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Preliminary Treatment Facilities

Design and Operational Considerations

PRELIMINARY TREATMENT FACILITIES: DESIGN AND OPERATIONAL CONSIDERATIONS

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This document is based on an EPA research study of the design and operation of preliminary treatment processes at municipal wastewater treatment facilities. The document has been subjected to the U.S. Environmental Protection Agency's peer review. The information contained herein does not constitute EPA policy, guidance or directive, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The continuing efforts to upgrade and improve the level of municipal wastewater treatment throughout the country have stimulated investigations into the design and operation of various unit processes of wastewater treatment facilities. Based on a belief that preliminary treatment processes are a very important, but often overlooked, part of a treatment facility, a study of the design and operation of these processes was undertaken. Preliminary treatment processes can have a significant impact on the efficiency and effectiveness of downstream treatment processes, and should be designed to operate economically and reliably in the removal of grit and screenings from the wastewater flow. The purpose of this investigation was to document possible improvements to the design, operation, and maintenance of preliminary treatment systems for the removal and handling of grit and screenings.

The information in this report is intended to supplement and qualify information available from manufacturers and published literature. The report provides a basic understanding of preliminary treatment systems and presents concise information on design considerations, operational characteristics, and process and equipment problems and possible solultions. The report also addresses guidelines for the design of new grit handling and screenings removal facilities and upgrading of existing facilities. This report will be useful to design engineers, governmental agency review personnel, municipal officials, operators, and others who are considering installing preliminary treatment systems, or who are concerned with optimizing the performance of existing preliminary treatment facilities.

The information for this project was collected from various sources. Available literature and review of previous surveys of wastewater treatment plants established the data base. This data base was updated and supplemented through the inhouse experience of the study contractor and with information from manufacturers of grit and screenings collection and handling equipment. Site visits to wastewater treatment plants nationwide and contacts with manufacturers provided most of the information regarding problems, deficiencies, and guidelines for successful operation of preliminary treatment systems.

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SECTION 1

INTRODUCTION

Preliminary treatment processes are among the oldest in wastewater treatment facilities. Their main purpose is removal of grit and screenings to prepare the wastewater for subsequent processing. Inadequate removal of grit and screenings can result in damage to downstream equipment, disruption of routine operation of that equipment, and disruption of many aspects of plant operation. While many of the nation's wastewater treatment plants have been expanded and upgraded in recent years, in many cases insufficient attention has been paid to preliminary treatment. The information presented in this report is based on an EPA sponsored study of preliminary treatment processes in a variety of facilities throughout the country. The report provides basic information on common preliminary treatment processes and their operational characteristics. Process and equipment problems related to preliminary treatment are discussed, along with possible solutions to those problems. Recommendations for the design of new grit handling and screenings removal facilities, as well as for the upgrading of existing facilities, are also presented.

The report includes several cost curves for estimating the capital and operation and maintenance (O&M) costs of various preliminary treatment processes. Selected case studies from the study are presented to help illustrate the adverse impacts of inadequate preliminary treatment, the possible solutions to preliminary treatment problems, and the benefits of improved preliminary treatment on downstream processes.

This report is not intended as a detailed design guide or as a replacement for other design guides available from manufacturers or for technical information contained in published literature. The report should be regarded as a summary of technical design and operational information, and should be used as a supplement to other sources of information when making decisions regarding the design, upgrading, or operation of preliminary treatment processes.

GRIT CHARACTERISTICS

Grit consists of sand, gravel, cinders or other heavy materials that have specific gravities or settling velocities considerably greater than those of organic putrescibles. In addition to these materials, grit can include eggshells, bone chips, seeds, coffee grounds and large organic particles such as food wastes. Generally, what is removed as grit is predominantly inert and relatively dry. However, grit composition can be highly variable, with moisture content ranging from 13 to 65 percent, and volatile content from 1 to 56 percent. The specific gravity of clean grit particles reaches 2.7 for inerts, but can be as low as 1.3 when substantial organic material is agglomerated with inerts. A bulk density of 100 lb/cf is commonly used for grit. Often, enough organics are present in the grit so that it quickly putrifies if not properly handled after removal from the wastewater (2). Particles 0.2 mm and larger have often been cited as the cause of most downstream problems, but documented evidence is very limited. The historical basis for 0.2 mm as the lower size limit can be traced to an early literature citation (7). There has been little or no subsequent questioning or challenging of this value since that time. Since the term "grit" is, therefore, somewhat arbitrary, the lower limit of grit size of concern will depend upon the nature of the collection system and the wastewater treatment processes and equipment.

Generally, most removed grit particles are retained on a No. 100 mesh (0.15 mm) sieve, reaching nearly 100 percent retention in some instances. However, grit can be much finer. In the southeast, where fine sand known as "sugar sand" constitutes a portion of the grit, less than 60 percent of one city's grit was retained on a No. 100 mesh screen.

Grit quantities removed vary greatly from one location to another and depend on collection system type (separate or combined); winter road sanding; condition of sewers; infiltration and inflow (I/I); presence of household garbage grinders; scouring velocities in sewers; the growth of slimes on sewer walls; and the efficiency of the grit removal system itself. Ranges of from 1/3 to 24 cu. ft of grit per million gallons of flow have been reported (1). Table 1 shows typical data on removed grit quantities in several cities (2) (8).

It is difficult to interpret grit removal data because grit itself is poorly characterized and almost no data exist on relative removal efficiencies. The information on grit characteristics derives from what has been removed as grit. Sieve analyses are not normally performed on grit chamber influents and effluents. For these reasons, the efficiencies of different grit removal systems cannot be compared in relative terms, except in a side-by-side study.

SCREENINGS CHARACTERISTICS

Screenings are the material retained on screens. The smaller the screen opening, the greater will be the quantity of collected screenings. While no precise definition of screenable material exists, and no recognized method of measuring quantities of screenings is available (3), screenings exhibit some common properties.

Coarse screenings (collected on racks or bars of about 1/2 inch or greater spacing) consist of debris such as rocks, branches, pieces of lumber, leaves, paper, tree roots, food particles, fecal matter, rubber products, plastics, and rags. The rag content can be substantial and has been visually estimated at 64% and 70% of total screenings volume on coarse (>1-inch) screens (3). Coarse screenings are highly organic in nature (70-90% or more), have a nominal dry solids content of 10-20%, and density of 40-70 lb/cf (2, 17, 34, 35) Coarse screenings amount to 0.5-5.0 cu. ft/million gallons of flow, but can be much greater at plants served by combined sewers, particularly during storm events.

TABLE 1
QUANTITIES OF REMOVED GRIT AND SCREENINGS (2,8)

Plant	Flow MGD	Grit cu.ft/mil gal	Screenings cu.ft/mil gal
Norwalk, Connecticut	11.75	3.3	0.17
Portsmouth, Virginia	9.7	0.39	0.82
East Hartford, Connecticut	4.0	2.4	1.33
Oklahoma City, Oklahoma Southside	25.0	1.95	2.1
Taunton, Massachusetts	3.5	1.11	1.0
Uniontown, Pennsylvania	3.0*	10.5	0.9
Fargo, North Dakota	2.7*	1.0	4.55
Minneapolis-St. Paul, Minnesota	134. *	5.2	0.9
Waterbury, Connecticut	15.	4.15	2.35
Bridgeport, Connecticut, East Side	14. *	1.25	2.04
Duluth, Minnesota	12.	0.8	0.56
Marshalltown, Iowa	4.0	3.4	0.25
Richmond, Indiana	6.2*	2.0	3.44
Detroit, Michigan	450. *	4.0	0.47
E. Bay Mun. Utility., S.D. No. 1 WPCP	128.	1.26	0.83
Chicago, Illinois, Northside	333.	0.41	0.83
New York, New York, Jamaica WPC	100.	2.24	0.42
New York, New York, Port Richmond WPC	60.	0.50	0.17
New York, New York, North River WPC	220.	1.50	1.0
San Francisco, California, Southeast	30.	--	11.7
Boston, Massachusetts, MDC, Nut Island	112.	0.68	0.41
St. Louis, Missouri, Lemay	167.	2.69	0.06
Passaic Valley Treatment Plant	225.	3.82	0.76
Allegheny Co., Pa., Alcosan WTP	200.	3.32	0.38
Fort Worth, Texas, Village Ck. WTP	45.	1.29	0.72
Hampton Roads Sanitary District, Chesapeake-Elizabeth WPCP	12.	2.17	1.17
Lamberts Point WPCP	20.	4.85	1.20
County of Milwaukee, South Shore WTP	120.	0.48	0.60
Twin Cities Metro, WTP	218.	4.82	1.15
Santa Rosa, California, College Avenue	--	0.88	--
San Jose, California	143.	2.5	--
Manteca, California	--	5.2	--
Santa Rose, California, Laguna	12.	5.0	--
Seattle, Washington, West Point	125.*	2.6	--
Dublin-San Ramon, California	--	7.0	--
Los Angeles, California, Hyperion	420.	2.0	--
Livermore, California	6.25	1.0	--
Gary, Indiana	--*	8.6	--
Renton, Washington	--	4.1	--

* Large percentage of combined sewers

Fine screens with openings from about 0.01 to 0.25 inches are normally used downstream of coarse screens for protection from large objects in the wastewater stream. Screens with 0.09-0.25-in. openings remove 5-10% of influent suspended solids, while those with openings of 0.03-0.06 inches can remove 10-15% of suspended solids, although greater removals have been claimed (3). Fine screenings have been reported to have volatile solids contents of 68-99%. Compared to coarse screenings, their bulk densities are slightly lower and moisture contents are somewhat greater. Because some suspended solids are also collected with fine screenings, quantities are considerable, ranging from 5-30 cu.ft/million gallons, or more (1).

The amount of screenings captured by different sizes of screens has not been ideally established since each wastewater has its own unique characteristics. British studies (3, 36, 38, 39) have yielded removal curves for specific and nominal municipal wastewaters at different screen openings. U.S. screenings capture vs screen opening curves are also available (34, 35, 41). Each curve differs owing to the nature of the wastewater, but all indicate that finer screens remove more material than coarser ones and that for any given sewerage system removals increase with flow. Therefore, screens must be capable of handling the quantities of screenings which will be generated during peak flows.

Because putrescible matter, including pathogenic fecal material, is contained within screenings, they must be carefully handled. Fine screenings contain substantial grease and scum, which require substantial care in handling.

EQUIPMENT AND PROCESS PROBLEMS

Recognition of the problems associated with inadequate preliminary treatment has recently begun to emerge. Among the major findings are that downstream and sludge system impacts related to inadequate grit and screenings removal are extensive; that accelerated equipment wear due to heavy grit loads can result in expensive and time-consuming repairs; and that jamming or clogging of process equipment by screenings can require significant manpower efforts to remedy. Some specific studies include:

EPA Surveys (4, 5) - A U.S. EPA survey of 287 municipal wastewater treatment plants revealed that preliminary treatment was rated the 15th most common design deficiency adversely affecting plant performance.

Environment Canada Survey (6) - A survey of Canadian treatment plants found that of the plants surveyed:

- Thiry-two percent experienced problems with grit removal.
- Twenty-four percent experienced problems with comminution equipment.
- Fifteen percent had screening problems.

British Survey (3) - The British Construction Industry and Information Association's (CIRIA) Technical Note 119, Screenings and Grit in Sewage: Removal, Treatment and Disposal, listed a number of impacts, including:

- Many downstream problems are caused by ineffective screening or comminution. Unfortunately, these problems are often considered normal or unavoidable by plant operating personnel. These problems include settlement of solids in pipes, channels and chambers; collection on weirs and stilling boxes; blockage of pumps, heat exchangers, and pipelines; frequent repair and cleaning of anaerobic digesters due to fouling of mixers and loss of available volume; and blockage of small diameter pipe work associated with sludge dewatering equipment.

- Disintegration (grinding/comminution) of screenings and their return to the plant flow causes more problems than screenings removal.

- Fine screens are seen as a way to eliminate downstream problems. However, capital and O&M costs are significantly higher due largely to greater volumes of screenings.

- Inefficient removal of grit causes fewer and less severe downstream problems than inefficient removal of screenings. However, downstream problems most frequently cited as grit related are settlement in wells, chambers, channels; accelerated wear of pumps; and buildup in anaerobic digesters.

SECTION 2

PRELIMINARY TREATMENT PRACTICE

Some form of preliminary treatment is provided at most wastewater treatment plants in the United States. The 1984 Needs Survey conducted by the U.S. EPA (33) shows over 15,000 wastewater treatment facilities now in use with a variety of preliminary treatment processes. That survey also indicates that over 6000 treatment facilities are yet to be built. Based on these estimates, it can be anticipated that there will be a significant level of activity in the design of preliminary treatment processes for new plants, and in the upgrading and replacement of processes and equipment in existing facilities.

COMMON EQUIPMENT TYPES AND THEIR BASIS OF DESIGN

Characteristics of Grit Chambers

Horizontal-flow grit chambers and aerated grit chambers represent the two most commonly used grit chamber designs in the United States. Recently, devices in which the flow goes through a vortex motion have appeared, along with fine static screens that have been used successfully to remove larger grit particles. Fine static screens are discussed more thoroughly under the "Screens" portion of this Section.

In horizontal flow chambers, flow velocities of 0.5 to 1.0 ft/sec and a chamber sized to provide a 1-minute detention are historic design criteria (7). The grit particles settle under gravitational force. The maximum velocity reached by the particle at which it continues to settle is called the terminal velocity. The terminal velocity of a 0.2 mm diameter particle (specific gravity of 2.65) has been experimentally established at about 0.075 ft per second. For particles of equal specific gravity in the same liquid, the theoretical settling velocity varies as the square of the diameter (Stokes' law). Consequently, a 0.1 mm diameter particle of the same density would settle about one-fourth as fast. For a given flow velocity, a horizontal flow chamber must either be about four times longer at equal depth, or one-fourth as deep at equal length, to remove the smaller diameter particle. Although grit chambers are designed to allow grit to settle and organics to remain in suspension, the settled grit can in fact contain significant organic material, requiring separate grit washing (3).

The two principal types of horizontal flow grit chambers are long, velocity controlled channels and square, shallow sedimentation (detritus) tanks. Velocity controlled channels have been used since at least the 1920's. The theoretical length must be increased by as much as 50 percent to accomodate inlet and outlet turbulence (1). To maintain the design velocity of 0.5 to 1.0 ft/sec, channels of rectangular cross section use proportional or sutro weirs; parabolic channels use rectangular control sections or a Parshall Flume. The weirs require a free discharge and hence need relatively more head loss (approximately 36 percent of the flow depth).

In larger plants, grit is usually removed from channels by a conveyor with scrapers, buckets or plows. Screw conveyors or bucket elevators are used to elevate the removed grit for washing or disposal. Because velocity controlled channels often serve older, big city plants with combined sewer systems, the grit removal machinery is subjected to excessive wear due to the larger grit load, and may be hard to repair because of its age. In smaller plants, an additional grit chamber is usually provided so that one unit may be taken out of service and the grit removed manually with shovels, clamshell buckets, or other devices. Some older small plants may have long grit channels without a section to control velocity. These may experience velocities significantly greater than the design velocity of 1.0 ft./sec.

Detritus tanks are shallow, short detention sedimentation tanks that have been in use for about fifty years (9). They are nominally designed to remove 95% of 0.15 mm diameter (100 mesh) particles at peak flow. Influent is distributed over the cross-section of the tank by a series of vanes, flows in straight lines across the tank, and overflows a weir in a free discharge. Settled grit is collected with a circular rake, and then may be pumped through a hydrocyclone to separate remaining organic material and concentrate grit. The concentrated grit then may be washed again in a classifier utilizing a submerged reciprocating rake. A reciprocating rake alone is also used to separate organic solids from the collected grit. Head loss, through the influent gates and over the effluent weir, is modest. As with long channels, however, the grit removal and washing equipment is subject to extensive wear.

Aerated grit chambers remove grit by creating a spiral rolling motion with diffused air. They are nominally designed to remove particles 0.2 mm or larger, with 2-5 minute detention times. Whereas horizontal flow grit chambers are "once through", in aerated grit chambers, the spiral flow results in a particle making two or three passes across the tank bottom at maximum flow, more at lesser flow. The size particle of a given specific gravity which is removed is governed by the amount of air, which should be adjustable, and the design of the basin, baffling, inlet and outlet. The roll maintains the lighter organics in suspension, allowing the longitudinal flow to eventually carry them out of the tank.

Aerated grit chambers have become very popular in the U.S. and Canada in the last several decades; over 500 were in place 20 years ago, with many more added since then (13). Their popularity is due to more controllable performance, benefits of preaeration and grit washing due to the introduction of diffused air, and low headloss.

The equipment used to remove grit from aerated chambers includes that used with velocity controlled channels, as well as air lift pumps, grit pumps, and vacuum trucks. Tubular and screw conveyors reportedly discharge the dryest grit (12, 13), while air lift pumps are particularly suitable for small plants because of their low first cost. Grit removal equipment for aerated chambers is subject to the same wear experienced in horizontal flow chambers.

Various configurations for aerated grit chambers have been used (12, 13), ranging from square tanks to long, narrow channels. Although there is some flexibility for site considerations, overall shape may not be as important as proper placement of air diffusers, volume of air, and adequate influent and effluent baffling (12).

Grit is also removed in devices with a vortex flow pattern. The two principal devices are the PISTA™ and the Teacup™, both proprietary.

In the PISTA™ grit trap, wastewater tangentially enters and exits a cylindrical basin. At the bottom of the basin is an axial flow propeller, and below this, a conical hopper. The propeller maintains constant flow velocity, and its adjustable pitch blades promote separation of organics from grit. The action of the propeller produces a toroidal flow path for grit particles. The grit settles by gravity into the hoppers in one revolution of the basin's contents. Solids are removed from the conical hopper either with an impeller-type grit pump, or an air lift pump. The impeller-type pump operates at a higher head than does the air lift pump, and, in conjunction with a cyclonic concentrator, can remove some of the remaining organics in the grit.

The PISTA™ unit is sized to provide 30 seconds detention at average flow, and remove 0.15 mm (100 mesh) particles at a minimun of 0.25 in. headloss. Area requirements are minimal, but the unit is relatively deep (9' to 16').

About 400 units of this type have been installed in over 300 plants in the U.S. (15). The maximum unit size available is 70 mgd; using six of the largest units. All installations are relatively new, hence operating histories are short. European practice has not been fully satisfactory (3).

In the device known as the "Teacup", a vortex is generated by the flow tangentially entering the top of the unit. Effluent exits the center of the top of the unit from a rotating cylinder, or "eye", of fluid. Centrifugal and gravitational forces within this cylinder minimize release of particles with densities greater than water. Grit settles by gravity to the bottom of the unit, while organics, including those separated from grit particles by centrifugal forces, exit principally with the effluent. Organics remaining with the settled grit are separated as the grit particles move along the unit floor.

Headloss in the Teacup™ is theoretically a function of the size particle to be removed and increases significantly for very fine particles. It is claimed that 2 feet of headloss is needed to remove a design 0.1 mm diameter particle. While grit removal and organics separation improve at higher or peak flows, the unit should not be subjected to flows in excess of design peak, or to wide fluctuations in flow. Pumps can level out flow variations, and may be required in any event to provide necessary operating head. Wedgewire screens have been used prior to these units to remove larger solids that could clog the grit underflow drain. However, the screens add additional height and headloss to the unit.

The oldest Teacup installation is only about four years old, so operating experience is limited to new equipment at approximately a dozen installations. The manufacturer of the Teacup™ recommends pilot studies to characterize the grit before final design of a unit, a procedure more suitable for retrofits, or new installations with measureable influents (10). Thus far, units have only been developed to treat peak flows of about 2 mgd, so a large installation would require many units and a means of distributing flow to all such units and keeping flows to each operating unit within prescribed limits.

Characteristics of Screens

Screens used for preliminary treatment are broadly divided into coarse screens and fine screens. The purpose of coarse screens is to remove potentially problem-causing debris, while fine screens are often used to provide a level of treatment approaching primary as well as some degree of grit removal.

Coarse Screens. Design criteria for coarse screens include bar size, spacing, the angle from vertical, and fluid approach velocity. Manually cleaned bar racks typically have 1 to 2 inch openings, are inclined 30-45 degrees from the vertical, and require approach velocities of 1-2 ft/sec. Mechanically cleaned screens usually have clear spacing between 1/2-inch and 1-1/2-inches, are inclined from 0-30 degrees from the vertical, and require approach velocities of 2-3 ft/sec (1). To prevent penetration of debris at peak flows, velocity between bars should not exceed 3 ft/sec. An approach velocity of at least 1.25 ft/sec is recommended to minimize solids deposition in screen channels (16). Head loss through partially clogged coarse screens is typically limited to about 6 inches through operational controls.

Types of coarse screens include trash racks, manually cleaned screens, and various types of mechanically cleaned screens.

Trash racks consist of vertical or inclined bars with clear openings from 2 to 6 inches. They are designed to trap timbers and heavy debris. They are often used in combined systems, and may be mechanically or manually cleaned.

Manually cleaned racks consist of inclined bars across a wastewater channel. Maximum water depth is about 3 to 5 feet in the channel to facilitate manual raking. Screenings are manually removed using a rake with tines matching the openings in the rack. The screenings are pulled up to the top of the rack onto a drainage plate, allowed to drain, then removed to a container for disposal.

An advantage of manually cleaned screens is that there is virtually no equipment to maintain. A disadvantage is that they are labor intensive and prone to clog if not attended regularly (3). They are found most frequently at older small (1 mgd and less) plants, but also serve as bypasses to comminutors and to mechanically cleaned screens in larger plants. They are rarely specified for new plants of any significant size.

Mechanically cleaned screens have been extensively used in the U.S. since the 1920's. Spacing between bars can vary in size but often is about one inch. Once used mainly in the larger plants, they are now being used in smaller plants as well. Mechanically cleaned screens come in several major varieties: chain operated (the most prevalent), reciprocating rake, cable and catenary.

Chain operated screens can be divided into categories based on whether the screen rakes clean from the front (upstream) side or the back (downstream) side of the rack and whether the rakes return into the flow from the front or back. Each type has its advantages and disadvantages, but bacically the operation is similar. In general front clean, front return screens are newer and more efficient in terms of retaining captured solids, but they may be more susceptible to jamming by solids that collect at the rake's base. With back cleaned screens, the bars protect the rake from damage by debris. However, they may be prone to solids penetration, particularly as rake wipers wear out. The rake tines which protrude through the bars may bend and break. All of the chain driven screens share the disadvantage of submerged sprockets that require frequent operator attention and are difficult to maintain. The heavy weight of chains and rakes causes the mechanism components to wear rapidly and require labor for adjustment and repairs. The major disadvantage is that the channel must be dewatered for proper inspection and repair of submerged parts.

A reciprocating rake screen imitates the movements of a person raking. A major advantage is that all parts requiring maintenance are above water and can be easily inspected and maintained without dewatering the channel. The front clean, front return design minimizes solids carryover. They have only one rake, instead of the multiple rakes on chain operated screens; this may limit their capacity to handle heavy screenings loads, but may offer the opportunity to improve removal efficiency by use of intermittent cleaning or "matting" techniques during dry weather flow periods. The high overhead clearance required can limit the instances in which they can be retrofitted.

In the front clean, front return catenary screen, the rake is held against the screen by the weight of the chain. An advantage is that the driving mechanism has no submerged sprockets. A disadvantage is the relatively large amount of space needed to install the screen.

Cable driven screens are front cleaned, front return devices which use a pivoting rake that is raised and lowered on tracks by a cable and drum drive. The rake is lowered by gravity, pivots through the debris, and is raised by the cable drive. The rake itself is the only mechanical part entering the wastewater. The device is limited in its capacity to remove large debris from the screen, and operating experiences with this equipment include problems such as slack cables, fouled cable reels, and improperly operating brake mechanisms.

Fine Screens. Fine screens used for preliminary treatment are distinguished by the small size of the clear openings - from less than 0.01 inches to about 0.25 inches. They may be either fixed (static), or utilize a rotating cylinder or drum. They are designed on the basis of hydraulic loading on the screen area.

Static wedgewire screens with 0.01 to 0.06 inch openings are designed for flow rates of 4 to 16 gpm/in. of screen width (10-30 gpm/sq ft of screen area) and require 4 to 7 feet of headloss. The screens require appreciable floor area for installation, and must be cleaned (usually daily) with high pressure hot water, steam and/or a degreaser to remove grease buildup (14,18).

Rotating wedgewire screens with the same openings have a hydraulic capacity of 16 to 112 gpm/sq ft of peripheral area and require 2.5 to 4.5 feet of headloss. In wedgewire screens, the headloss is attributable to the wastewater entering the top of the unit and flowing down through it. Rotating screens may be fed either from the top or internally. The cascading action of the water helps to clean the rotating wedgewire drum (14,18), although high pressure cleaning is often needed with the rotating screens.

A fine screen should be placed after a coarse screen, such as a bar rack, for protection in large systems (14). They have been retrofitted upstream of grit chambers, and have been used by themselves to remove grit. The high headloss through fine screens means wastewater usually has to be pumped prior to or after the unit.

Comminutors

Comminutors retain solids (screenings) on a screen and shred them until they become small enough to pass through slots (usually 1/4" to 3/8") and proceed downstream. They are in-channel units. While different manufacturers' models share this common feature, designs differ. Units with rotating drum screens operate with the drum nearly submerged. Devices with stationary semicircular screens operate with the screens about half submerged. In a barminutor, solids are retained on a bar rack and shredded by a device that rides up and down on the bars. Headloss through a comminutor usually ranges from several inches to a foot, and can reach three feet or more in large units at maximum flows.

When introduced, it was envisioned that comminutors would completely eliminate the screenings removal phase of preliminary treatment. Furthermore, it was expected that the comminuted solids would be small enough to no longer cause problems with downstream equipment.

Comminutors can theoretically eliminate the messy and offensive task of screenings handling and disposal. This can be particularly advantageous in a pumping station by eliminating the need to handle and dispose of screenings. Installations are compact. In cold climates, their use precludes the need of preventing collected screenings from freezing.

However, the comminuted solids often present downstream problems. The problems are particularly bad with rags, which tend to recombine after comminution into ropelike strands. These recombined rags can have a number of negative impacts, such as clogging pump impellers, sludge pipelines, and heat exchangers, and accumulating on diffusers and digester mixers. Experience in Great Britain, Canada and elsewhere has been generally unsatisfactory, resulting in their elimination from existing plants and new designs (3,37,39,40,42).

Locating comminutors downstream of a grit chamber reduces abrasion on wearing parts, but rag accumulations in grit chambers can be severe. Locating them upstream of the grit chamber may reduce the rag problem, but makes comminutor overhaul due to abrasion more frequent, and grit can accumulate in comminutor channels. New units experience early wear on the lower cutting surfaces in contact with low initial flows.

Comminutors must be maintained to function properly. Comminutors are constructed with a bypass arrangement so that a manual bar screen is used if the unit is down. This arrangement permits screening to continue while the unit is out. In such cases, the high repair cost of comminutors often results in their being left inoperative.

Regardless of their size, comminutors should be high quality, heavy duty devices. They should have cast iron frames with submerged parts constructed of cast iron or of corrosion resistant metal; rotating cutters constructed of stellited, tungsten carbide or equally hard cutting edges; stationary cutters constructed of hardened tool steel; motors with ample capacity to operate the comminutor under maximum conditions of loading; gearheads capable of continuous power transmission at required cutter operating speeds; and a comminutor shaft designed for continuous service which operates in heavy-duty ball bearings and employs mechanical type seals to prevent the entrance of liquid. Motors should either be mounted to avoid submersion under peak flow conditions, or should be capable of submersion without damage.

Sidestream Disintegration of Screenings

This process is similar to comminution, except that screenings are first removed from the flow, then ground up and returned to it. Devices used include comminutor/macerators and hammer mill grinders. Downstream processing disadvantages associated with sidestream disintegration are similar to those affecting in-channel comminution. The disintegrators themselves are often high maintenance items.

Similar to sidestream disintegration is the use of grinders upstream of sludge pumps. Grinders are a "second line of defense" in that their purpose is to reduce larger solids, not removed in the headworks, that could impact pump operation. Grinders themselves are high-maintenance items.

DISPOSAL METHODS

Grit and screenings are generally disagreeable materials to handle. Disposal practice and need are often specific to the plant and its surroundings and reflect character and quantity of those materials as well.

Disposal of grit and screenings must comply with all applicable state and Federal regulations, which are designed to minimize adverse impacts on floodplains, surface and ground water, endangered species, and air quality.

Grit Disposal. Grit may be disposed of as fill and covered if it has not been adequately washed. Small treatment plants often bury grit on plant grounds. In large cities, grit is sometimes incinerated with sludge. However, this practice can have adverse impacts on the operation of incinerators, as discussed in the next chapter. In larger coastal cities, grit is sometimes barged to sea.

Screenings Disposal. Screenings collected from small installations may be buried on site or disposed of with municipal refuse. Large plants may incinerate screenings. However, unground screenings can jam the feed mechanism to the incinerator. The grease and other unstabilized materials contained in fine screenings require that disposal be prompt to avoid odor problems.

SECTION 3

PRELIMINARY TREATMENT PERFORMANCE DATA

Many treatment facilities have downstream treatment problems resulting from inadequate preliminary treatment, but the source of these problems often is not readily recognized. In general, downstream problems are more clearly noted with respect to screenings removal than to grit removal. It appears that grit-related problems (equipment wear and grit build-up) take longer to occur than screenings problems, and are considered more routine in nature.

In order to identify and better quantify some of these problems and the costs related to them, some existing facilities were investigated. A total of 38 plants were contacted in 1985 and 1986 to characterize methods of removing grit and screenings, to identify equipment problems associated with those methods, and to determine the role of preliminary treatment in mitigating downstream impacts. Most of the preliminary treatment methods described in the previous section were included in the sample. The facilities ranged in size from less than one mgd to 900 mgd. Tables 2 and 3 are summaries of the facilities contacted. A number of plants on this list were selected for detailed evaluation based upon their particular experiences with preliminary treatment. Case studies of these facilities are presented in a later section. Additional plants described in detailed articles in the technical literature are also included as case studies.

GRIT REMOVAL

Most treatment facilities report that their grit removal systems are effective if they are not experiencing grit chamber problems. Since there is no readily available method by which an operator can quantify the effectiveness of grit removal, the presumption is that if there are no mechanical problems, the system is working well.

Operators tend not to associate downstream operational problems with poor grit removal. This was so even when downstream impacts such as grit deposition in channels, blinding of vacuum filter cloth, or frequent digester cleanout were noted. Impacts on plant operation were never rated "serious". This indicates that operators may expect grit removal facilities to have limited effectiveness, and to expect a certain amount of downstream impacts as routine.

Table 2 represents a summary of information on grit handling from the plants contacted. The plant ratings are subjective and are based on contact with the plants' operating personnel. Among these plants, aerated and centrifugal grit chambers are good performers in the eyes of their operators. Horizontal flow grit chambers have experienced problems with grit removal equipment, which has impeded their effectiveness.

SCREENS AND COMMINUTORS

The effectiveness of screens and comminutors is more readily gauged in terms of the presence or absence of downstream impacts than in the case for grit. Perceived effectiveness is a subjective judgment of operators and reflects quantities of screenings collected, as well as estimates of what has passed through. In general, effectiveness was considered "good" if most of the incoming rags were believed to be removed by the screens. This is so even in some cases where downstream impacts made operation difficult. Downstream impacts from "screenings", generally rags, can jam machinery and wrap around or block just about anything if they get through. Rags also tend to recombine after comminution, or if they are removed, ground up, and returned to the flow.

Table 3 presents the information and subjective ratings obtained on screens and comminutors from the plants contacted. The major findings of this review are:

- About 60 percent of the plants had some downstream impacts related to grit.

- About 63 percent of the plants had some downstream impacts related to screenings (mainly rags).

- Measuring the effectiveness of screens in terms of material retained versus what is passed is not performed.

- Three of the fourteen plants contacted which have a history of comminutor use stopped using them, either abandoning and/or bypassing them, or removing and replacing them with a screen.

- Three plants previously ground screenings and returned them to the flow but have stopped doing so. At one of the two plants that still does this, the practice is being reviewed. Personnel at the remaining plant counsel against the practice of reintroducing ground screenings to the flow due to operating problems downstream of the operation.

DATA SOURCES

Literature

A computer aided key word search produced a list of 400 titles, from which 150 abstracts relating to preliminary treatment were selected and reviewed. From these abstracts, over 40 articles were reviewed in detail. In general, the articles were design-related or focused on descriptions of equipment; information on downstream impacts and quantification of them was minimal. Two articles of particular note are entitled "Screenings and Grit in Sewage - Removal, Treatment and Disposal - Preliminary and Phase 2 Reports". These reports are Technical Notes No. 119 and 122 by the Construction Industry Research and Information Association (CIRIA) and Water Research Centre (WRC) of the U.K. (3,37).

TABLE 2

PLANTS CONTACTED: GRIT REMOVAL

Grit Chamber Type	Plant Size (MGD)	Plant Type	Collection System	Effectiveness of Grit Removal	Downstream Impacts	Extent of Operational Problems
Horizontal Flow						
Velocity Controlled*	0.4	Secondary	Separate	Fair	Yes	Routine
	0.4	Secondary	Separate	Fair	Yes	Routine
	1.0	Secondary	Separate	Fair	Yes	Routine
	2.25	Secondary	Separate	Poor	Yes	Routine
	3.1	Secondary	Separate	Good	No	Routine
	3.4	Primary	Combined	Good	No	Routine
	5.0	Secondary	Separate	Fair	Yes	Difficult
	6.0	Secondary	Separate	Good	No	Routine
	6.0	Secondary	Combined	Poor	Yes	Difficult
	270	Secondary	Combined	Good	Yes	Routine
	900	Secondary	Combined	Poor	Yes	Routine
Detritor	0.6	Secondary	Separate	Fair	Yes	Difficult
	2.8	Secondary	Separate	Good	Yes	Routine
	3.0	Primary	Separate	Good	Yes	Routine
	3.6	Secondary	Separate	Fair	Yes	Routine
	30	Secondary	Separate	Fair	Yes	Routine
	64	Secondary	Combined	Poor	Yes	Difficult
	170	Secondary	Combined	Good	Yes	Routine
Aerated	1.0	Secondary	Separate	Good	No	Routine
	2.5	Secondary	Separate	Good	Yes	Routine
	4.0	Secondary	Separate	Good	No	Routine
	15.0	Secondary	Separate	Bypassed	No	Routine
	24.0	Secondary	Separate	Good	Yes	Routine
	30.0	Secondary	Separate	Good	Yes	Routine

TABLE 2 (continued)

PLANTS CONTACTED: GRIT REMOVAL

Grit Chamber Type	Plant Size (MGD)	Plant Type	Collection System	Effectiveness of Grit Removal	Downstream Impacts	Extent of Operational Problems
Aerated (con'd)	30.0	Secondary	Combined	Fair	Yes	Difficult
	45.0	Secondary	Separate	Good	Yes	Routine
	120	Secondary	Combined	#	Yes	Difficult
	125	Primary	Combined	Fair	Yes	Routine
	180	Secondary	Combined	Good	Yes	Routine
Centrifugal						
Forced Vortex (PISTA)						
	0.65	Secondary	Separate	Good	Yes	Routine
	1.0	Primary	Separate	Good	No	Routine
	1.2	Secondary	Separate	Good	No	Routine
	15	Secondary	Combined	Good	No	Routine
	20	Secondary	Combined	Good	No	Routine
Free Vortex (Teacup)	0.35	Secondary	Separate	Good	No	Routine
	0.5	Secondary	Separate	Good	No	Routine
	1.96	Secondary	Separate	Good	No	Routine
	2.0	Primary	Combined	Good	No	Routine

*Plants below 6.0 mgd did not have sections to control velocity.

#Seventy percent of flow enters after grit chambers.

TABLE 3

PLANTS CONTACTED: SCREENS AND COMMINUTORS

Screen Type	Plant Size (MGD)	Plant Type	Collection System	Screen Opening (In)	Effectiveness of Screen/ Comminutors	Downstream Impacts- Yes/No	Extent of Operational Problems
Coarse							
Manually Cleaned	0.6	Secondary	Separate	1.0	Good	Yes	Difficult
	2.25	Secondary	Separate	1.5	Good	Yes	Routine
	3.4	Primary	Combined	1.5	Good	Yes	Routine
Mechanically Cleaned	1.2	Secondary	Separate	0.625	Good	No	Routine
	9.0	Primary	Combined	1.0	Good	Yes	Routine
	15.0	Secondary	Separate	1.5	Good	No	Routine
	24.0	Secondary	Separate	1.0	Good	Yes	Routine
	30.0	Secondary	Separate	1.0	Good	Yes	Routine
	30.0	Secondary	Combined	1.0	Fair	Yes	Difficult
	45.0	Secondary	Separate	0.75	Good	Yes	Routine
	64.0	Secondary	Combined	2.0	Fair	Yes	Routine
	120.0	Secondary	Combined	1.0	Good	Yes	Difficult
	125.0	Primary	Combined	0.5	Good	Yes	Routine
	270.0	Secondary	Combined	1.0	Good	No	Routine
Comminutors							
Screen in Series Prior to Comminutor	0.4	Secondary	Separate	0.75	Good	Yes	Routine
	0.4	Secondary	Separate	1.5	Good	No	Routine
	3.0	Primary	Separate	1.5	Good	Yes	Routine
	3.6	Secondary	Separate	1.5	Good	Yes	Routine
	4.0	Secondary	Separate	1.0	Good	Yes	Routine
	6.0	Secondary	Separate	1.0	Fair	Yes	Routine
	30.0	Secondary	Separate	3.0	Fair	Yes	Routine

TABLE 3 (continued)

PLANTS CONTACTED: SCREENS AND COMMINUTORS

Screen Type	Plant Size (MGD)	Plant Type	Collection System	Screen Opening (In)	Effectiveness of Screen/ Comminutors	Downstream Impacts- Yes/No	Extent of Operational Problems
Comminutors							
w/ By-pass Screen	1.0	Secondary	Separate	1.0	Good	No	Routine
	1.0	Secondary	Separate	3.0	Good	Yes	Routine
	3.1	Secondary	Separate	1.25	Good	No	Routine
	5.0	Secondary	Separate	1.5	Fair	Yes	Difficult
Fine							
Static	2.5	Secondary	Separate	0.06	Good	No	Routine
	3.0	Secondary	Separate	0.06	Good	No	Routine
	20.0	Secondary	Separate	0.06	Good	No	Routine
Drum	0.65	Secondary	Separate	0.03	Good	No	Routine
	2.5	Secondary	Separate	0.06	Good	No	Routine
	10.0	Secondary	Separate	0.02	Good	No	Routine

These reports indicate the areas in wastewater treatment plants where impacts related to inadequate preliminary treatment occur and conclude that grit accumulation in anaerobic digesters and grit settlement in channels constitute the extent of major O/M problems associated with grit. They also conclude that impacts caused by inadequate screenings removal or comminution are more widely felt. The reports present cost estimates for the aggregate savings achievable by implementing improved screening and comminution in the U.K., where sewage treatment practices and labor practices differ significantly from those in the U.S.

Reports to the USEPA. The following reports on sludge processing identified significant impacts of grit and screenings on sludge handling processes.

- Improving Design and Operation of Multiple Hearth and Fluid Bed Sludge Incinerators (21)

- Improved Design and Operation of Recessed Plate Filter Presses (22)

- Improved Design and Operation of Belt Filter Presses (23)

- Achieving Improved Operation of Heat Treatment/Low Pressure Oxidation of Sludge (24)

- Improved Design and Operation of Centrifuges (25)

These reports identified the impacts grit and screenings had on major equipment items and on elements such as heat exchanger tubes, centrifuge scrolls and nozzles, conveyors, mixers, grinders, pumps, and valves.

Case Studies from the Literature. A limited number of reports of actual plant experiences are in the literature. These reports included information on preliminary treatment improvements as well as frequency and cost of maintenance problems (11,19,27,36,38,39,47,50).

Plants Contacted and Visited

Discussions with plant operators provided information such as time spent in deragging pumps of various types and how often tasks like this had to be performed. In limited instances, information related to equipment repair costs could be obtained.

In general, information on problems and solutions related to screenings was obtained more readily than that related to grit, probably beacuse of the more immediate impact poor screenings removal has on plant operations.

Equipment Repair and Overhaul Specialists

Equipment repair specialists and vendors provided limited information on the costs and frequency of repair of various common plant equipment.

PROCESSES SUBJECT TO IMPACTS

Tables 4 through 8 summarize the impacts of grit and screenings on most wastewater treatment and sludge handling processes. They are arranged according to the following types of treatment:

Liquid Processes - Primary and General Treatment Components
- Secondary Treatment

Sludge Processes - Sludge Conditioning
- Sludge Dewatering
- Sludge Disposal

While the tables may not record every possible impact, they do document the following:

- In a plant with primary and secondary sedimentation, the primaries would experience more grit-related impacts. In a plant without primary sedimentation, relatively more grit would appear in secondary units.

- Grit can have a significant impact on sludge processes, including equipment wear as well as accumulation.

- Impacts related to inadequate screenings removal are more of an operational nature and, in general, do not appear as likely to result in equipment damage which would cause greater time out of service.

- Grit-related impacts are more likely to result in equipment repair or replacement than are impacts caused by inadequate screening.

- Sludge dewatering equipment, with its associated grinders, pumps, valves and small diameter piping, presents numerous opportunities for grit and screenings to cause problems.

TABLE 4

IMPACTS OF GRIT AND SCREENINGS ON PRIMARY TREATMENT & GENERAL TREATMENT COMPONENTS

Treatment Component	Problem	Cause	Impact
Primary Sedimentation	Slippage of chains on sprocket collector mechanisms	Screenings collect on mechanisms	Breakdown of mechanism; take unit off-line to repair
	Jamming of screw collectors in primary tank cross collectors	Screenings	Jamming prevents removal of sludge; take units off-line to clean
	Sludge collectors wear out prematurely	Abrasion due to grit accumulation	Greater frequency of replacement
	Sludge collectors jam	Blocked by volume of accumulated grit	Requires clean out of tank
	Blockage of center feed	Accumulation of rags due to poor screening and comminution	Labor to remove
	Sludge pump impellers wearing & replaced prematurely	Abrasion due to grit	Greater frequency of major repair - (new impellers, etc.)
	Excessive wear on plunger-type sludge pumps, and centrifugal pumps	Abrasion due to grit	Frequent repacking of pumps. Remachining required eventually at 40-50% of replacement cost; Impeller replacement
	Collection on weirs	Screening accumulation	Labor for removal
	Ball check valves on plunger pump discharge do not seat properly	Accumulation of rags	Affects capacity of pump; labor to remove rags

TABLE 4 (continued)

IMPACTS OF GRIT AND SCREENINGS ON PRIMARY TREATMENT & GENERAL TREATMENT COMPONENTS

Treatment Component	Problem	Cause	Impact
Primary Sedimentation (continued)	Increased scum volume	Screenings accumulation	Odors, aesthetic problems; increased removal O/M
	Fouling of level probes	Screenings accumulation	Labor for removal
	Settlement in channels, etc.	Grit & screenings accumulation	Labor for removal
	Excessive pump wear	Grit accumulation	Major repairs more frequent

TABLE 5

IMPACTS OF GRIT AND SCREENINGS ON SECONDARY TREATMENT

Secondary Treatment Component	Problem	Cause	Impact
Activated Sludge - Aeration	Oxygen transfer efficiency of diffusers reduced	Rag buildup on diffusers	Impairs oxygen transfer, especially for fine bubble diffusers; requires more power and possible draining of tank for removal
	Excessive wear of surface aerators and accumulations on submerged turbine or propeller blades	Rag buildup	Loss of O_2 transfer efficiency and increased power required. More frequent replacement cost. Labor to remove rags; may have to drain tank as last resort
	Automatic shutdown of surface aerators	Rag buildup on impellers trips overload switches	Labor to remove rags
	Uneven distribution of flow to aeration tanks	Settlement of grit in distribution channels and accumulation of rags on weir plates	Labor to remove
	Grit accumulation in aeration tanks of plants without primary clarifiers	Grit passing through preliminary treatment	Possible O_2 transfer efficiency reduction; eventually need to have aeration tanks out of service and clean
	Floatables in final effluent without primaries	Screenings passing through secondary	Unaesthetic; permit violations

TABLE 5 (continued)

IMPACTS OF GRIT AND SCREENINGS ON SECONDARY TREATMENT

Secondary Treatment Component	Problem	Cause	Impact
Trickling Filters	Ponding, odors, unaesthetic appearance due to accumulation of debris on media	Screenings passage through distributors	Labor for cleanup of media surface
	Blockage of distributor arms	Plugging by rags	Must flush lines to remove
RBC	Fouling of media and tank accumulations	Screenings and grit accumulation	Potential reduction in treatment efficiency; labor to clean
Oxidation Ditches	Return sludge pumping/ piping clogging	Screenings accumulation	Labor to clean
Secondary Sedimentation	Blockage of draft tubes in rapid sludge removal type clarifiers	Plugging by rags - post A.S. only (w.o. primaries)	Affects sludge removal rate; must flush to remove
	Wear of casing and impeller rings of centrifugal sludge pumps	Grit abrasion - post A.S. only (w/o primaries)	More frequent replacement costs
	Clogging of centrifugal sludge pumps and check valves	Rag accumulation - post A.S. only (w/o primaries)	Labor to remove rags

TABLE 6

IMPACTS OF GRIT AND SCREENINGS ON SLUDGE PROCESSING

Conditioning Method	Problem	Cause	Impact
Heat Treatment	Plugging of various components - Valves - (grit & rags) - Sludge transfer pump - Heat exchange tubes, particularly in sludge to sludge exchanger with stabilizers in annular space	Rags cause plugging. More severe when comminuted rags recombine and form rope-like strands	Shut system down to clean; shutdown and restart waste energy. Cleaning can be hazardous and labor intensive
	Premature wear of some components, especially 180 degree elbows in heat exchangers, pressure-reducing valves, and rubber "boots" of progressive cavity pumps	Abrasion due to grit, compounded by turbulence in the case of the elbows and valves	Shut system down to clean; parts and labor for repair. Progressive cavity pumps have needed new rotors and stators after 1500 hours of operation
Aerobic Digestion	Operational difficulties	Rags accumulate on air diffusers or on mechanical aerator shaft and impeller	Labor to remove rags
		Grit accumulation	Labor to drain, remove and dispose; must shut digester down during cleaning
Anaerobic Digestion	Reduction of effective digester volume	Gradual buildup of grit in digesters	Reduced HRT in digester and reduced stabilization; Reported costs vary from $<1 to >5/100 gallons of capacity

TABLE 6 (continued)

IMPACTS OF GRIT AND SCREENINGS ON SLUDGE PROCESSING

Conditioning Method	Problem	Cause	Impact
Anaerobic Digestion	Floating debris accumulation	Rags	Efficiency of internal gas diffusers and mixers impaired. Labor to remove; access may be difficult, unsafe, and costly.
	Premature wear of digester transfer pumps	Grit abrasion	More frequent repair
	Heat exchanger problems	Rags; screenings	Labor to remove; frequency of cleaning increases during storm periods for combined sewers

TABLE 7

IMPACTS OF GRIT AND SCREENINGS ON SLUDGE DEWATERING

Dewatering Method	Problem	Cause	Impact
Vacuum Filters	Non uniform performance (coil filters)	Rags accumulate under coils	Shut down unit; labor to remove
	Early cake fall-off; Sludge cake will not form or stick	Excessive grit in sludge feed	Reduces cake dryness
Centrifuges	Excessive scroll wear	Grit abrasion	Rebuilt scroll costs $3-50,000, depending on size, plus labor to replace
	Excessive vibration and noise	Unbalancing due to rags	Shut unit down; labor to remove rags
	Sludge feed tube and nozzle erode	Grit abrasion	Replace nozzles and feed tubes; labor to replace for each centrifuge
	Bowl and scroll bind on solid bowl centrifuge	Rags, hair, scum fill space between bowl and scroll	Major labor requirement to disassemble and clean
	Downtime of progressing-cavity sludge feed pumps	Grit abrasion	Parts and labor to rebuild pumps.
	Poor performance of discharge conveyor	Grit erodes parts and clogs screw conveyors	Labor to clean; parts and labor for bearings

TABLE 7 (continued)

IMPACTS OF GRIT AND SCREENINGS ON SLUDGE DEWATERING

Dewatering Method	Problem	Cause	Impact
Belt Filter Presses	Failure of belt roller	Screenings reach belt and then stress rollers	Replacement of roller is expensive and time consuming, and requires temporary shutdown of equipment
Recessed Plate Filter Presses	Cracking of polypropylene plates	Rags get into space between plates	Replacement of plate is expensive and time consuming and requires temporary equipment shutdown
	Clogging of in-line mixers	Rags which carry through to dewatering system	Reductions in sludge flow and poorly conditioned sludge; can result in higher O&M costs for frequent cleaning
	Failure of drives on progressive cavity type feed pumps	Rags bind rotor	Cost of repair at one plant was $2,000; occurred after 2500 hours
	Blockage by grit of vertical sludge discharge line	Grit accumulation "exacerbated" by non-use periods	Three days required to remove line, unplug, and reinstall at one site

TABLE 8

IMPACTS OF GRIT AND SCREENINGS ON SLUDGE DISPOSAL

Disposal Method	Problem	Cause	Impact
Incineration Systems	Generation of black smoke when grit is burned in multiple-hearth furnace	Uneven feed of grit	Exerts high demand on combustion air, causing reduced efficiency of combustion
	Premature wear of sludge feed conveyors	Abrasion caused by grit contained in sludge	Replace auger; requires equipment shutdown
	Clogging of sludge feed mechanisms	Collected screenings jam mechanisms	Interruption in feeder operation to clean

SECTION 4

CASE STUDIES

In this section, 12 case studies of treatment facilities that have experienced problems related to poor grit and screenings removal are presented. The studies demonstrate the nature of the problems encounterd. In some cases, they also illustrate the efficacy of improved preliminary treatment practices.

Plants rarely report retrofits of grit removal systems. Where grit removal problems are recognized, plants normally make modifications to their existing grit system. In some cases simple revisions to operating procedures, such as adjustment of the aeration rate in aerated grit chambers, have been adequate.

In cases in which poor screenings removal is a problem, equipment substitutions are often made. A number of case studies are presented in which substitutions of screening and comminution equipment have been made.

Case History No. G1

A 0.5 mgd secondary treatment plant serves an area with sandy soils. The plant consists of an aerated lagoon, a final clarifier, and a chlorine contact chamber. Extensive maintenance was required to remove grit buildup in the lagoon. The plant was upgraded in 1982 by installing a static screen and Teacup™ grit removal facility before the aerated lagoon.

The grit removal facility prevents the buildup of grit in the aerated lagoon. The screenings consist largely of grit and are collected in metal cans, dewatered, and disposed of in a landfill. The grit removed in the teacup is collected in a separation box, dewatered, and disposed of in a landfill. The system removes approximately 15 cubic feet of grit per million gallons of flow.

Case History No. G2

A 30 mgd primary treatment plant serves an old combined sewer system. Hilly terrain results in a heavy grit load from winter road sanding. Prior to upgrading, grit removal facilities included velocity controlled grit chambers, chain and flight mechanisms, and a grit hopper. Operating problems with the grit system included maintenance difficulties with the chain and sprocket drive collectors and grit carry-over into the primary settling tanks during high flows.

Three years ago, aerated grit chambers were selected for grit removal as part of a plant expansion and upgrading program. During the plant upgrading, the existing chain and flight mechanisms completely failed. The plant was operated without grit removal facilities for a year. During this period, excessive wear on the primary sludge pumps required them to be repacked every two weeks.

Since the aerated grit chambers have been put on line, the plant has not experienced any operating problems due to grit and sludge pump maintenance has returned to a more routine schedule.

Case History No. G3

The grit removal system at a west coast 36 mgd activated sludge treatment plant consists of two aerated grit chambers, 12 grit pumps, and four cyclone grit separators. Prior to improvements in this system, problems included excessive loading and clogging of some of the grit pumps due to grit deposition at the entrance to the chambers, blockage of the separators due to the accumulation of large or light objects in the separators, grit carry-over into the primary settling tanks, and excessive wear on primary sludge pumps caused by grit.

Actions to correct these problems included the installation of manually cleaned bar screens ahead of the grit separators. Reducing the aeration rate and tapering the amount of aeration along the length of the grit chamber distributed grit more evenly throughout the chamber and increased grit removal by an estimated 400 to 500 percent. Manually cleaned bar screens were installed on two cyclonic grit separator overflows. This reduced grit pump clogging from 2 to 3 times per shift to virtually none by catching rags, sticks and plastics that were rejected by the cyclones and found their way back to the grit pump intakes.

Grit carry-over into the primary sludge has been reduced by approximately 28,800 cubic feet per year. Due to the large quantity of grit in the cyclone overflows, however, the manually cleaned bar screens will be replaced by mechanically cleaned screens in the future.

Case History No. G4

A 64 mgd activated sludge plant currently has an average daily flow of 35 mgd and a peak flow of 200 mgd. The plant serves a combined sewer system. Grit is removed at the plant in two degritor-type tanks with rake arms and grit pumps. These facilities were installed in the 1950s. They are difficult to maintain due to the age of the grit removal mechanism and are frequently out of service for maintenance. The grit pumps are frequently plugged. When one unit is out of service, the grit removal capacity is limited to handling only dry weather flow.

Poor grit removal results in grit carry-over into the primary settling tanks. The grit causes excessive wear on the sludge collectors and sludge pumps and causes blockages in the aeration tank air diffusers.

These units will be replaced with aerated grit chambers within two years.

Case History No. G5

Prior to upgrading, a 180 mgd tertiary wastewater treatment plant had four covered aerated grit chambers, constructed in 1957. This grit handling system consisted of chain and flight collectors, screw conveyors, and bucket elevators. The system was inaccessible for maintenance. Inadequate ventilation of the grit chambers resulted in a corrosive environment above the water surface which attacked the concrete, the air diffuser headers, and the influent and effluent sluice gates. To remedy this situation, the concrete covers over the grit chamber were removed and new concrete walls were built around the existing grit chambers. The new grit chambers were constructed with clamshell buckets mounted on a traveling bridge crane. To further improve the operation of the grit handling system, mechanically cleaned screens were installed upstream of the grit chambers. With these modifications, the performance of the grit facilities has substantially improved.

Case Study No. S1

A 0.8 mgd extended aeration plant treats 0.3 mgd of domestic wastewater by means of a detritor, aeration tanks, and secondary clarifiers. Sludge is stabilized in aerobic digesters and dewatered on belt filter presses. A collection system pump station, equipped with a manually cleaned bar rack and comminutor, pumps all flow into the plant.

Several operating problems are caused by rags recombining in the plant. Rags accumulate on the influent slide gates to the aeration tanks and must be removed daily. The build-up of rags on the impellers of the surface aerators in the aeration tanks and on the submerged turbine aerators in the aerobic digesters frequently trip overload switches. The tanks must be dewatered and the rags manually unwound from the impellers to remove them. Rags also accumulate in the secondary clarifiers, clogging the return activated sludge pumps. These pumps are cleaned daily, which takes approximately one hour per pump.

The plant staff is planning to install a manually cleaned bar rack after the detritor in an effort to remove rags upstream of the aeration tanks.

Case Study No. S2

A midwestern 1.2 mgd activated sludge plant was put into operation 1-1/2 years ago. The plant is equipped with a front cleaned/front return (chain and sprocket operated) screen with clear openings of 3/4-inch. The screen is installed in a channel and is pivoted so that it can be swung out of the channel for inspection and maintenance, leaving the channel in operation.

The screen was installed outside so that cold weather caused the screenings to freeze and shear pins to break. To alleviate these problems, a shed was constructed around the screen to protect it from the weather. The plant has not experienced any significant difficulties from rags.

Case Study No. S3

A 2.25 mgd extended aeration facility has a headworks consisting of manually cleaned bar racks, velocity controlled grit chambers, and comminutors. The influent waste is primarily domestic but does contain some industrial wastes with rags. In the past, these rags accumulated on the floating surface aerator impellers, causing excessive wear on this equipment, and clogged the return activated sludge pumps which had to be manually cleaned.

To correct these problems, manually cleaned bar racks were installed in the return activated sludge channel to the aeration tanks to collect the rags. This reduced pump blockages. Installation of mechanically cleaned screens is under consideration.

Case Study No. S4

A 3 mgd collection system pump station is equipped with a comminutor/macerator, which has been in operation for one year. The wastewater consists of normal domestic wastes with minor industrial flow contributions. The unit has worked well, requiring only routine maintenance. Only one operating problem has occurred. The comminutor/macerator motor was submerged and had to be rebuilt due to failure of a pump which caused the wet well to overflow.

A similar incident occurred with a comminutor/macerator at a pump station in another location. The wet well level rose, submerging the motor which, consequently, had to be repaired. This comminutor/macerator had been in operation for two years with only routine maintenance required.

Installation of three new units at other pump stations is planned. These units will be equipped with submersible motors to prevent damage from wet well overflows.

Case Study No. S5

A midwestern 10 mgd contact stabilization plant experienced operating problems with screening operations. The system consisted of influent pumping, a bar rack with 1-inch clear openings, two externally fed submerged rotating drum screens with 1/8-inch openings, and a grit channel. Operating problems included flooding and mechanical breakdowns of the screen drives and seals, clogging of screens by grease and oil, and freezing of screenings. This resulted in poor screening removal efficiency, allowing floating debris to pass through the plant to the aeration tanks, digesters, and thickener, and causing odor problems at the screenings dumpsters.

This system was replaced by internally fed rotating drum screens, constructed of stainless steel wedgewire with clear openings of 0.020-inch, mounted above the floor. Because the influent wastewater has non-emulsified greases and oil, which interrupt the screening operation, a multi-staged centrifugal pump was installed to wash the drum screens. The pump supplies tap water at 300 psi at short duration (60-120 second) cleaning cycles 10 to 15 minutes apart to keep the screens clean. This cycle is controlled by timers. Enclosing the screenings dumpsters in a building prevents the screenings from freezing and provides a drainage area for the perforated 16 cubic yard dumpsters. Because of high landfill fees, a screenings press was installed to reduce their volume.

These improvements have increased screenings removal from 3 to 12 cubic yards per day with a dry solids content up to 15 percent. This improvement in screenings removal has decreased process air requirements, improved sludge quality, significantly reduced deposits in the aeration tanks and piping, and reduced pump blockades. Removal of BOD and suspended solids by the screens is over 10 percent and floating material is also effectively removed by the screens. The enclosed dumpster area and screenings press have substantially reduced odors.

Case Study No. S6

In 1975, a west coast 15 mgd activated sludge plant replaced existing comminutors with comminutor/macerator devices to improve grinding efficiency. The comminutor/macerators worked well and ground most solids except for spherical objects. However, the grindings recombined, forming rags which accumulated on the air diffusers in the aerobic digesters. The units were replaced in 1978 to increase the treatment capacity of the headworks. Two mechanically cleaned front cleaned/back return (chain and sprocket) screens and a manually cleaned bypass bar rack were installed. Although the wastewater was 90 percent domestic flows, these screens experienced severe corrosion and became unuseable within four years. During this period, a hammermill grinder was installed to grind the screenings and return them to the flow. This grinder failed within six months and was replaced with one of the comminutor/macerator devices formerly installed in the headworks. The comminutor/macerator worked well in grinding the screenings.

In 1982, the screens were replaced by two rack and pinion driven reciprocating rake screens which are located outside. Screen openings are 3/4-inch in 4-foot channels with a water depth of 2.5 to 3.5 feet. Initial difficulties in operating the spring assisted wiper bar shock absorbers were solved by replacing them with a hydraulic oil shock absorber, which has worked satisfactorily. Approximately 8 cubic yards of screenings are removed weekly by the rake screens and carried by a belt conveyor to a dump truck to be hauled to a landfill. The rake screens have worked well for the past 2-1/2 years.

In order to minimize clogging in sludge pumps, a comminutor/macerator was installed upstream of the primary sludge pumps. These are used to pump co-settled grit, primary and waste activated sludges to belt filter presses. Originally, the comminutor/macerator was installed in a vertical position, which resulted in grit accumulations that damaged the bottom seals. The unit was then installed in a horizontal position which has greatly extended the life of the bottom seal.

Case Study No. S7

A 30 mgd advanced treatment plant with primary lime treatment, nitrification, denitrification, and dual media filtration processes has three screening units located before aerated grit chambers. One unit is a front cleaned/back return screen, which was installed in 1957. The other two screens are front cleaned/front return chain and sprocket operated screens, installed in 1975. Clear openings are 3/4-inch. Screenings are removed from the flow, ground up, and then returned to the flow.

Prior to improvements, screenings problems included poor capture and removal, plugging of grit and sludge pipelines and pumps due to rags, and difficult maintenance due to the location of the screens. Turbulent flow in the channel to the screens reduced screenings capture. Removal of the screenings by belt conveyors was difficult because they were located 20 feet below ground level. Rags recombined and plugged grit and sludge pipelines and pumps. Inspection and maintenance of the lower sprockets of the chain operated screens was difficult because they were below the wastewater flow and required dewatering of the channel.

A recent improvement is the installation of a comminutor/macerator, and planned improvements include catenary screens and a screenings press. A comminutor/macerator was installed in the primary sludge line to reduce plugging of the line and sludge pumps by rags. This unit has worked well with little required maintenance. Two new catenary screens will be installed to replace existing screens. The catenary screens will be able to handle the wide range of flows that the plant experiences (up to 150 mgd). A screenings press is planned to be installed to remove the screenings from the flow, which will eliminate the problems of rags in the plant.

Case Study No. S8

An east coast 31 mgd activated sludge plant, constructed in the 1950s, is undergoing a second upgrading. The headworks are being rebuilt to reduce inefficient screenings removal presently accomplished by three 5-foot wide screening/comminuting devices (barminuters) which are located before velocity controlled grit chambers. The barminuters replaced mechanical rakes, having 1/2-inch clear openings, and grinders which returned the screenings to the flow. This original system resulted in high screenings load and wear on the grinders due to the grit. The barminutor equipment was ineffective in removing the screenings and was very maintenance intensive because of the complex machinery. Frequent problems and blockages were encountered with the sprockets and chain drives. In order to perform maintenance on the equipment, the channel had to be dewatered which caused operational difficulties due to unequal flow distribution to the other channels.

Downstream operating problems were mainly with the primary sludge pumps where rags recombined to form long strings which clogged the pump impellers. Sludge pumps had to be inspected weekly and flow in the sludge pumps was reversed daily to unwind rag accumulations. Rags accumulated on any obstruction, particularly at the influent channel weirs at the primary settling tanks. Rags also caused blockages in the sludge lines to the digesters.

The barminutor equipment was replaced by catenary screens which have been operating for six months with good screenings capture. Maintenance on these screens is expected to be considerably less than on the barminutors. Blockage problems in the sludge treatment processes are not as frequent.

Case Study No. S9

In 1982, a study of the existing screen facilities in a major city was undertaken to determine their condition, reliability, and operational performance and to make recommendations for the repair, modification, or replacement of the screens. Ten facilities with a total of 57 screens and average flows of 20 to 300 mgd were studied. The screens were either front cleaned/back return or front cleaned/front return chain operated devices installed between 1970 and 1978.

The study concluded that inefficient screening capture was caused by excessive velocities in the screen channels forcing screenings through the bar racks, by flapper plate malfunction in back return screens which allowed screenings to pass under the bar rack, and by screenings being re-deposited in the sewage flow downstream of the screens due to inefficient operation of the wiper mechanisms. In addition, the existing chain and sprocket operated screens were maintenance intensive and permitted screenings to bypass and carry-over to downstream processes.

Inefficient screening of raw wastewater was the cause of many operational problems due to rag accumulation in downstream processes. These problems included the following:

- Slippage of sludge collector chains and breakdown of the mechanisms in primary and secondary settling tanks

- Jamming and overloading of screw-type sludge collector mechanisms in the primary settling tank cross collectors

- Reduced oxygen transfer efficiency, equipment breakage, and high cleaning costs of aeration tank diffuser tubes, piping, and headers

- Reduced reliability of sludge concentration tanks from pump clogging and scraper mechanism blockages

- Inefficient operation of anaerobic sludge digesters' internal gas diffusers and mechanical mixers.

Short term corrective measures taken to increase screenings removal included plates with new flappers and replacement of lower chain sprockets and shafts. Operational changes instituted were bi-weekly flapper plate inspection, daily adjustment of screen components, and operation of additional screens, as necessary, to reduce velocities through the screens.

After evaluation of available screening devices, the recommendation was to replace the existing screens with rack and pinion reciprocating screens as existing screens reached their service life limits. Several of these new units have been installed and are working well with increased screenings capture and reduced maintenance.

SECTION 5

DETAILED EVALUATION REQUIREMENTS

To fully evaluate the costs and benefits of improved preliminary treatment, i.e., to perform a cost-effective analysis, the engineer must have a variety of information available. This information should include present operation and maintenance (O&M) costs for both the preliminary treatment and downstream wastewater treatment processes and sludge treatment and disposal steps. These total and individual costs must be compared to either other plants with similar wastewaters and treatment components or to available information which identifies these same costs in terms of manpower or dollars for similarly designed facilities. Sources of the latter information can be found in references 3,5,14,29,30,34,37,45,47,48,49,50, 51, and 52. However, few of these sources are comprehensive in nature, especially when dealing with the impacts of preliminary treatment on downstream O&M requirements. Sidwick (37) illustrated and quantified downstream O&M tasks in typical British trickling filter facilities resulting from inadequate screening. The most time consuming and costly task was found to be the cleaning of trickling filter distributors.

To perform this cost-effective analysis, quantified information is required on the time required to perform O&M tasks resulting from inadequate preliminary treatment, the cost of labor and tools to perform these tasks, and the external costs for contract specialists, replacement parts and other direct costs to the treatment facility. One relatively straightforward example of cost-effective analysis would be pumps. After the effect of grit abrasion or partial screening blockages has become significant, the efficiency of the pump may drop by 40-60%, resulting in significant increase in energy consumption. When the plant staff become aware of this problem, the pump will be removed for repair. The cost of repair for different types of pumps varies. Progressive cavity pumps worn by grit may require a repair cost nearly equal to the original price. Plunger pumps which "bell out" from grit abrasion can be resurfaced with ceramics for about 50% of replacement cost. Centrifugal pumps worn from grit also require about 50% of their replacement cost to repair. To all of these external costs must be added the plant labor costs to remove and replace the units.

The USEPA conducted a study to evaluate the mechanical reliability of treatment plant components (20). An early finding of this study was that only a few large plants kept proper records to perform such an analysis. The data that was available showed a ratio of almost 5 to 1 of service life to down time for failures of pumps at those facilities, and the primary cause of centrifugal pump failure was worn wear rings or plates due to grit abrasion. Mean times to repair, availability, and maintenance times for certain components were also recorded.

Data of the above type must be developed for all downstream components in order for engineers and plant managers to perform the necessary cost-effective analyses for preliminary treatment processes. Some other data that have been developed in addition to the above study include:

- Comminutors normally require overhaul every 3 years at a cost of 50-60% of the purchase price, in addition to labor costs for removal and replacement. Teeth sharpening at 1-to 3-month intervals and replacement every 6 months have been reported (3).

- Grit removal equipment requires overhaul every 4 to 5 years at 10-15% of total grit chamber installation cost.

- Digester cleaning should not be required more often than every 5-10 years, but excessive grit has caused this frequency to be as often as once every 1 to 3 years (3,19). The USEPA (53) reports that the most frequent cleaning interval of plants contacted was every 3 years. Costs of digester cleaning can vary from less than 1 to more than 5 cents per gallon of digester capacity (19,53). The length of time required for repair is a function of digester size, available facilities, and need for contract services.

- Centrifuge scroll wear from grit abrasion may result in rebuilding costs of $3,000 to $50,000, depending on centrifuge size. Similar grit abrasion of sludge feed tubes and nozzles require replacement as often as 6 times per year at $400 to $1,400, plus labor (minimum of one day).

Other information of a similar nature must also be gathered to develop an adequate picture of normal treatment plant component service life between repairs and the costs of those repairs. To accomplish this the following must occur:

- Plant owners/operators must become aware of the potential impacts of preliminary treatment on subsequent unit processes. Many O&M requirements presently considered to be inherent or routine in these processes may result from inadequate preliminary treatment.

- Plant record keeping must be upgraded. Frequency of repair and time requirements for labor and materials to perform O&M tasks resulting from pretreatment process inadequacy must be documented in order to properly quantify their relationship to improved performance.

To illustrate the information required to complete a cost-effectiveness analysis, examples of two typical facilities were created. The first is a typical small (1 mgd) municipal wastewater treatment facility employing a manually cleaned bar screen, a controlled-velocity grit removal chamber, comminution, oxidation ditch, and final clarifier with waste activated sludge thickening, aerobic digestion and sand drying beds. For the components provided in this typical facility, Table 9 was then developed from literature references, contacts with treatment plant operations staff, and interviews with contract operating staff of Metcalf and Eddy. If, for example, the O&M program of this facility were adequate, the high and low ends of the table's O&M costs may be considered the difference between this plant's operational costs and that of a plant with excellent preliminary treatment processes. The plant manager or engineer could then calculate the additional O&M costs incurred due to inadequate preliminary treatment. These additional costs could then be compared to the estimated capital and O&M costs of improved preliminary treatment.

Similarly, Table 10 shows the ranges for annual O&M costs resulting from various efficiencies of preliminary treatment for a typical large (30 mgd) treatment plant consisting of primary clarifiers, conventional diffused-air aeration, and secondary clarifiers, sludge thickening (primary by gravity and waste activated by centrifuge), belt-filter-press dewatering of combined sludge and incineration. An engineering analysis similar to the one described above would also be possible for this facility if the same assumptions were made.

Several potentially important issues are not addressed by Tables 9 and 10 which may further add to the total cost of preliminary treatment impacts. These include the cost of increased power as hydraulic components, e.g. pumps, are reduced in efficiency either prior to the decision for major repairs or as a result of inadequate frequency of corrective maintenance. Sidwick (37) reported energy losses of 40% to 60% at one plant due to this problem. Therefore, the cost-effective analysis must consider these and other site-specific issues which are less obvious effects of inadequate preliminary treatment in developing the total annual cost due to this problem.

Sidwick (37) provides an excellent analysis of the labor costs resulting from inadequate screening in typical trickling filter plants in Great Britain. These analyses resulted in the conclusion that the greatest benefits from improved screening accrue to small plants with part-time operation, rather than to larger facilities. However, significant benefits can be derived from such improvements in the form of power savings at larger plants.

It should be restated that the normal British design practices for smaller treatment plants, i.e., primary clarifiers and slow-rate trickling filters, are different from U.S. practice. The applicability of these British conclusions to U.S. practice, therefore, may be limited to similarly designed facilities.

TABLE 9

HYPOTHETICAL IMPACTS OF GRIT AND SCREENINGS ON A TYPICAL SMALL PLANT

IMPACT	REMEDY	COST PER OCCURRENCE ($)			OCCURRENCES PER YEAR	COST PER YEAR ($)
		LABOR	EQUIPMENT	TOTAL		
Grit abrasion on comminutor	-Set and sharpen teeth	40	---	40	3-6	120-140
	-Overhaul comminutor	160	7,500	7,660	0.33-0.5	2,550-3,825
Rag accumulation on surface aerators, weirs and baffles in oxidation ditch or aeration tank	-Remove screenings	10	---	10	4-52	40-520
Grit Accumulation in oxidation ditch	-Drain and remove grit with vacuum track	250	250	500	0.5-2.0	250-1,000
Draft tubes in secondary settling tanks plug with rags	-Flush to remove screenings	20	---	20	4-24	80-480
Rag accumulation on mixers in secondary settling tank scum wells	-Remove screenings	20	---	20	1-6	20-120
Clogging and wear of the two centrifugal return/waste sludge pumps	-Remove screenings	60	---	60	4-24	240-1,440
	-Rebuild the pumps	160	5,000	5,160	0.14-0.33	740-1,740
	-Repacking and resealing	15	100	115	4-12	460-1,380

TABLE 9 (continued)

HYPOTHETICAL IMPACTS OF GRIT AND SCREENINGS ON A TYPICAL SMALL PLANT

IMPACT	REMEDY	COST PER OCCURRENCE ($)			OCCURRENCES PER YEAR	COST PER YEAR ($)
		LABOR	EQUIPMENT	TOTAL		
Clogging and wear of two plunger-type thickened sludge pumps and valves	-Remove screenings from ball checks	5	---	5	100-700	500-3,500
	-Replace balls	10	400	410	0.33-1	140-410
	-Repacking and resealing	15	100	115	4-12	460-1,380
	-Resurface plungers due to belling	160	400	560	0.067-0.2	40-110
Clogging of pipeline due to accumulation of grit and screenings (eg. - line between gravity thickener and thickened sludge pumps)	-Flush or rod line; worst case - remove line and rod	500	---	500	0.2-1.0	100-500
Rag accumulation on diffusers in aerobic digester	-Remove screenings	10	---	10	12-24	120-240
Grit build up in aerobic digester	-Remove when tank is down	400	400	800	0.10-1	80-800

Note: Labor costs based on $10.00/hr.

TABLE 10

HYPOTHETICAL IMPACTS OF GRIT AND SCREENINGS ON A TYPICAL LARGE PLANT

IMPACT	REMEDY	COST PER OCCURRENCE ($)			OCCURRENCES PER YEAR	COST PER YEAR ($)
		LABOR	EQUIPMENT	TOTAL		
Blockage of aerated grit chamber diffusers due to rag accumulation	-Remove rags	80	-	80	1-4	80-320
Grit accumulation in channel feeding primary clarifier	-Shovel out	480	-	480	0.1-0.5	48-240
Wear on chain and flight in rectangular primary clarifier due to grit accumulation	-Replace chain and cross flights	10,000	40,000	50,000	0.1-0.2	5,000-10,000
Rag accumulation on chain and fight or other collection equipment usually accompained by grit buildup	-Drain tank remove buildup and replace flights as needed	160	200	360	2-4	720-1,440
Buildup on mixer system in scum wells	-Remove screenings	20	-	20	6-24	120-480
Clogging and wear of the four plunger-type primary sludge pumps	-Remove screenings from ball checks	20	-	20	180-365	3,600-7,300
	-Replace balls	20	2,400	2,420	0.5-1	1,210-2,420
	-Replace shear pins	10	2	12	8-12	100-140

TABLE 10 (continued)

HYPOTHETICAL IMPACTS OF GRIT AND SCREENINGS ON A TYPICAL LARGE PLANT

IMPACT	REMEDY	COST PER OCCURRENCE ($) LABOR	EQUIPMENT	TOTAL	OCCURRENCES PER YEAR	COST PER YEAR ($)
Clogging and wear of the four plunger-type primary sludge pumps (continued)	-Resurface plungers	320	1,000	1,320	0.2-0.5	260-660
	-Repacking and resealing	40	200	240	1-2	240-480
Blockage of draft tubes in rapid sludge removal secondary clarifiers	-Flush to remove screenings	60	-	60	12-52	720-3,120
Clogging and wear of the four centrifugal return sludge pumps	-Remove screenings	10	-	10	26-52	260-520
	-Rebuild the pumps	320	10,000	10,320	0.067-0.1	690-1,032
	-Repacking and resealing	30	200	230	2-4	460-920
Grit abrasion on scroll surface of solid-bowl centrifuge	-Replacement of scroll edges	480	20,000	20,480	0.17-0.33	3,400-6,800
Rag accumulation on sludge blending tank shaft. Causes vibration and can snap motor mount bolts.	-Empty tank and remove rags	20	-	20	12-52	240-1,040
	-Replace bolts as needed	20	50	70	2-4	140-280
Grit accumulation in sludge blend tank	-Remove grit when tank is down	5,000	-	5,000	0.1-0.2	500-1,000

Note: Labor costs based on $10.00/hr.

TABLE 10 (continued)

HYPOTHETICAL IMPACTS OF GRIT AND SCREENINGS ON A TYPICAL LARGE PLANT

IMPACT	REMEDY	COST PER OCCURRENCE ($)			OCCURRENCES PER YEAR	COST PER YEAR ($)
		LABOR	EQUIPMENT	TOTAL		
Clogging and wear of the progressive cavity blended sludge pumps.	-Remove rags and screenings buildup	10	-	10	50-150	500-1,500
	-Replace rotor and stator	320	2,000	2,320	1-2	2,320-4,640

Note: Labor costs based on $10.00/hr.

SECTION 6

RECOMMENDED DESIGN PRACTICES

In this Section, recommended practices for the selection and design of grit and screenings removal systems are discussed. In selecting such systems a number of factors must be considered, including operability, safety, cost, and specific local conditions.

GENERAL DESIGN CONSIDERATIONS

Engineering practice dictates that the designer consider preliminary treatment in every facility served by conventional sewerage. Most state design regulations are typified by the commonly known "Ten State Standards" (16). In essence these standards require the use of coarse bar racks or screens for protection of pumps, comminutors and other equipment. Grit chambers are required for combined sewers and are suggested for all facilities. Grit removal, when employed, should precede comminutors, and the latter should not be used where fine screens or primary clarifiers are present. Such requirements eliminate uncertainties as to whether to use specific preliminary treatment processes and in what order to apply them.

Screening

Although a coarse screen can be commonly accepted as protection for downstream equipment from physical damage by large objects, its removal capability for other problematic screenings such as rags has until recently been unquantified save for numerous references as to the quantity of screenings per given volume of flow at various locations (1,2,17,34,35). The primary factors which affect the type and quantity of screenings removed are the raw wastewater characteristics, the size of screen openings, velocity of flow through the screen and the method of screen operation. The designer can control the last three factors and should be aware of the first prior to design.

Given a specific wastewater with known flow variation and screenings content, smaller screen openings will remove more material per unit of flow. Therefore, the question arises as to "how fine is fine enough" as it pertains to screen openings. A recent British study has demonstrated that a 0.5-in. opening will remove all the screenings likely to cause downstream impacts (36). Material captured on smaller subsequent screens was observed to be plentiful (an additional 30% by weight on a 0.3-in. screen), but of a nature which would have no downstream impact. Ten State Standards limits the minimum opening to 0.6 in. (16).

The velocity of flow through the screen is limited by the Ten State Standards (16) to 3.0 ft/sec "to prevent forcing material through the openings." A similar figure (3.3 ft/sec) is proposed by Sidwick for British practice (3). Therefore, the engineer must determine the required screen area by application of this figure to peak flow conditions.

The method of screen operation can significantly affect the removal efficiency of screens. With better control of mechanical cleaning rates, many facilities have improved efficiency by use of "matting" techniques where deliberate methods are employed which use previously retained screenings to remove finer materials from subsequent flows. These techniques are generally applied only at larger plants (54).

The one major design factor which cannot be controlled but should be known by the designer is the wastewater characteristics. Flow variation has already been noted as a major design factor; however, the screenings content as it relates to the flow of the wastewater also can have a major effect on the screening facility. One phenomenon often noted in practice is the increase in screenings content during higher flow periods. Although this relationship is primarily related to combined sewers, it can also be significant in separate sanitary sewers. Recent British work has shown that one combined sewer with flow peaks of less than 3 to 1 over the average flow yielded screenings peaks of as high as 73 times the average, although a screenings capture peak of 29 times the average was more common (36). Therefore, designers must take these peaks into account in choosing both the mechanical raking systems for the screens as well as the screenings handling facilities. The ability to deal with the excessively high screening content would be enhanced by use of mechanically cleaned screens with two speeds of raking and improved control systems (3).

Although several sources (3,17,41) contain graphs of screen opening sizes vs average and peak screening quantities, such graphs must be used with caution owing to variations in sewer and other service basin characteristics which may cause a significant change in the quantities present.

All major references discourage new facilities from grinding of screenings and returning them to the flow, an enigma in light of the general approval of in-line grinding/disintegration (comminution). Therefore, removal of screening from the wastewater flow and disposal by other means is now generally recommended such as, burial or landfilling of screenings, either on the grounds or at a local landfill, and incineration. The first method is by far the most popular, and is almost exclusively used in smaller treatment plants with screens. The second method, incineration, has been used by some of the larger treatment plants for many years. Because of the need to prevent putrefaction, screenings must be washed and dewatered quickly prior to separate or co-incineration with sludge cake. Although this latter method may be cost-effective for larger facilities, the equipment is expensive, and labor requirements and odors may be significant. Recently, British engineers have been investigating several new screenings handling devices, recognizing both that present equipment is less than satisfactory and that the trend toward finer screens will accentuate the need for better equipment (3,34,37,38,39,42,43, 44, 45). Among these devices are washers, dewaterers, baggers, incinerators and maceration systems.

Comminution

The Ten State Standards (16) recommend the use of comminutors in plants that do not have primary clarifiers, fine screens or mechanically cleaned bar screens. Since this scenario describes thousands of small U.S. municipal wastewater treatment plants, the number of comminutors installed is significant. Contrary to this recommendation, however, is the growing concern over the performance history of these devices. British studies conclude that truly effective comminuting devices have yet to be developed and note their removal from existing facilities (3,39,42,45). A Canadian study (47) of extended aeration plants showed that malfunctioning comminutors were a major cause of the failure of over 50% of these plants to achieve effluent quality requirements. The Province of Ontario recommends against the use of comminutors in municipal wastewater facilities (40). Several of the facilities contacted in this study and the case histories described earlier appear to reinforce the experience of the British and Canadians.

The original purpose of comminution in smaller treatment facilities was to overcome the manpower-intensive task of manually cleaning screens by grinding those screenings for settlement in a subsequent primary clarifier for disposal with the sludge (41). Although as a purpose this goal was laudable and reflected the practice of wastewater treatment in the 1930's, the use of these devices should be reevaluated in light of present practice by both the design profession and the design guidance authorities. Based on performance, the utility of comminutors should be reconsidered.

Grit Removal

The designer must evaluate several factors during design. The first issue is whether grit removal is required. British authors have recently reviewed their practice and concluded that the common practice of not requiring grit removal at small plants (<5,000 population served) was basically sound since most facilities employ primary treatment and do not employ anaerobic digestion of sludge (3). It was also noted that detritus tanks might be advantageously employed for plants serving more than 2,000 population, and improved methods of grit removal from constant-velocity channels were needed (45). The latter conclusion has also been noted in the U.S. and elsewhere (13,42,46). Before any designer were to decide against grit removal it would be necessary to characterize the wastewater for grit. If this is not feasible the designer must evaluate each of the following:

- Type of collection system. If a system is combined, grit removal is required. Most separate (sanitary) sewers will also require grit removal.

- Degree of sewer system corrosion. Grit may include products of hydrogen sulfide corrosion.

- Scouring velocities in the sewers. If scouring velocities are not regularly maintained, grit will build up in the sewers. During peak flows, the grit may be resuspended and conveyed to the treatment plant.

- Presence of open joints and cracks in the sewer system. These permit soil around the pipes to enter the sewers. This effect also depends upon soil characteristics and groundwater levels.

- Structural failure of sewers. Such failures can deliver enormous amounts of grit to the wastewater system.

- Characteristics of industrial wastes.

- Degree to which household garbage grinders are used.

- Amount of septage or other trucked wastes.

- Occurrence of construction in the service area or at the treatment plant.

This evaluation may be necessary where design standards reflect the Ten State Standards, which require grit removal facilities for all combined sewers, but not for separate sanitary sewers. If the evaluation is at all marginal, grit chambers should be installed.

It is important to recognize that extreme variations occur in grit volume and quantity. A generous safety factor should be used in calculations involving the storage, handling or disposal of grit (35). In a new system where there are separate sanitary sewers and favorable conditions such as adequate scouring velocities, an allowance of 5 to 15 cubic feet per million gallons should suffice for maximum flows. For combined sewers 15 to 30 cubic feet or more per million gallons may be necessary with conventional removal systems. The use of high efficiency techniques which capture smaller grit sizes may increase these estimates.

Sandy areas have the potential to introduce large quantities of grit, even in separate sanitary systems. In several instances, vortex flow devices have demonstrated the ability to meet performance criteria for removal of fine grit ("sugar sand" from the Southeast; "blow sand" from Northwest beaches), based on removals in full-scale and pilot units (15, 27). The design for grit handling facilities must take into account significantly greater volumes of grit captured.

Although numerous references (1,7,12,17,34,35,40) exist which provide excellent information on grit chamber design, the basis of most grit chamber design methods is removal of particles of 0.2 mm size with a specific gravity of 2.65. This criterion can be traced to Camp's 1942 paper (7) which stated:

"Experience has indicated that if the chamber will remove all sand 0.2 mm in size and larger (material retained on a 65-mesh sieve) it will remove most of the grit which gives trouble in treatment plants."

Consequently, grit chamber design has been driven (16,17,35) by this criterion which was introduced without scientific basis. Treatment plant operators in several areas of the country where fine sands dominate the local soil characteristics will attest to the inadequacy of this criterion. However, no better criterion has been determined scientifically. Annen (56) did similarly note that grit particles of less than 0.1 mm size do not disturb sludge treatment, but failed to provide data to prove this contention.

With grit removal, the designer is usually faced with few options. Location is generally specified by guidance (16) to precede all other plant unit processes, except for coarse screening. New plant designs generally provide either constant velocity channels or aerated grit chambers, although detritus tanks are still fairly common in older facilities and a few centrifugal devices and fine screens are in use. Most small plants are equipped with constant-velocity channels, while aerated grit chambers have generally been employed by larger facilities.

Operability of Grit and Screenings Removal Systems

Grit and screenings removal equipment is subject to the same impacts that affect downstream equipment: abrasion, clogging and jamming of submerged moving parts. Hence, ease of maintenance is of paramount concern. For example, the channel in which mechanically cleaned, chain-driven screens with submerged moving parts are installed will require dewatering for access to these parts. Grit removal equipment is subjected to extremely harsh conditions and must be accessible for maintenance and repair. To remove rags, cleanouts should be provided at inlets to progressive cavity or plunger pumps, and at chemical mixing tanks with paddle type mixers. The ability to flush rags from secondary clarifier draft tubes, particularly in plants without primary clarifiers, should be provided. In a previous section the general advantages and disadvantages of the various methods of removing grit and screenings were described.

Headworks and pump stations can be hazardous environments, as the possibility exists for corrosive or explosive gas concentrations to be present. Therefore, operator safety should be a major concern in design and operation of preliminary treatment systems.

The need for housing the screening equipment is dependent on the equipment and the climate. If housing is required, adequate ventilation will provide a safer environment and prolong the life of the equipment by preventing the accumulation of gases and moisture. Grit chambers should be designed to provide safe access to the chamber and mechanical equipment. Stairway access is required for units located in deep pits.

In one of the case studies, the grit handling system serving four covered aerated grit chambers consisted of chain and flight conveyors, screw conveyors and bucket elevators, and was inaccessible for maintenance. Corrosion in the enclosed, moist environment enhanced deterioration of parts above the water surface. The covers were removed, and clamshell buckets mounted on a traveling bridge crane were installed for grit removal.

Working clearances around equipment should be sufficient for maintenance purposes and conform to state and local codes. Platforms on and around machinery at locations not easily reached from floor level should be provided. Designs should provide operating personnel with railings around channels and shrouds over moving equipment (chains, sprockets, or rakes). Electrical equipment should be explosion proof and kept to a minimum because of the damp corrosive conditions.

DESIGN CONSIDERATIONS FOR SMALL PLANTS

Staffing

Municipal wastewater treatment plants that are less than 1 mgd in size are distinguished by small staffs and non-specialized personnel that often have less specialized training than those found in larger plants. These plants may also be intermittently staffed. In these plants, preliminary treatment systems should be mechanically simple, operate reliably, and require only part-time attention. Although automatic operation is desirable, instrumentation to allow such operation must be kept simple.

Because approximately 80 percent of the facilities to be built in the next 15 years are to be less than 1 mgd in size, there is a growing need for appropriate small plant preliminary treatment systems.

Special Design Considerations for Small Plants

The first small community design issue is the type of sewer. Although most small communities are served by conventional gravity separate sewers, a large number of recently constructed facilities employ alternative sewers. For those systems preliminary treatment issues are significantly different. Sewer systems which employ on-lot septic tank pretreatment include septic tank effluent pumping (STEP) systems and small-diameter gravity (SDG) systems. The wastewaters which enter the treatment plant from these sewer systems do not require preliminary treatment since the grit, screenings and grease which these processes are designed to remove have already been removed by the septic tanks and, if the sewers are properly designed with no or just a few manholes at critical junctions, there is no means of reintroduction during wastewater transmission to the plant.

Grinder-pump (GP) pressure sewers are different in that the wastewater has only been ground (comminuted) prior to transmission to the treatment plant and has minimal opportunity for dilution due to infiltration. Therefore, grit will still be present in the wastewater, while solids have been comminuted. Since the comminutors in this case are an integral part of the wastewater pumping process, the designer may have some flexibility in pretreatment system design, although conventional guidance (16) would dictate that normal pretreatment processes should be employed. Given the normal tendency for comminuted solids to recombine, a mechanically cleaned screen with relatively fine openings would appear prudent. Since GP wastewater tends to be high in solids and organics due to the lack of infiltration, designs incorporating preliminary treatment or lagoon technology are desirable.

Vacuum sewers provide a wastewater which is very similar in character to conventional sewers and should be subject to similar design guidance. The major difference is the hydraulic violence which occurs in transmission which may result in screenings of somewhat reduced size, suggesting the use of screens finer than used in conventional applications.

The wastewaters delivered to the plant by alternative sewers have certain other characteristics of importance to the designer. These sewers minimize infiltration and thereby result in lower average flows to the plant. Peak flows tend to be similar to normal dry weather flow peaks, even during storms if the sewer is properly constructed. Pressure sewers (STEP and GP systems) and SDG sewers have high sulfide contents which must be taken into account by the designer to minimize odors and corrosion problems at the treatment facility.

Where the collection system is a mixture of sewer technologies the designer should assume the worst characteristics of each type of collection technology. For example, if conventional sewers and GP pressure sewers convey the wastewater to the plant, the designer should assume that the wastewater will exhibit the higher flows and flow variation of conventional sewers and the potential for odor and corrosion of the GP sewer. In practical terms this would mean that preliminary treatment processes should be designed for the higher peak flows of the conventional sewer, but with preliminary treatment process choices which minimize turbulence (potential hydrogen sulfide stripping) and corrosion-resistant materials of construction.

Another significant design consideration is climate. In climates where freezing occurs, screenings can freeze, damaging equipment and becoming difficult to handle. In such climates bar racks should be located in a heated enclosure. In one case study a mechanically cleaned screen installed outside experienced shear pin breakage due to screenings that froze. Construction of a heated enclosure alleviated these problems.

Small treatment plant technologies for accomplishing required levels of treatment will also impact the preliminary treatment system design. Since the majority of small treatment systems are lagoons or lagoon-based technologies, grit removal may be applied only in special cases, such as those where fine grit concentrations are high in the incoming wastewater. Many such areas exist in the U.S. where fine "blow" or "sugar" sands could fill lagoons in a relatively short period unless removed at the headworks (preliminary treatment location). The grit removal systems provided must be capable of removing these very small grit particles. Therefore, conventional designs do not provide the necessary degree of grit removal, unless modified. Trickling filters and long-solids retention time (SRT) activated sludge systems are common types of small community treatment systems. The former type generally employs primary treatment, while the latter does not. Historically, controlled-velocity channels have been the dominant grit removal process for these small trickling filter plants and for the long-SRT facilities, when grit removal is employed. This design choice is consistent with the operational needs of these treatment systems. In recent years, designers have been applying aerated grit chambers to smaller facilities where wide fluctuations in flow cause the controlled-velocity channel to yield variable performance. However, the preceding screen performance requirements increase with the aerated chamber, necessitating finer, mechanically cleaned screens.

A British preliminary treatment survey of eight Water Authorities (3) indicated that there was a unanimous response as to the unacceptability of comminution, as historically practiced with currently available equipment. There was some sentiment on the part of the respondees that better (more heavy-duty) devices might have beneficial application in smaller treatment plants in the future. U.S. and Canadian experience is consistent with that of the British.

The need to improve screenings removal in small package plants, usually high-SRT activated sludge systems without primary clarification, is also clear. Such improvement requires finer screens which must employ mechanical cleaning or frequent manual attention. Since most small treatment plant designs attempt to minimize O&M requirements, the designer must evaluate the tradeoffs between increased preliminary treatment efficiency and its O&M requirements with reduced O&M requirements downstream. Finer screens increase capital costs over coarser manually cleaned designs, with or without comminutors, but the difference must be compared against the savings in reduced O&M for downstream treatment and sludge handling processes. For example, if the downstream process is a facultative lagoon, there is little concern over the efficiency of the screen since downstream effects are primarily of an aesthetic nature. However, if surface aerators are employed, some tradeoffs will exist in reduced O&M of the aerator. With trickling filters, properly designed primaries would be expected to capture almost all of the screenings and tradeoffs will be found in reduced skimmings handling, clarifier mechanism O&M and sludge pumping and handling O&M. Since land spreading is a likely sludge disposal method for these plants, improved acceptability of the sludge may also be a tangible tradeoff (3). With long-SRT activated sludge systems, reduced O&M requirements for aerators, secondary clarifier scum and sludge collection, return sludge pumping and other waste sludge handling and disposal must be weighed against increased preliminary treatment costs.

Specific Recommendations for Small Plants

- Mechanically cleaned screens with fine (0.5-to 0.75-in.) openings should be considered where mechanical (trickling filter and activated sludge) treatment systems are employed.

- Preliminary treatment designs must be compatible with the collection system and downstream processes employed.

- Special cases where very fine grit concentrations would interfere with downstream treatment may benefit from new vortex or fine screen technologies, on which more design, performance and cost data are required.

DESIGN CONSIDERATONS FOR LARGE PLANTS

Staffing

Large municipal wastewater treatment plants should have round-the-clock staffing, with specialized, highly skilled personnel. They may have well-equipped machine shops as well. The greater quantities of wastes handled means labor-related economies of scale can be achieved; consequently, processes and equipment tend to be more mechanically complex than for smaller plants.

Design Considerations for Large Plants

There are fewer plants with treatment capacities greater than one mgd, but their combined capacities treat the great majority of the wastewater volume treated in the U.S. (31,33). For the most part the previous discussion of this section pertains to facilities which generally have a diversity of processes that can be adversely affected by inadequate preliminary treatment performance.

Systems for removing grit and screenings from large treatment plants must be suited to the type of collection system (separate or combined), specific characteristics of the waste stream, and subsequent downstream and sludge handling processes.

Combined sewers will bring in much greater quantities of grit and screenings during periods of storm flushes than will separate systems. Designs must recognize greater ratios of peak to average flow and even greater ratios of peak to average quantities of screenings and grit. There appears to be no available guidance on these latter ratios. Wastewater characterization information is vital for the designer to evaluate the adequacy of screenings and grit handling equipment. Some references (1,3, 17,36) provide data on the ratio of peak flow screenings to average flow screenings quantities. The two U.S. sources (1,3) appear to be reasonable estimates for separate domestic sewers in that they indicate rather small (<2 to 1) peak to average values. The two British references (17,36) are more typical of combined sewers where ratios of 25 or more to 1 are experienced. The amount of screenings to be expected at the treatment plant will also vary with the length (and time of travel) of sewer, the flow rate, and the climatic records of the preceding period.

Some industries can influence waste stream characteristics for both grit and screenings. Plastic sheet material or fabric sweepings from textile mills can magnify the screenings problem. If such sweepings are fine, they will pass through any coarse screen and will enter the sludge streams. In such cases, finer bar screens should be considered. Another method which should be considered is the use of a screen or heavy-duty grinder in the sludge line prior to the sludge pump as a "second line of defense". This additional screening or grinding could reduce pump and pipeline clogging and additional downstream problems. In one case study, screens were installed in the return sludge lines of an activated sludge plant to intercept rags. This reduced aerator ragging and pump blockages caused by the inability of comminutors to properly eliminate these problems.

The choices of specific screening designs for large wastewater treatment plants tend to reflect local conditions and preferences. With regard to screening, most large facilities employ trash racks (very coarse screens) for equipment protection followed by mechanically cleaned screens for actural removal of rags and other troublesome materials. Although this practice appears appropriate, there is much disagreement with regard to the best mechanically cleaned screen design. British engineers prefer backraked designs (3), while some cities prefer front-raked screens (54). The only concepts which appears to engender agreement are the need to have all moving parts above the water level to facilitate maintenance and the need to have better control of raking speeds, such as two-speed raking controls.

There is a clear trend toward reducing the size of mechanically cleaned screen openings in Great Britain where numerous recent studies have investigated the potential benefits and disadvantages of this change (3,36,37,38, 39,43,45). Although such efforts are yet negligible in the U.S., the potential benefits of this design change are clearly apparent and quantifiable.

As discussed earlier, grit quantities are subject to dynamic influences in addition to soils of the service area and other natural and man-made conditions. The greater grit quantity variation in larger plants, especially those served by combined sewers, has led the design profession to wider use of aerated grit chambers with variable and controllable air supplies. British practice has tended more toward detritus tanks, but aerated grit chambers and vortex-separation types have gained in popularity in recent years (3). Grit removal systems have been maintenance intensive owing to the inherent difficulty of handling this abrasive material. Odors tend to be minimized with well-operated aerated grit chambers, but can be significant with other types of grit removal systems, and odor control systems may need to be included. Grit disposal for large plants may be to landfills, incineration or ocean disposal, depending on the location and local circumstances.

Specific Recommendations for Large Plants

- Openings for mechanically cleaned bar screens should be as small as 0.5 inches.

- All bar screen mechanical equipment should remain above the water line in the screening chamber to facilitate maintenance.

- Mechanical cleaning of bar screens should have at least two speeds to handle peak screenings loads as well as to optimize removals during lower flow periods.

- Grit removal by aerated grit chambers is well-suited to larger treatment plants when supplied with proper baffling, chamber design, and controllable air supplies.

- Vortex-type grit removal devices and improved methods of settled grit collection should be considered if sufficient justification data can be provided.

DESIGN CONSIDERATIONS FOR RETROFITS

Many municipal wastewater treatment plants are presently in need of upgrading and many relatively new plants will be at some time in the future. Consequently the need for retrofitting grit and screening removal devices is significant and will persist.

Many of the considerations that apply in designing a new facility also are applicable in retrofits. However, a number of constraints are more influential: hydraulic profiles are established, space may be limited, and plant personnel are accustomed to existing conditions.

When retrofitting devices for grit and screenings removal, the following must be considered:

- Reliability and need for redundancy.

- Maximum use of existing equipment if present equipment is adequate for subsequent needs.

- Need for odor control or other ancillary systems.

When replacing screens, space considerations can direct the decision. For example, reciprocating rake screens consume little channel length, but require relatively high vertical clearance. Catenary type screens are not as tall as reciprocating rake devices, but require more horizontal space.

Odor control systems for preliminary treatment facilities should be capable of effectively removing hydrogen sulfide and methyl mercaptan in addition to plant-specific compounds. Acid-alkali scrubbing has not been found effective, but activated carbon and ozonation have. Small plants should consider soil/compost or iron oxide/woodchip contact units for simplicity.

Conversion to aerated grit chambers should eliminate the need for a separte grit washing step. Chain and bucket collection of removed grit should be avoided, while screw conveyors and air-lift pumps have had success.

Fine screens and teacup-type grit chambers may require pumping to satisfy their need for head differential. In retrofits, use of these units may necessitate additional pumping which may not be physically possible or economically feasible.

OPERATION AND MAINTENANCE CONSIDERATIONS

The heavy wear on equipment in grit and screenings removal systems requires that sufficient preventive maintenance be practiced. Regular maintenance of the preliminary treatment system will also help to minimize downstream impacts due to poor grit and screenings removal.

Preventive maintenance required by preliminary treatment systems is generally small and limited to observation, good housekeeping and oil/lubrication needs. Total O&M requirements include labor and power. For mechanically cleaned (MC) screens operation is usually intermittent, varying from 5 to 15 minutes per hour, but may be full-time during storm events. Electrical requirements for MC screens in smaller plants vary from about 1.7 kWh/day at 0.1 mgd to 11 kWh/day at 100 mgd, while aerated grit chambers require from 30 to 740 kWh/day over this size range (48). Non-aerated grit chambers trade power savings for increased labor requirements. Generally, the O&M labor requirements for preliminary treatment constitute about 10% of the plant total (49). However, the time required to operate and maintain preliminary treatment systems and impacted downstream processes during a major storm event may be significantly greater (55).

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ENGLISH TO METRIC UNITS CONVERSION TABLE

English	Conversion Factor	Metric Equivalent
Foot, ft	0.305	Meter, m
Feet per second, ft/sec	0.305	Meters per second, m/s
Million gallons per day, mgd	43,800	Milliliters per per second, mL/s
Cubic feet per minute, cfm	0.472	Liters per second, L/s
Pounds per cubic foot, lb/cf	0.016	Kilograms per liter, Kg/L
Cubic feet per mllion gallons, cf/mg	7.48×10^{-6}	Liters per liter, L/L
Gallons per minute per square foot, gpm/ft^2	0.679	Liters per second per square meter, Lps/m^2