DEVELOPMENT OF THE POROX (HYDROGEN PEROXIDE) PROCESS

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One major development of this program, the so-called Small-Scale Waste Management Project (SSWMP, or "swamp") was a modified mound system for use at sites with problem soils. This design was intended to forestall failures of systems attributable to installation at inappropriate sites [2]. Recent studies of typical mounds installed by commercial contractors in Wisconsin have revealed that these modified systems perform as well as, or better than, conventional septic tank–absorption systems with respect to both wastewater acceptance and purification, despite the deficiencies in the soils at the installation sites [3]. Another development was a method to rehabilitate systems that had been properly installed at acceptable sites but which had failed naturally through prolonged use [4]. Such systems fail simply because the soil underneath their absorption areas gradually loses its initial permeability because the soil pores become clogged with a black, slimy deposit composed of organic wastes, bacteria, inorganic precipitates and other debris. These are then removed from septic tank effluent as it percolates through the soil. Rehabilitation is accomplished by removing any stagnant water from the system and treating the soil with strong solutions of hydrogen peroxide. This treatment removes the bulk of the organic and some of the inorganic materials and essentially restores the soil to its initial permeability [4].

Prior to this discovery, clogging of soil by these black, slimy deposits or "biological crusts" following applications of septic tank effluent had been studied repeatedly in the laboratory using columns of sand or lysimeters [5-7]. Partial restoration of soil permeability had been observed when effluent applications were discontinued for several days or weeks and the soil was "rested" [5]. However, the recovery of soil permeability on resting was usually partial and short-lived [5]. On the other hand, clogged columns treated with small amounts of hydrogen peroxide were restored to essentially their initial permeability within minutes to hours [4].

Following the successful unclogging of crusted sand columns in the laboratory in November 1973, in May 1974 the silt loam soil under two trenches of a failed household septic system at the University of Wisconsin Experimental Dairy Farm near Arlington, Wisconsin was unclogged by peroxide treatment. A soil tensiometer–a simple device used to measure the moisture content of soils by observing the height to which a column of mercury is raised against gravity by the surface tension in the soil capillaries [8]–indicated that the soil below the crusted trenches was much drier before the crusting material was destroyed by peroxide. The higher soil moisture indicated by the tensiometer after peroxide treatment revealed that water started to percolate easily into the soil again because the clogging layer had been destroyed

(Figure 1). These experiences were reported at the Second National Symposium on Individual Onsite Wastewater Systems [4]. This system is still working satisfactorily; tensiometer readings taken for three years following treatment showed that water continued to percolate readily from the gravel leach field into the soil below, but a small gradual increase in the soil moisture tension or "dryness" suggested that the system was slowly beginning to clog again.

Three other systems in sandy soils in a mobile home park at Rhinelander, Wisconsin, a second system at the University Dairy Farm, and a fifth system in a clayey soil just north of Madison's Lake Mendota were also treated in the summer and fall of 1974. Again, tensiometer readings indicated that the soil

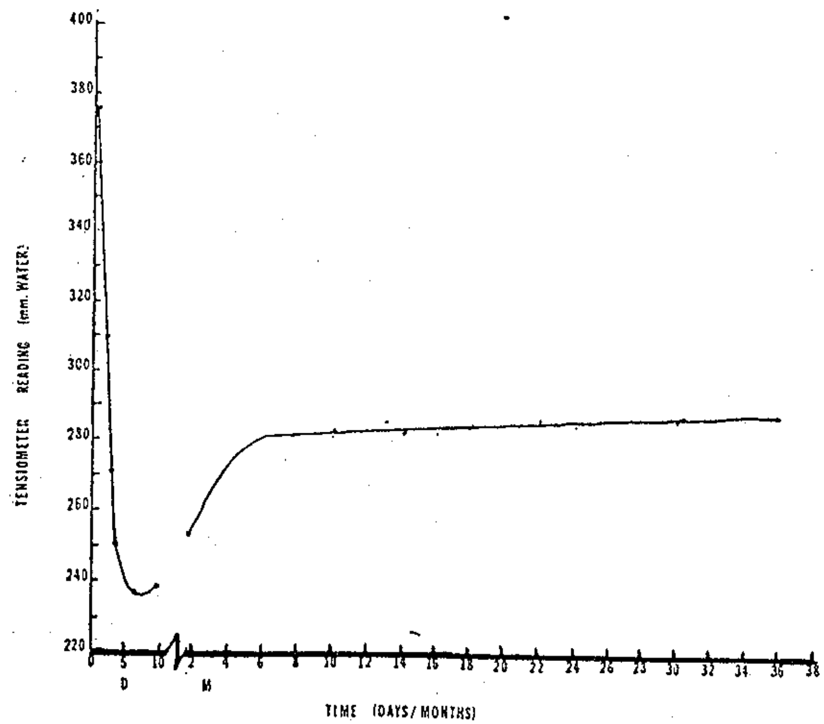

Figure 1. Changes in subcrust moisture tension following a POROX treatment in a field system. The initial steep drop indicates wetting of the soil as the crust is dissolved. The rise in tension during the first few days probably reflects resorting of soil agitated by decomposing peroxide. The slow rise over several months suggests gradual reformation of a biological clogging layer.

below these ponded, clogged systems became wetter after treatment, indicating that the clogging layer that had been inhibiting percolation of septic tank effluent into the soil had been destroyed by peroxide. These systems were also monitored by tensiometry. One of the systems in the sandy soil failed again soon after treatment, but was properly rehabilitated by a second treatment. Insufficient chemical had been added during the first treatment to dissolve the crust satisfactorily. Similar observations had been made previously with clogged soil columns in the laboratory; unless enough peroxide was added, the crust was not completely dissolved and permeability not adequately restored. In the laboratory, too, a second treatment invariably destroyed the residual crust left after the first inadequate treatment and returned the column to its initial permeability.

The advantage of this chemical method of system repair is that it restores soil permeability without creating major disturbances at the site or inconveniencing the users of the system by restricting water use [4].

Following the success of these laboratory and field experiments, an application was submitted for a patent covering chemical rehabilitation of septic tank systems, sand filters, etc., which had become clogged by biological crusts following applications of wastewater. This patent was issued in May 1977 and was assigned to the Wisconsin Alumni Research Foundation (WARF), the organization that handles patents for the University of Wisconsin [9]. WARF also coined the name POROX to designate the process and received a registered trademark for this name. Anyone practicing chemical treatments of such systems as failed septic tanks using hydrogen peroxide must be licensed by WARF. Further, in Wisconsin, anyone performing chemical treatments of failed septic tank systems must be licensed by the State Division of Health [10].

Since 1974 several hundred failed systems have been treated using the POROX process, either by licensees of WARF or by the author and his associates, who continued to experiment to determine the limitations of the process and improve ways to simplify and ensure uniform treatment of the clogged soil. A variety of system sizes, types and configurations have been treated: absorption trenches, beds and seepage pits (drywells) in a variety of soil types serving single-family dwellings, multiple housing units (mobile homes, small apartment buildings, etc.); retirement homes; restaurants; and even industrial plants. Modifications of the treatment solution have been developed to improve the treatment. For example, special stabilizers are sometimes added to inhibit enzymatic breakdown of the peroxide by catalases in the soil bacteria, and special equipment has been developed to facilitate the peroxide additions and ensure its thorough dispersal throughout the system. Details of the exact procedures for performing POROX treatments cannot be revealed because this is information supplied only to licensees by WARF.

Although a large measure of success was registered in these treatments, not all were successful. Paradoxically, many systems, (especially in sandy soils) that were expected to work well after treatment did not respond, while others performed amazingly well, even though treatment seemed unlikely to help because the systems were undersized, poorly constructed, etc. Closer inspection of systems where POROX treatments were ineffective generally revealed peculiarities with the system, which explained the lack of success. Recognition of these problems revealed patterns of shortcomings in system installation. Some interesting case histories are described in the following so that these inadequacies can be recognized and avoided in future.

CASE HISTORIES

Inappropriate Use of an Aerobic Unit

While a treatment was being performed at an industrial plant in upstate New York it was discovered that the system was not clogged in the customary fashion. Instead, in addition to the soil clogging, it was found that the distribution lines were half-filled with a black, greasy material, so that water could not drain out through most of the holes in the pipes. A small distribution box at the head of the system was also half-filled with the same material. The system was being served by an aerobic unit, which had been installed to replace a 5000-gallon septic tank used initially. The aerobic unit had been purchased because of an increase in the number of employees. It was expected that the aerobic unit would more effectively treat the wastewater and forestall any problems with the system. In fact, the aerobic unit was the real cause of the problem.

Workers in the plant used large amounts of barrier creams or hand cleaners containing lots of lanolin; the lanolin was not being degraded in the aerobic unit and was held in suspension as a fine dispersion by the agitation caused by the aeration device. Most of the lanolin passed out of the unit with the effluent. As soon as the effluent passed beyond the aeration unit, it became anaerobic. The lanolin settled out as a sludge in the pipes and in the soil of the absorption area, which was colored black by precipitates of metal sulfides formed under the anaerobic conditions. This system was rehabilitated by cleaning out the lines, regenerating the field permeability with a POROX treatment and reinstalling the septic tank in series in front of the aerobic unit. The quiescent flow conditions in the septic tank allowed the lanolin to separate before the septic tank effluent entered the aerobic unit, where further biological treatment was continued before the water passed into the absorption field, which now functions properly.

Improper Septic Tank Baffles

In several systems that were examined to determine whether they should be given a POROX treatment, problems with the outlet baffles were observed that had led or contributed to failure of the system. In some tanks the outlet baffles or sanitary tees were too long, so that the septic tank effluent flowing into the field was coming from a layer in the tank just above the sludge layer. Incompletely settled solids were forced into the absorption area, increasing the clogging in the soil and sometimes blocking the pipes in the distribution system. It has been shown that the amount of suspended solids in septic tank effluent is a major contributor to clogging and failure of soils [11]. In these systems, shorter baffles had to be installed and the pipes cleaned in addition to POROX treatment of the field to rehabilitate each system.

In several other systems, the outlet baffles were found to be so badly damaged or corroded that they were ineffective in retaining the scum layer in the tank. In some cases the baffles were missing altogether. Here, the load of solids from the scum layer was helping to clog the soils and sometimes completely blocking the outlet pipe from the septic tank, so that cleaning of the pipes and unusually large amounts of peroxide were required to rehabilitate these systems.

Problems were encountered with both metal and concrete baffles. Some metal baffles were so pitted and corroded that they were totally ineffective at retaining scum. No scum layer was observed in these tanks. The hydrogen sulfide and organic acids produced in septic tanks by bacterial action on the sulfates and putrescible organics in the wastewater are probably responsible for the dissolution of the iron in the baffles. In several other cases, metal baffles had fallen into the bottom of the tank because they had been inadequately anchored into the walls; either the bolts securing the baffles or metal anchors embedded in the concrete to hold the fastening bolts had corroded away. Some anchors had been set too shallow to begin with. Presumably galvanic cells are set up when baffles and bolts and metal anchors of different materials are exposed to the aggressive atmosphere in a septic tank and accelerate corrosion of the metals. Lightweight fiberglass baffles secured with plastic anchors or polyvinylchloride (PVC) sanitary tees were used to replace metal baffles in these systems.

Many concrete baffles were found to be damaged or missing. These were usually half-round baffles in monolithic concrete tanks. Where baffles were missing, the original baffles had not been reinforced with wire mesh. In some reinforced baffles the concrete had eroded away and the residues adhering to the wire were weak and of powdery, sandy consistency. Apparently, a weaker concrete mix had been used to facilitate slumping in the formation of the thin baffle walls because the tank walls were strong and undamaged. In the alkaline environment of septage, the poorer quality concrete had evidently deteriorated rapidly, leading to failure of the baffle and subsequent failure of the system by accelerated clogging.

Systems Installed in Sloping Sites

A variety of problems were encountered with systems installed on sloping sites. In at least four different systems examined, which had been installed parallel to the slope, the elevation of the normal water level in the septic tank was higher than that of the soil surface at the end of the seepage beds or trenches. Here soil clogging created a type of artesian well that regurgitated untreated effluent to the surface almost as rapidly as wastewater entered the systems. POROX treatments provided temporary relief for these systems, but they soon clogged and failed again at the bottom end because the bulk of the water entering the system was running down to the end of the system, overloading it in a localized area. Holes augered into the upper part of one of these systems revealed that the upper part of the bed was dry and unclogged, although water was surfacing at the low end.

Most sanitary codes and installation guidelines recommend that beds or trenches should be laid across slope at sloping sites. However, here too problems were encountered. In at least four systems, water was observed in the seepage trenches or beds soon after they had been unclogged by POROX treatments. Samples of water taken from the distal end of one of these systems were examined for fecal indicator organisms (total coliforms, fecal coliforms and fecal streptococci) and found to be nonseptic. The water levels in the trenches of two systems that were monitored varied according to the patterns of precipitation. Measurement of the water levels in shallow groundwater wells placed upslope from the systems frequently revealed that the water table came close to, or rose above, the level of the trench bottoms. The trenches actually were acting as interceptor drains and occasionally collecting groundwater moving down the slope at a high level in the soil horizon following heavy rains. Such systems could have been easily protected by drainage lines (curtain drains) installed upslope from the seepage trenches.

Similar problems were observed with some deep systems at the downslope end of long slopes; the homeowners had installed deep systems to accommodate toilets and showers in the basement level of their houses while avoiding the extra expense of a grinder pump to elevate the waste to a higher level in a shallow system. These deep systems also intercepted groundwater moving downslope through the soil; homeowners with shallow systems upslope from these sites experienced no such problems. Cross-slope systems are apparently particularly vulnerable to unusual groundwater flows. Therefore, careful soil inspection for signs of mottling (or preferably monitoring of the site) seems advisable before any system is installed at sloping sites. In any case, shielding of the system by a curtain drain is recommended before the site is landscaped.

Intrusion of Soil into Gravel Beds

The most frequently observed reason for lack of success of POROX treatments, especially in sandy soils, which are very easily unclogged in the laboratory, was intrusion of soil into the gravel within the absorption field.

When a soil absorption field is being installed, after gravel has been placed in the trenches or bed, and the septic tank effluent distribution system (perforated pipes or drainage tile) has been installed and embedded or covered over with a further thin layer of gravel, normally some barrier material is placed above the gravel before the system is backfilled with the soil removed during excavation. Typical materials used to cover the gravel are untreated building paper, straw or marsh hay, or pea gravel, which often are prescribed in state sanitary codes.

These materials are supposed to prevent soil from falling down into the gravel during backfilling. Untreated building paper is recommended for two reasons: (1) it is easy to apply, and (2) it is intended to be only a temporary barrier, remaining in position only until the soil has become consolidated above the gravel. In time, untreated paper rots away so that no barrier is left between the gravel and the soil. This is supposed to be beneficial because nothing is left to prevent movement of water vapor up through the soil or of air down into the soil. This situation is supposed to enhance both loss of moisture from the system by evapotranspiration and biological treatment of the wastewater by admission of oxygen to the soil bacteria. On the basis of such reasoning, use of impermeable barriers (plastic sheet, treated paper or roofing felt) is not permitted in many states.

The benefits of this theory are not realized in practice for unforeseen reasons. At fault is again the clogging of the system by biological crusts. As the system clogs and begins to pond, water becomes deeper and deeper within the gravel bed. Some ponded water seeps laterally into the soil, clogging the side walls of the trenches or bed as well (Figure 2). In time, the ponded water becomes so deep that it fills the whole absorption area, thus impinging on the soil overlying the gravel. Although this soil may have remained in place until that time, it is easily dislodged when wetted and can trickle down into the gravel.

The forces normally holding soil particles together in a consolidated mass above the gravel are the cohesive forces (mainly hydrogen bonding) of the

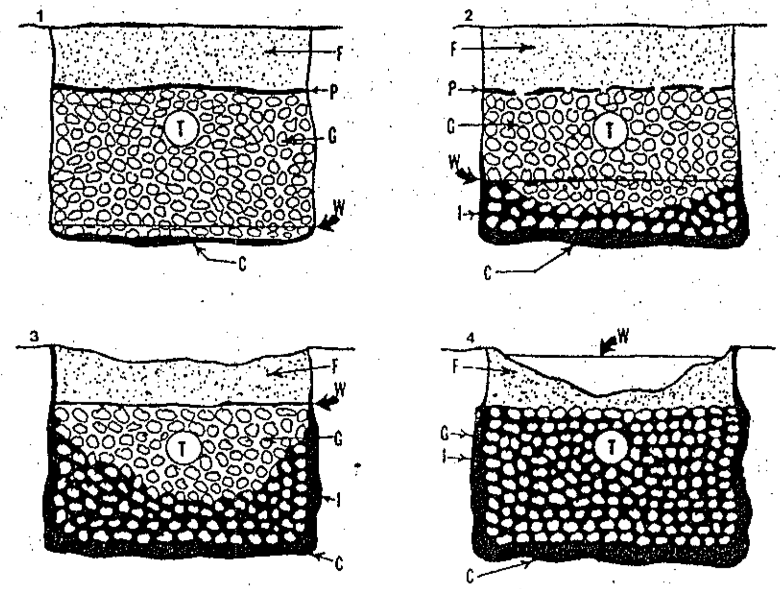

Figure 2. Schematic representation of the progressive stages in failure of a field system installed in sandy soil with untreated building paper as barrier material (C = biological clogging material, W = level of ponded water, P = paper in barrier layer, G = gravel, F = backfilled soil, T = drain tile or distribution pipe, I = infiltrated soil in gravel):

1. A thin biological clogging mat is forming under the gravel, causing water to begin to pond: paper is still undecomposed and retains backfilled soil.
2. Sidewalls are beginning to clog, ponded water is becoming deeper, paper is beginning to rot, some soil (probably mainly from sidewalls) is invading lower gravel.
3. Paper is totally decomposed, water level is now at top of gravel, sidewalls and bottom are more heavily clogged, soil from the fill is beginning to wash into the gravel.
4. The gravel is almost totally filled with soil, the backfill is slumping, and ponded water is surfacing.

extremely thin films of moisture surrounding the individual grains in the soil. Because these moisture films are so thin, the cohesive forces are strong when the soil is relatively dry; however, when the soil becomes waterlogged (saturated) as the effluent rises in a clogged and ponded system, the moisture between the soil particles is abundant and the cohesive forces become weak or are totally overcome. Thus, the soil particles are loosened and can trickle down into the gravel, filling up all the spaces between the stones. Some soil from the sidewalls of trenches or beds may invade the gravel in the same way while the water depth is increasing in the system. The soil that intrudes into the system fills up the pore space between the gravel and rapidly reduces the seepage area available for septic tank effluent infiltration (Figure 2).

This phenomenon was readily demonstrated using a laboratory model of a clogged drainfield (Figure 3). A Plexiglas® cylinder 12 inches in diameter and 4 feet high was sealed with a Plexiglas base and filled with gravel (1- to

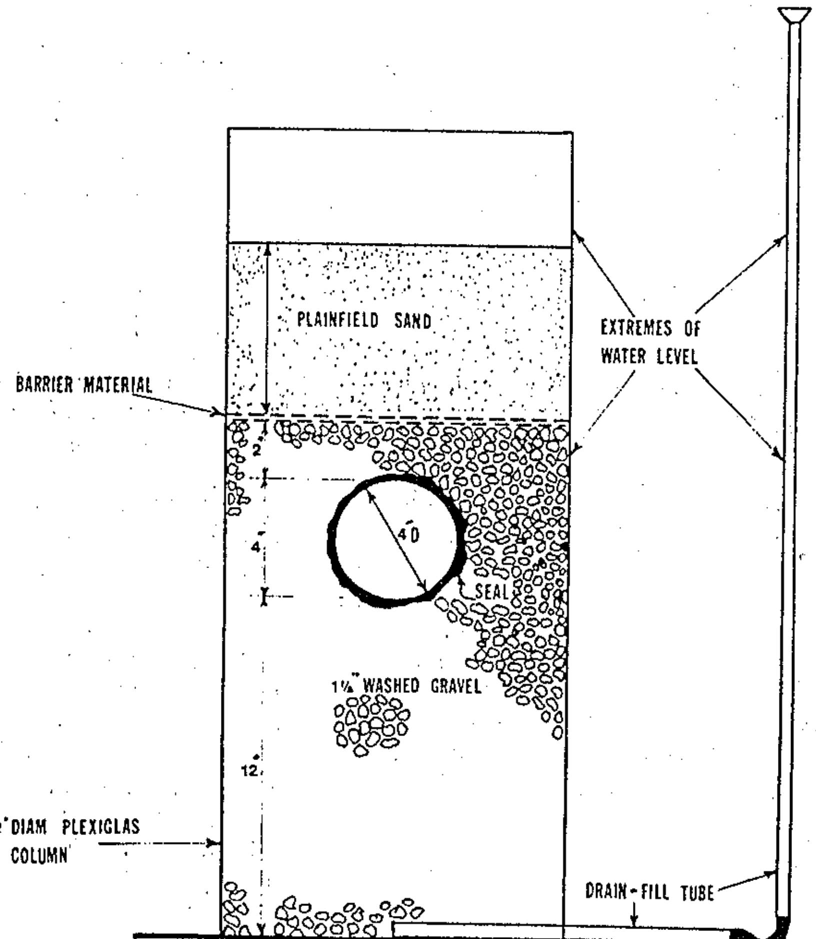

Figure 3. Laboratory model for testing barrier materials. Water levels were raised from the gravel–sand interface into the sand or the surface of the sand (ponding) and vice versa by adding or draining water from the tube.

1.5-inch diameter) to a depth of 12 inches. A section of 4-inch perforated pipe was puttied onto the sides. The pipe was surrounded with gravel and covered to a 2-inch depth with gravel. One of a variety of barrier materials was then placed above the gravel, being taped to the Plexiglas sidewalls if needed to provide an adequate seal, and 1-2 feet of Plainfield sand (C horizon) was placed above the barrier material and compacted by tamping. Plainfield sand was the soil chosen because (1) it is a common soil in the central sand plains of Wisconsin; (2) it has a fast percolation rate and is therefore considered ideal for installation of conventional septic tank–absorption systems; (3) it has the texture recommended for fill material for Wisconsin mound systems [2]; and (4) it is the soil that had invaded the gravel in several septic tank systems that did not respond well to POROX treatments.

Using this model, the efficacy of different barrier materials in preventing invasion of soil into the gravel in the unponded and ponded conditions was easily measured. To simulate ponding of a system, water was filled into the gravel using a tube sealed into the bottom of the plexiglass cylinder. When the water level was close to the barrier material and just above or below it, the water level was raised and lowered at different rates to simulate two different conditions: first, the slow minor fluctuations that result in a ponded system from normal patterns of household water use (increased water level during the day corresponding to peaks of water use in the house, drop in water level overnight) [12]; second, a sudden drop in water level that would occur if the septic tank were pumped in a system that was ponded and overfilled.

The barrier materials tested were: untreated building paper ("Red Rosin" paper); a 2-inch uncompressed layer of marsh hay; an 8- to 10-inch layer of marsh hay compressed to a thickness of 1–2 inches; a 2-inch unbacked fiberglass (building insulation); and a spunbonded polypropylene filter fabric.

Fresh undamaged building paper was an effective barrier that prevented both dry and wet sand from falling into the gravel and allowed both air and water to pass through the barrier. However, torn paper did not retain the dry sand, and even pinholes in the paper allowed wet sand to trickle into the system, especially when the water level was fluctuating in the vicinity of the barrier. Dry sand fell easily through holes in torn paper during "backfilling" and tamping. Wet sand cascaded through holes or tears in the paper when the system was flooded, regardless whether the water level was rising or falling and whether the rate of change of water level was fast or slow.

To examine how paper used as a barrier material in a real system might behave after it was weakened or rotted by biological action in the soil, undamaged paper was taped onto the sidewalls of the cylinder above the gravel and covered with tamped sand in the usual manner. The paper was then attacked chemically with strong acid or alkali. Paper weakened in this way was not an effective barrier to prevent wet Plainfield sand from invading the gravel when the water level fluctuated near the paper.

A loose layer of marsh hay was also not an effective barrier to either dry or wet sand. Some sand fell into the gravel immediately during "backfilling" and tamping of the sand layer. More sand trickled in when "ponded" water reached and fluctuated around the gravel/hay/sand interfaces. On the other hand, the 2-inch layer of compressed hay was quite an effective barrier. Dry sand did not flow easily through the compressed hay layer, and very little wet sand passed through this barrier. The practical disadvantages of using such a barrier are the expense of a sufficient amount of hay and the amount of labor needed to spread and compress it uniformly. Hay does not rot as easily in the soil as paper because hay contains some lignin [13]. Most of the lignin in paper is removed by Kraft pulping [14]. Consequently, hay will remain in position and prevent soil from entering the gravel for a longer time than paper, although eventually it may not, especially in well-drained, aerobic soils.

Pea gravel obviously will not rot in the soil, but is not a good barrier material. Some dry sand and more wet sand pass through a 2-inch layer of pea gravel. Experiments with soil drainage, graded sand filters, etc. have shown that particles pass easily through the interstices between particles that are more than seven times larger in diameter.

Unbacked fiberglass also does not rot in the soil and forms an excellent barrier to movement of both dry and wet soil. The only problems with fiberglass are its relatively high cost and occasional scarcity, because of the competing market for building insulation and difficulty in its application. A large amount of material would be needed to cover a field absorption area, and normally only batts or rolls of the relatively narrow standard widths used for building insulation are available. Fibers that penetrate the skin or are inhaled cause itching or throat irritation.

These problems are not shared by a large number of synthetic filter fabrics presently available on the market (Table I). These are also excellent barrier materials, as indicated by tests in the model system. They are applied in long rolls of varying widths and are also easy to cut, either with a saw while still rolled up, or with scissors when unrolled. The advantage of these materials over all others is that they can be used to prevent soil intrusion from trench or bed sidewalls as well. A layer of filter fabric can be placed around, or tacked into, excavation sidewalls before spreading the gravel during installation of field systems.

The choice of material used should be determined by cost, performance, strength and ease of application. Production costs are largely determined by the nature of both the synthetic fiber used and the fabric. Polyolefins are cheaper to manufacture than polyesters or nylon; nonwoven felts are cheaper to make than spunbonded (compressed felts whose individual strands are

Table I. Synthetic Filter Fabrics (Suggested for Use as Barrier Materials in Septic Systems)

Name	Fiber	Weave	Producer	U.S. Distributor	Efficiency[a]	Type	Approx. Cost ($/yd²)	Weight (oz/yd²)
Typar	Polypropylene	Spunbonded	DuPont	DuPont	120	3201	0.38	2
						3301	0.55	3
						3401	0.75	4
						3601	1.00	6
Bidim	Polyester	Nonwoven	Rhone-Poulenc (France)	Monsanto	60	C-22	0.75	4.5
						C-28	0.95	6
						C-34	1.25	8
						C-38	1.55	10
						C-42	2.40	17
Mirafi	Nylon-polypropylene	Nonwoven	ICI (Britain)	Celanese	140	140	0.90	5
Supac	Polypropylene	Nonwoven	Phillips Petroleum	Phillips Fibers	120	4P	0.75	4.1
Stabilenka	Polyester	Nonwoven	Dutch ENKA (Holland)	American ENKA	40		0.68	2.5
							0.73	3.2
							1.05	4.4
Cerex	Nylon	Spunbonded	Monsanto	Monsanto	50	–	–	2
Polyfilter X	Polypropylene	Woven	Carthage Mills	Carthage Mills	210	PFX	1.75	7.2
						FX	2.55	6.6
						PFGB	2.80	12

[a] 100% retention of particles greater than given diameter (μ).

bonded by melting) or woven fabrics. The strength and performance of the materials are determined by their weight (thickness), weave and pore size. Thick felts are relatively impermeable to soils but of lower tensile and tear strength; woven materials are expensive and relatively porous; spunbonded materials are strong and relatively impermeable. Considering all factors, spunbonded polyolefins seem best suited. Unlike building paper, when spread over gravel in field systems they do not tear or rupture when walked on or when backfill soil is dumped on them. Although more expensive than the paper, they supply lasting protection to soil intrusion while allowing unhampered passage of liquids or gases through the soil. Field systems installed on sloping sites using these materials are currently being monitored and performing well. even though one trench was intentionally allowed to pond completely.

DISCUSSION AND CONCLUSIONS

The POROX process is an effective method for rehabilitating septic tank systems that have failed because of soil clogging. The process is much less expensive and far less upsetting to the users of the system and their property than replacement of the failed system. However, complicating factors such as those described above can thwart the effectiveness of the chemical treatment or expedite recurrence of failure. The process should be applied only by properly trained and licensed practitioners who have been taught safe handling of the chemicals involved, appropriate techniques for their application, proper methods of diagnosing causes of failure, and proper techniques concerning how to decide whether a treatment should be performed and how much chemical should be used. Inappropriate application of the procedure can only result in failure and disappointment and bring the process into disrepute.

In time, as the design and quality of septic tank system installations improve, the natural process of biological clogging caused by aging of systems should become the only reason for system failure, so that the applicability of the POROX process should increase. Research is continuing to determine whether there are yet other factors that complicate or frustrate application of the process and to improve diagnosis of system problems and the quality of POROX treatments.

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