poor operator understanding of basic treatment plant operation is focused on a lack of understanding and application of solids inventory control and improper monitoring. 104(g) trouble shooters typically approached these basic skill deficiencies by providing guidance in techniques for keeping daily plant operating records, calculating wasting rates, and properly wasting sludge from the final clarifiers. Trainers have also recommended that operators attend training and certification courses sponsored by the state water quality agency or the regional or state operator's associations.

The facility O&M manual should also include a detailed discussion of sludge facility operation. Operational checklists for sand drying beds should be included in the O&M manual to direct and operator in a step-wise fashion on how to load and unload sand drying beds.

that arise are generating false and often misleading information about plant performance.

- Because of problems with hardware or staff expertise, the treatment plant is using offsite labs to conduct NPDES testing. This approach has distinct disadvantages: it diverts funds needed at the plant and it fails to provide the process control information that is needed regularly.

Operators Must Be Flexible in Responding to Variable Loads

Many small treatment plants experience difficulty in adjusting to changes in the strength and volume of sewage entering the plant. This problem was cited frequently in OME files, particularly in the Midwestern regions and older areas with combined sewers. Yet the operator's ability to adjust process control to accommodate variable organic and hydraulic loads is crucial to the plant's ability to meet its discharge limitations.

Very small treatment plants can be upset easily—overloads can be caused by just one industrial user on the system, or by wet- weather flow conditions. The most frequent operational problem resulting from *I/I* was solids washout during high flow events. This typically resulted from the combination of *excessive I/I flows* to the plant and poor *solids management*.

Since high-inflow events are ephemeral by nature, they probably occur more often than they are observed or revealed through data analysis. While a thorough understanding of the treatment process can help an operator handle such problems, even experienced operators were often unable to cope with particularly high loadings.

Table 1.2 **Five Most Frequently Occurring PLFs* by Region**

Region I	**A****	**K**	**C**	**B**	**F**
Region II	**A**	**K**	**F**	**H**	**N**
Region III	**Q**	**A**	**K**	**F**	**B**
Region IV	**A**	**K**	**F**	**Q**	**B**
Region V	**A**	**K**	**F**	**Q**	**B**
Region VI	**A**	**C**	**K**	**B**	**F**
Region VII	**A**	**Q**	**K**	**B**	**F**
Region VIII	**A**	**N**	**C**	**H**	**K**
Region IX	**A**	**N**	**K**	**Q**	**H**
Region X	**A**	**C**	**Q**	**F**	**H**

***As identified in the 104 data base**

****See Table 1 for a listing of the PLF codes.**

Design Errors Can Frustrate Operations

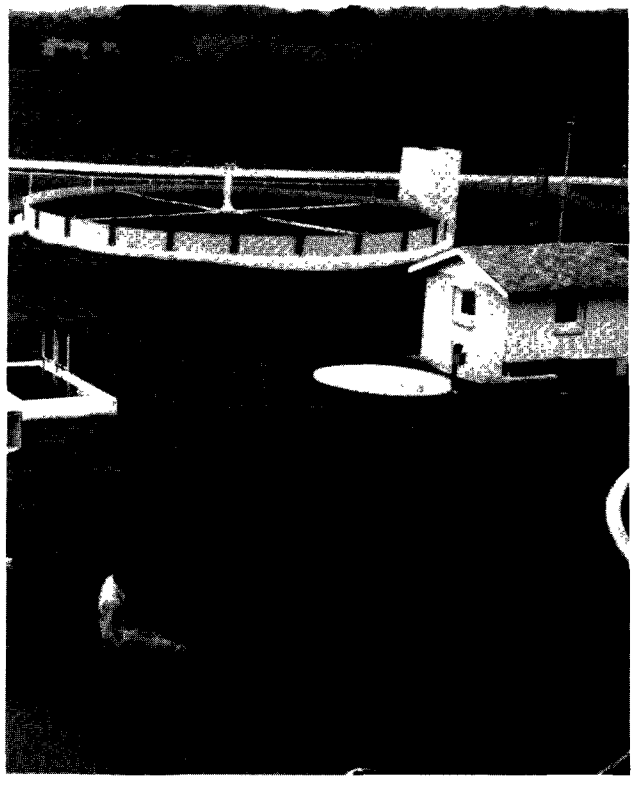
The POTW's design can exacerbate the impact of other factors limiting plant performance by being inflexible, unreliable, or only marginally capable of meeting its own operating parameters. On the other hand, top-notch operation can be used to overcome design deficiencies.

Although design errors were generally not identified as the primary factor undermining plant performance, 27 percent of the OME reports stated that they contributed to poor performance.

Maintenance is the "Flip Side" of Operations

Operations also suffered where the *preventive maintenance* system was inadequate or nonexistent. The plant operator is generally responsible for running this program; thus, its absence or ineffectiveness can be seen as a result of operator inexperience.

An effective preventive maintenance program will reduce the cost of operating the facility over time by increasing the service life of many of the plants' major components. The lack of such a program leads to crisis management, inefficient operation, and unreliable performance.



Case Study

A 0.3 mgd trickling filter plant located in the Mid-Atlantic region was experiencing frequent violations of its fecal coliform limits. The OME reported that operators were not using the correct sampling and test procedures for pH, chlorine residual, and fecal coliform, and were not correctly recording what monitoring data was being gathered.

The correct sampling, testing and record keeping procedures were presented to the plant operators and to plant administrators. Particular attention was given to making sure that the operators understood the correct method for conducting the fecal coliform test. The plant was then monitored for 12 months, during which time the plant experienced no violations of its NPDES limits.

2. OTHER FACTORS RELATE TO THE DESIGN OF SMALL WASTEWATER TREATMENT PLANTS

Poor Design Can Exacerbate Problems Caused by Inexpert Operators

Poorly designed treatment plants compound the problems resulting from inadequate operator expertise. Design deficiencies were cited as contributing to poor performance at nearly 18 percent of the plants whose OME files were reviewed. Furthermore, they were discovered in 30 percent of the cases where the *operator's lack of knowledge and application* was cited.

Too frequently, plant designers have appeared to disregard the realities of small plant operation. The simplest, most flexible approach is often overlooked in favor of a scaled-down design more appropriate for a larger plant. A simple design with some redundant unit processes built in can do much to overcome imperfect expertise and still achieve acceptable performance.

Some Wastewater Designs May Be Too Complex for Small Communities

Certain wastewater treatment processes are just more difficult to run than others. Indeed, an underlying cause of problems related to the *operator's understanding of the treatment process* may be the prevalence of activated sludge plants, even in the smallest plant-size category. These plants are much more complex than lagoon and fixed-media processes, and may not be appropriate where staff skill levels are likely to be low.

Small Towns Can Be Unpleasantly Surprised By Plant Staffing Needs

The design of a small wastewater treatment plant can aggravate *staffing* or other *administrative* problems. *"104"* troubleshooters interviewed several town administrators who said that they were not made aware of (or perhaps just didn't "hear") the plant's full staffing requirements during either the planning or design phases. Officials also failed to realize how difficult it would be to obtain staff with the skills or talents necessary to run their plant. Many small community budgets can't absorb the cost of hiring the full complement of staff demanded by the facility's design. The result: the plant ends up operating with fewer—or less qualified—staff.

The Case of the Disappearing Flow Capacity

Design was also observed to play a supporting

role in the *I/I problems* identified at some plants. While it is easy to say that the plant was not designed to handle peak flows, there is another side to the story. Engineers may design a treatment works with a certain maximum capacity in good faith, after the municipality assures them that it will fix the existing I/I problem to save money on plant size. "Design problems" arise when the I/I "fix" is never carried out.

Sometimes Designers Just Make Mistakes

The basic design process for sewage treatment works is well developed for the types of facilities found in the OME reports reviewed. Nonetheless, in numerous instances, designers had plainly made errors in planning specific unit processes. These are summarized below on Table 2.1. Design errors seem to be most prevalent in the inlet works and the sludge dewatering equipment. At the headworks of the plant, engineers often failed to install adequate bar screens, comminutor, or similar devices. The sludge dewatering equipment was frequently undersized for the amount of sludge the plant produced.

Case Study

Poor performance at a 0.75 mgd rotating biological contactor facility in Georgia was attributed to a lack of operator skills, an undersized secondary clarifier, and an inadequate sludge drying bed area. The 104(g) trainer worked with the operator to develop skill in process control and to specifically overcome design deficiencies that were contributing to the poor performance. The operator learned how to control the solids inventory and to monitor the process. Alum was added to mitigate the effect of the undersized clarifier.

Solids Handling: A Design Issue?

More than 75 percent of the plants with *solids handling and disposal* problems identified undersized dewatering facilities, especially sand drying beds, as being responsible. Several *"104"* troubleshooters reported treatment works that were designed with no solids handling facilities at all! These cases were usually extended aeration plants. One Regional *"104"* coordinator believes that consulting engineers have somehow misrepresented the process, implying that it would produce little or no sludge.

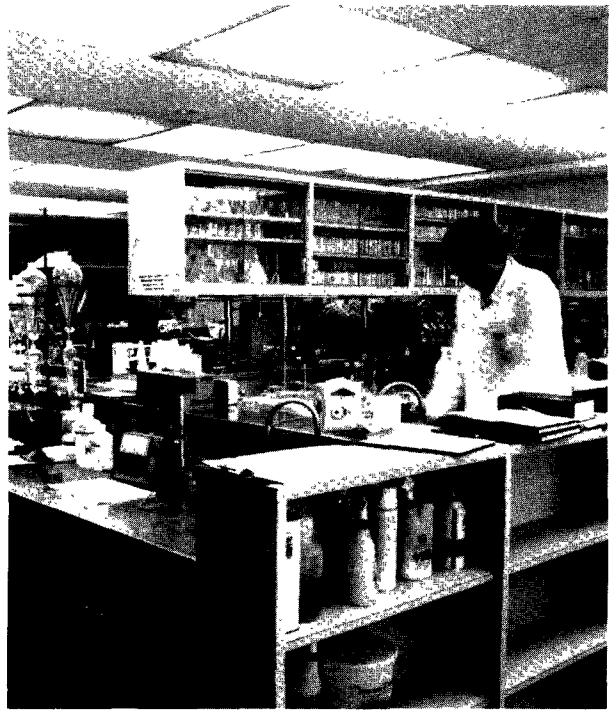
Table 2.1 Categorization of Design Problems by Unit Process

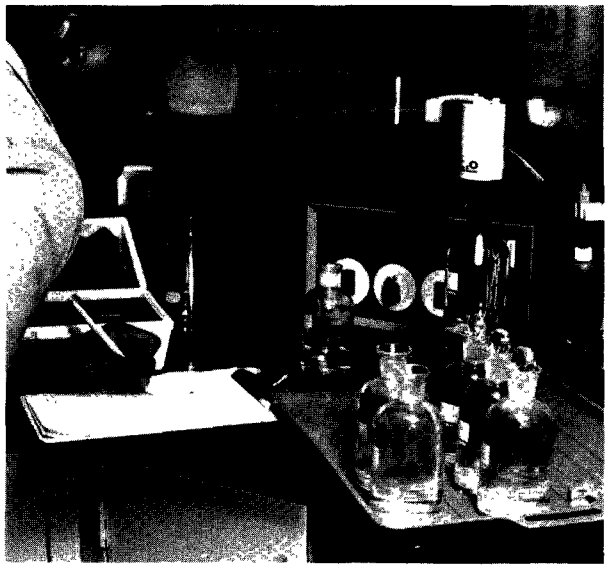
Item	Type of Process Unit	Primary or Secondary Performance Limitation	Number of Times Cited*
A.	Inlet Works	Secondary	13
B.	Primary Clarifier	Primary	2
C.	Aeration Basins	Secondary	6
D.	RBC or Trickling Filter	Secondary	10
E.	Lagoon	Secondary	3
F.	Secondary Clarifier	Secondary	5
G.	Disinfection	Primary	2
		Secondary	8
H.	Sludge Transport	Secondary	2
I.	Sludge Dewatering	Secondary	15
J.	Sludge Digestors	Primary	2
		Secondary	3

*Number of times a design problem was cited for a particular unit process in the OMEs reviewed during the study

Poorly Designed Laboratories Undermine Plant Performance

Two design-related issues contributed to laboratory problems and their related effects. First, engineers failed to design a laboratory into the plant (although this was reported in only two of the OME files reviewed). The more widespread deficiency was design of an inadequately supplied laboratory. This design limitation was observed in more than half of the OME files reviewed where *laboratory capability* was cited as the dominant PLF. Centrifuges and settleometers were identifed as the equipment most frequently missing.





Solutions

Laboratory capability was a frequently cited problem at many of the treatment plants assisted by the program. If no lab was present the 104(g) trainers assisted plant staff in identifying other laboratory facilities which could perform the necessary analyses. If equipment was missing from an existing laboratory then trouble shooters identified what equipment the town needed to purchase. In cases where limited funds prevented the town from purchasing the equipment, a financial plan was developed that identified the source of the funds in future budget cycles.

3. CERTAIN FACTORS ARE TIED TO PLANT ADMINISTRATION

It can be claimed that lack of municipal support is at the root of nearly all of the other PLFs, since it was found to contribute to operational and even to design problems.

Administrative Apathy Can Debilitate Operations

No treatment plant can operate successfully without good staff. And at the plants where *staffing* was identified as the dominant factor frustrating plant performance, administrative issues were blamed in one-third of the cases reviewed. These issues included lack of administrative support or funding for training, and failure to fund the hiring and retention of good staff.

Another one-third indicated that the *staffing* problem was aggravated by a user charge that was set too low to cover the costs of plant operation. This is an example of the overlap that occurs between PLFs. While the visible problem is *staffing*, the root cause is a lack of *support from the municipality*.

Town Managers Who Ignore Staff Needs Find that Turnover is High

In more than 30 percent of the OMEs that named *staffing* as the dominant PLF, turnover was cited as a problem. It is not surprising that staff turnover is high at small treatment plants. Some small towns do not offer adequate salary levels. The position often has a low job prestige level. Low operator morale is the general rule, and was implied as an aggravating factor in many OMEs. Most capable people stay only long enough to get some experience and then move up to a larger town where the pay is better. Naturally, plant performance suffers as each new recruit learns the ropes.

Operations Deteriorate When Officials Ignore Training

One-third of the OME files listing *staffing* as the dominant PLF cited operators and staff with insufficient experience and training. Often, plants were being operated by personnel whose State-required certification was below the level specified in the plant's O&M manual, or who had no certification at all. Small communities

Case Study

A 0.22 mgd aerated lagoon in the northeast was experiencing frequent violations of its discharge permit. 104(g) experts identified insufficient and inappropriate use of staff as the problems afflicting the plant.

The Village Administrator was the only certified operator, but had so many other duties that he was only able to attend to the plant sporadically. The plant was also staffed by a part-time laboratory technician. The lack of adequate staffing resulted in many problems at the plant, including a build up of sludge in the lagoon and numerous maintenance deficiencies. It was determined during the OME that sludge had never been wasted from the lagoons since the plant went online.

The recommended solutions consisted of hiring a full time certified operator for the plant and having the Village Administrator provide a limited amount of assistance. It was also recommended that the part time laboratory technician position be increased to full time. The village followed through on these recommendations and plant performance improved significantly.

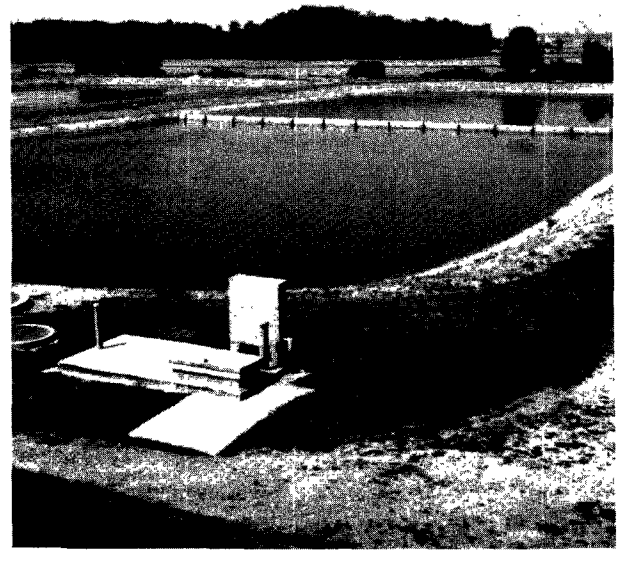
often withhold *municipal support* by failing to include any money for staff training in their wastewater budgets. This prevents the operator from attaining the proper level of certification.

Some Municipal Administrators Stretch Staff Too Far

Small-town treatment plant operators are commonly assigned to other public works duties that restrict the amount of time they spend at the plant. In this case, *poor municipal support* means assigning too low a priority to the physical and technical needs of the sewage treatment plant. A person with too many jobs will perform none of them well, and will probably be too busy to train thoroughly on the technical aspects of wastewater management.

Authority Struggles Can Lead to Poor Operations

Lack of municipal support can also mean a poor relationship between the municipal administrator and the wastewater treatment plant manager/operator. A balance of power must be achieved between these two if the facility is to operate well. This balance is difficult to achieve if the plant staff is constantly turning over. Issues in this area centered around poor *delegation of authority*. In some cases, the plant operator was prevented from ordering even basic equipment and supplies. In others, the plant manager was not permitted to hire or fire staff at the facility.



Inadequate User Charges Set the Stage for Troubled Performance

Inadequate user charges were identified in more than a third of the OME files where a *lack of municipal support* was cited as the dominant limiting factor. In many cases, the user charge system hadn't been evaluated since the plant went on line. While costs steadily rose, the budget either shrunk or remained constant.

Many user charge systems provided only enough money to pay staff and meet the basic requirements for utilities and expendable supplies. Such systems failed to include funds for proper parts, maintenance, and capital replacement (i.e., a sinking fund for purchasing major components). Aging treatment plants without the resources for refurbishing equipment are headed for permit violations sooner rather than later.

Solutions

The solutions identified for dealing with staffing issues generally require additional funds. Among the solutions recommended by the 104(g) trainers were:

- Performance of staffing evaluations to determine the real number of staff and level of skills needed to run the plant well;
- Hiring additional staff to bring the plant up to the level identified in the O&M manual as necessary for its operation;
- Assigning staff full-time to the treatment plant;
- Providing funding so that the operator of the plant is able to receive training and attain the certification level necessary to run the plant; and
- Using temporary work crews for non-technical maintenance tasks such as painting and lawn mowing.

4. CONCLUSIONS & RECOMMENDATIONS

Diagnostic evaluations and on-site troubleshooting are, by definition, reactions to existing problems. The conclusions and recommendations that follow are aimed at heading off such problems before they arise.

The information is organized for two audiences: The section on "Plant Design and Startup" is for the engineering design community; "Management and Regulation" is for those state and local officials ultimately responsible for plant compliance. Both engineers and officials should find all the material of interest, however.

❒*PLANT DESIGN & STARTUP*

CONCLUSION 1: ACTIVATED SLUDGE MAY NOT BE A GOOD DESIGN CHOICE FOR MANY SMALL PLANTS

The OMEs suggest that many plant designers are not considering the unique needs of small rural communities when selecting plant processes.

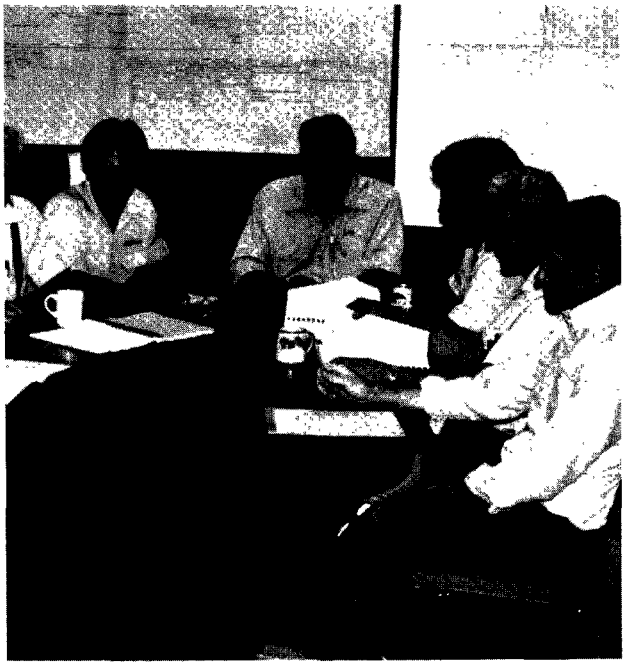
Activated sludge plants make up more than 60 percent of the plants included in the *"104"* data base. Yet report after report cited operators who did not adequately understand the activated sludge process or were not removing and disposing of solids properly. It is a fact that the activated sludge process requires more operator training and experience than fixed media or lagoon processes, and that process monitoring and laboratory knowledge (either at the plant or from a contract lab) are critical to proper process control. Small communities are the least likely to be able to provide such expertise.

RECOMMENDATIONS

1. Design engineers should recognize that small rural plants are not often able to keep highly skilled operators. **They ought to give fuller consideration to simpler treatment processes such as fixed media or lagoons.** Only where these techniques are unfeasible due to land limitations, climate, or other constraints should the activated sludge process be considered.

2. **The many alternative/innovative, low-technology systems that are easy to operate and maintain should be given increased consideration in the facility planning process.** They include facultative ponds, constructed wetlands, intermittent sand filters, communal leach fields, and other variations on land treatment.

3. **The final selection of a treatment technology should be based on a complete net present worth analysis including all annual costs**—staff salary, equipment maintenance, periodic recruitment of operators, staff training, monitoring, power equipment replacement, administrative costs, and full costs for sludge treatment and disposal. The cost of sludge treatment and disposal should be based on a conservative estimate of sludge quantity and solids content. Many of these costs are not considered or only liberally considered in most cost effectiveness analyses, biasing these assessments toward selection of conventional treatment technologies.



CONCLUSION 2: PLANT INFLEXIBILITY UNDERMINES OPERABILITY

While lack of plant flexibility was not a specific PLF, it was an underlying cause of difficulties at plants where poor operator understanding of process control was cited. Such plants often lacked the redundancy in unit processes that will permit a clarifier or aeration basin to be taken off-line for repairs or cleaning. This problem even exists in lagoon systems: two of the OMEs reviewed cited single lagoons and inflexible piping.

Plant inflexibility is also an issue relative to I/I. Many of the troubleshooters who identified I/I as the main PLF noted that the plant did not have sufficient capacity to accommodate higher flows during wet weather. Even a skilled, knowledgeable operator can do little to improve performance under such rigid circumstances.

RECOMMENDATION

4. **Designers should conscientiously build flexibility into small systems.** Rather than scaling one or two large clarifiers down to one medium or small clarifier, two small clarifiers should be specified. This recommendation applies not just to piping configurations and redundant unit processes, but to the use of variable speed pumps for sludge wasting and return and the application of flexibility in aeration. Overall, it is recommended that small plants be designed to accommodate a variation in flow of +/- 30 percent. Equilization tanks could also be considered to handle I/I flow extremes.

CONCLUSION 3: SMALL PLANTS HAVE FRONT- AND BACK-END PROBLEMS WITH PROCESS DESIGN

The OME files revealed O&M problems arising from certain unit processes, chiefly plant headworks/grit removal and sludge dewatering and disposal.

Many small plants were designed with inadequate screening and, in some cases, no primary clarifiers. Grit, rags, and solids were building up in the rest of the plant. Difficulties with the solids processing train led many *"104"* trainers to recommend abandoning sludge dewatering systems and moving to land application of liquid sludge.

RECOMMENDATIONS

5. **Although it may be cost effective to design plants with no primary clarifier and easier to dewater secondary sludge only, the entire plant should reflect these design approaches.** Pumps, piping, and aeration systems should all be designed to accommodate increased solids and rags in the system.

6. **Operators should be made fully aware of the need for removal of floating debris that passes primary screening.**

7. Small plant operators have widespread problems with **solids handling.** Thus, it is strongly recommended that engineers designing for them **always consider the feasibility of liquid sludge disposal.** Rural communities typically have relatively easy access to agricultural land and other areas suitable for disposal of liquid sludge*. In most cases, this will be found to be a cost-effective technique that also lessens the demand for technical expertise on the part of the plant operator.

* EPA and most state regulations do require that sludge be stabilized properly prior to disposal.

CONCLUSION 4: HEAVY LOADS CAN CONFOUND UNDERSKILLED OPERATORS

Hydraulic and organic overloading of small treatment plants was another common occurrence underlying many of the operational problems. Typical in cases where *I/I* was cited as the PLF, overloading was also identified in several OME reports as operators' inability to maintain process control. Small treatment plants are clearly susceptible to problems resulting from excess loading, particularly where the operator has limited experience.

The basics of wastewater design prescribe that the plant should have the capacity to handle the anticipated hydraulic and organic loading. Unfortunately, this is not always a simple matter, given the economic conditions in small towns. During facility planning the design engineer may duly discuss the need for hydraulic capacity to accommodate I/I. And to economize on plant costs, the town in good faith promises to fix the I/I problem. However, what often happens is that the plant goes on line without the capacity to accommodate wet weather peak flows.

Furthermore, small communities tend to see increased organic and industrial loads as a boon, not a problem. Small rural communities may often look past wastewater capacity problems in efforts to secure employment opportunities. Many communities are reluctant to bring stringent requirements to bear on an existing industry, including pretreatment requirements, even if the municipality's treatment plant cannot accept the load. Side-stepping of such constraints is even more common when a new industry proposes moving into the community.

RECOMMENDATION

8. It is recommended that **design engineers and community administrators carry out frank discussions during the planning process and agree on realistic loading levels for the facility.** It is incumbent on the design engineering community to take a conservative, if not skeptical, approach to the design of small plants and to take steps that accommodate I/I and industrial loadings realistically.

❒ *MANAGEMENT AND REGULATION*

CONCLUSION 5: STAFFING DIFFICULTIES AGGRAVATE POOR PERFORMANCE

Clearly, small communities have a great deal of difficulty attracting and keeping trained wastewater treatment plant staff. Analysts saw difficulty with staffing—which includes inadequate staff size, deficiently trained staff, and high staff turnover—reported very frequently, either as a PLF in its own right or as a contributing factor to other PLFs.

RECOMMENDATIONS

Because staffing is a pervasive problem, solutions must be broad-based.

9. **Increase operator status and visibility.**

Even small rural treatment plants need a strategy for finding and keeping good operators. Components should include:

> Full-Time Position — At least one full-time (or nearly so) operator/superintendent.
>
> Adequate Pay — Salary that is competitive with other critical municipal functions like police chief.
>
> Reasonable Authority — For budgeting, purchasing, hiring, and firing.
>
> Professionalism — Reasonable opportunities for staff training and certification.

These minimum requirements are a quantum leap forward for many small communities. Such a substantial shift will call for a change in attitude and the money to underwrite improvements.

10. **Seek to Attract Better Staff.**

Incentive-based pay levels for plant superintendents and operators would be one way of increasing compensation, while at the same time improving plant performance and the likelihood that the community is receiving a benefit equal to or greater than its increased outlays. Pay increases, even performance bonus pay structures, are feasible only where the municipality can afford the salary levels.

One radical approach to the staffing problem would be for states to require certain minimum "critical mass" for the areas served by new rural treatment plants. This could be accomplished by providing service through regional wastewater management districts serving, say, no fewer than 5,000 residents. These larger districts would be more able to afford realistic salaries and attract capable staff. A practical constraint on this approach can be excessive sewering costs which may be necessary to create such a district.

It is becoming more apparent that one of the biggest short falls in the industry is day-to-day operational expertise. This shortfall could be met by using circuit riders to supervise a number of small rural treatment plants. Several

small towns could pool resources to offer an adequate salary. Pooling also affords economies of scale in purchasing supplies and securing laboratory support.

11. Strive to Keep Good Staff.

Other measures will be needed to develop and advance staff so that turnover is minimized and capable people stay. One recommendation is that training outreach efforts be increased in rural areas. While low population density can make personalized outreach costly, computerized technical assistance and training may be the wave of the future. Many small communities now own personal computers, at City Hall if not at the treatment plant. Electronic bulletin boards and on-line training programs are promising methods for creating real wastewater professionals in small towns.

A second recommendation is that states become more active in verifying the certification of POTW operators. While certification is required in every state, the OMEs revealed widespread disregard for adequate certification. Serious regulatory attention to this important issue may affect plant performance positively.

CONCLUSION 6: PLANT BUDGETS AND USER CHARGES MAY BE TOO LOW

While insufficient funding was cited in fewer of the OME reports than was expected, this may be because only a limited number of the OMEs assessed finances in detail. Discussion of underlying problems related to staff pay, sinking funds, preventive maintenance, and operating revenues made it clear that plant budgets and user charges were often too low to meet the facility's current and long term needs. In too many cases, plants were run on general municipal revenues. Salaries were low, plants underequipped, and sinking funds and preventive maintenance funds nonexistent.

RECOMMENDATIONS

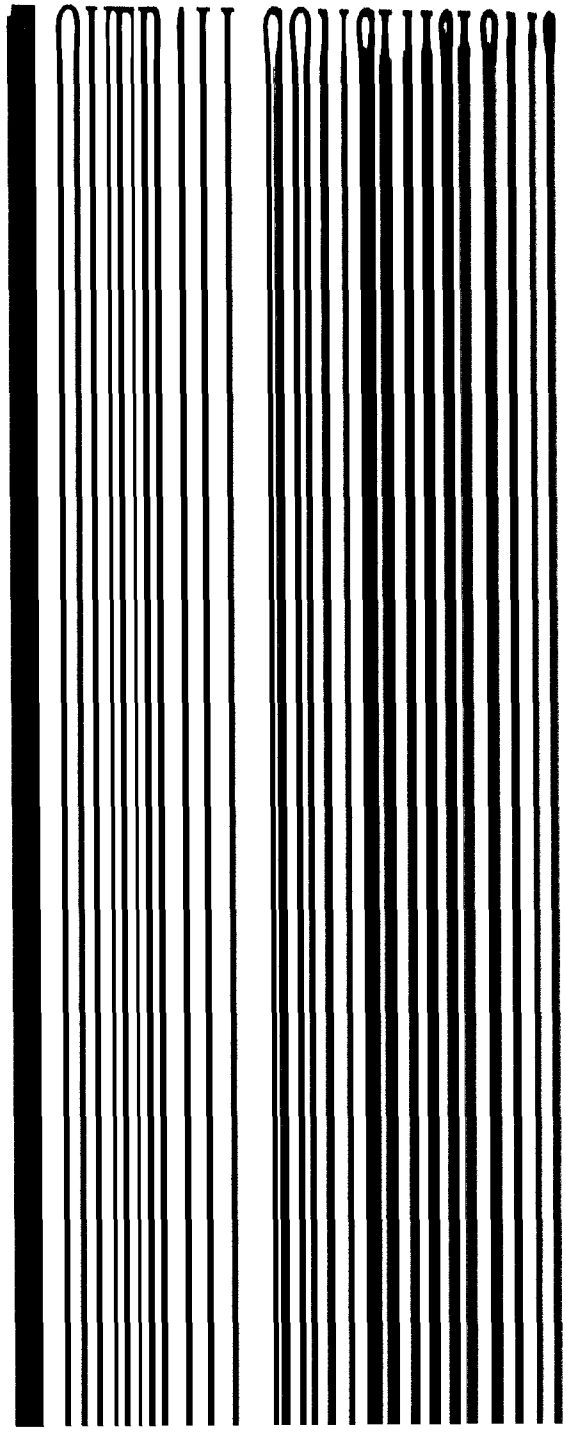
12. **Better fiscal management must start with a separate budget for the treatment plant.** This tool will make it possible to determine if the user charges are adequate to support the facility, and where they are not—to revise those charges. The plant budget should be developed annually to reflect changing cost levels and new requirements for plant upgrading or expansion as well as operations, repair and replacement needs.

13. **It is imperative that the budget provide for a sinking fund to cover replacement of major equipment.**

14. **The budget must also support adequate staff salaries as well as training and required certification courses.**

CONCLUSION 7: MUNICIPAL SUPPORT IS A SUBTLE BUT VITAL NEED

One very successful approach to this issue has been to make the treatment plant into a multi-use facility. The plant and grounds can often accommodate recreational facilities. Offices can be shared with other community agencies or organizations. Rooms can be made available for meetings. One very effective technique is to have monthly town council meetings at the treatment plant.



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CONCLUSION 7: MUNICIPAL SUPPORT IS A SUBTLE BUT VITAL NEED

Although lack of municipal support was not often cited as a problem per se, close reading of the OMEs indicates that it aggravated other PLFs. A community's attitude toward its wastewater treatment function affects many aspects of plant life: morale and turnover; funding and pay; disposal options; facility appearance and maintenance; and even operations. It is doubtful that the foregoing conclusions and recommendations will be adequately addressed unless general awareness and support for the wastewater treatment facility is generated within the community.

RECOMMENDATIONS

15. **Outreach and information transfer must be applied to increasing community support.** American attitudes have historically regarded sewage treatment as an unpleasantness best kept out of sight and out of mind. Wastewater specialists and technologies perform a commendable ecological service for both the human and natural communities. This service needs to be brought closer to the focus of municipal attention.

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❒ *OVERALL CONCLUSIONS*

The Section 104(g)(1) program has been very successful in identifying the factors that have typically limited performance of small treatment plants and in providing solutions to these problems. While the program is a cost-effective approach to meeting these needs, it is, by design, an after-the-fact approach. As the foregoing conclusions and recommendations demonstrate, there are many actions—mostly simple, straightforward, and inexpensive—that can be taken right from the beginning to forestall the problems that can limit small plant performance.