SUBSURFACE TRICKLE IRRIGATION SYSTEM FOR ON-SITE WASTEWATER DISPOSAL AND REUSE

Dr. B.L. Carlile P.E.
Cert. Prof. Soil Scientist†

Dr. A. Sanjines, Mech. E.
Geoflow, Inc. §

Summary of Process Description

The subsurface trickle irrigation system described in this report utilizes an aerobic treatment system in conjunction with a proven subsurface water application system developed by GEOFLOW, Inc. to offer a total system concept for safe and effective sewage disposal for site conditions considered marginal or unsuitable for conventional septic tank systems.

The integrated system described here is an improved dosing and distribution concept compared to the low pressure pipe system, approved and utilized in many states to overcome soil/site limitations. The proposed system is also an effective irrigation system allowing reuse of treated wastewater in home and lawn settings without the concerns of direct exposure of the effluent to human and animal populations.

The system proposed is an integrated package consisting of several components, each designed for a specific purpose in the treatment and disposal of wastewater by trickle irrigation. including:

1. Primary treatment - the wastewater is first passed through a primary tank to achieve physical settling of macro-solids and to assist in degradation of some pollutants including oil and grease. This will be achieved in a septic tank for home systems and a properly designed primary tank for larger flow systems
2. Secondary treatment - the primary effluent will be further treated in a secondary treatment process by extended aeration in a Clearstream Aerobic Treatment System that has been fully field and lab tested to show achievement of effluent quality of better than 20 mg/l Biological Oxygen Demand (BOD) and 20 mg/l Total Suspended Solids (TSS) at maximum design flow.
3. Disinfection - the secondary effluent will be treated by chlorination ozonation or ultra-violet radiation at adequate dosage to achieve disinfection of pathogens to drinking water quality standards.
4. Filtration - the treated effluent in passed through a 150 mesh disc filter, with manual or automatic backwash, prior to irrigation.
5. Subsurface irrigation - the relatively clean effluent is injected 6 to 10 inches below the soil surface through trickle emitters located on 24 inch centers throughout the disposal area. The effluent will be applied in several "pulses" per day at rates not to exceed the water absorption capacity of the soil. A typical system would be dosed 5 to 8 times per day at 50 gallons per dose. A

† Carlile and Associates, Inc. PO Box 2677 College Station, TX 77841

§ Geoflow, Inc. Subsurface Irrigation. 236 W. Portal Ave, #327 San Francisco, CA 94127

submersible effluent pump with water level controls in a pump tank will be used to control dosing volumes in most systems.

6. Economics - the estimated system cost will be slightly higher than a typical low pressure pipe or surface irrigation disposal system. The subsurface trickle system does offer a suitable irrigation system for lawns and landscape beds whereas the low pressure pipe system cannot be considered an efficient replacement for an irrigation system. While surface irrigation of wastewater is limited to off-hours application to remote or low use areas of a lot, the subsurface trickle irrigation system can be utilized for the entire high-use lawn area even through some fresh make-up water may be required to be added during peak water use months.

A schematic diagram of the treatment process is shown in Figure 1 and a typical field layout of the trickle irrigation system is shown in Figure 2.

Introduction

Many homes, communities, businesses, and schools in rural United States do not have access to public sewage treatment facilities and must treat and dispose of the daily sewage flow through on-site disposal systems or by wastewater treatment systems whose effluent flows to a receiving stream for discharge.

In the past, the system most often chosen because it was the simplest and cheapest to build was the conventional septic tank followed by soil trenches filled with stone which served as underground storage reservoirs and absorption surfaces for disposal of the sewage in the surrounding soil. Because of site specific factors such as poor soils, high water tables and excessive slopes, as well as the limitations of gravity distribution for large flows, the conventional septic tank-soil absorption systems often malfunctioned after a limited period of use.

Several alternatives have been developed and used for repair and replacement of the conventional septic tank system for these poor site locations. The major consideration in assessing the suitability of these alternatives for such installation were:

1) simple and reliable - ability to operate over a long period without continuous presence of a skilled operator

2) efficient - simple to install and efficient in operation with minimum operational costs

3) environmental impact - health, aesthetic and water quality problems should be minimized

4) costs - both installation and O & M costs should be within the range of current alternatives available

5) potential for reuse - effluents from the system should have potential for reuse for irrigation of lawns and shrubs with minimum impact on underlying groundwater

The soil absorption systems developed and most utilized currently for these fragile site installations include the low pressure pipe (LPP) system, and the surface irrigation system. Each of these systems have specific site and soil criteria where best utilized and require detailed site investigations for proper design. It is proposed that the subsurface trickle irrigation system proposed here is an improved and suitable replacement for both of the systems.

Soil Absorption System

The major factor in design of a satisfactory on-site waste disposal system for poor soil conditions can be summarized as follows: 1) distribution, 2) dosing, 3) sewage placement, and 4) improved pre-treatment and disinfection.

Distribution cannot be over-emphasized in the design of any on-site system for "low perc" soils due to the need to spread sewage over large land areas. The effluent must be distributed evenly over this large area so as not to exceed the capacity of the soil to absorb the hydraulic load. Adequate distribution is extremely hard, if not impossible, to achieve in any currently designed gravity flow system. Some portion of the system is inherently overloaded which results in initiation of the clogging phenomena and hence the "progressive failure" observed in many such systems. Low pressure systems improve on the distribution concept but have limitations in "low perc" soils in that trenches can only be installed on 4 or 5 foot centers and the relatively high flow from drilled orifices often result in effluent surfacing.

Dosing of effluent is equally important in maintaining the aerobic status of the soil system in and around the distribution trench, thus preventing the clogging or "slimming up" of soil interfaces and subsequent failure. Dosing concepts can be described as either 1) short term dosing or 2) alternate dosing.

Short term dosing usually refers to multiply daily dosings of effluent into a single system with several hours or sometimes days of resting and re-aeration between each dose. Two to eight doses per day has been shown to be satisfactory in systems designed for pressure dosing in either subsurface or surface application.

Alternate dosing refers to dual or multiple fields where one part of field receives all of the effluent for a specified period. at which time the effluent is switched to the alternate plot. This can be done each pump cycle, once per day or switched only when one field has a problem. Both short term and alternate dosing is often utilized in trickle irrigation systems.

Both dosing concepts as well as combinations and modifications of the above have been successfully utilized in several states to treat and dispose of sewage from individual homes as well as cluster developments, school systems, and mobile home parks with flows of up to 50,000 gpd.

The design factor of sewage placement refers to the concept of placing the sewage in the soil zone or horizon most conducive to absorption, treatment, and re-aeration. In soils with high water tables this usually means at least a one or two foot separation between the seasonal water table and the point of sewage injection. For soils with restrictive clay horizons or hardpans, the sewage should be injected as high above the restrictive zone as possible. This minimum separation allows for lateral or horizontal flow of effluent away from the distribution trench or pipe before interception by the restrictive zone and allows for more uniform absorption through the restricting layer. This, coupled with enhanced treatment of the sewage in the better soils above the restrictive horizon, greatly enhances the quality of effluent impacting the restrictive horizon. Generally, water tables and restricting layers must be deeper than 36" for conventional gravity systems to function adequately on such sites.

The final design factor is that of pre-treatment and disinfection. This factor becomes most important on sites located on fragile conditions such as high water tables and/or on soils having restrictive horizons near the surface. These conditions result in the potential for effluent impacting groundwater or surface water quality near the site location. If the soil treatment zone is not sufficient to adequately treat the injected sewage flow, some pre-treatment and disinfection must be utilized prior to soil disposal to offer needed protection of surface and ground water resources.

System Design Parameters.

A. Primary and Secondary Pre-treatment -

Both primary and secondary pre-treatment will be afforded to the sewage to achieve greater than 90 percent removal of suspended solids and organic contaminants from the wastewater prior to disinfection and disposal.

Primary treatment will be by anaerobic treatment in an initial settling tank with at least 1 day detention time. Primary treatment is both a physical and biological process that achieves about 40% degradation of soluble BOD and 50 to 60% removal of solids by physical settling.

Secondary treatment will be by the aerobic process which applies the principles of an aerobic environment to provide more rapid and complete decomposition of organic waste material, greater reduction of pathogens, and oxidation of nitrogen products as compared to an anaerobic environment. A Clearstream aerobic system that is properly sized and maintained should provide an additional 85 to 90 percent removal of BOD and TSS from the wastewater

Aerobic decomposition and treatment can be accomplished at the least cost through small mechanically aerated treatment systems. The better small aerobic units are capable of producing an effluent exceeding that of the most sophisticated municipal treatment plants. Table 1 shows the summary of effluent quality from a two year operational study of the Clearstream Aerobic Treatment System, field tested at several homes in Florida and Texas and by extensive testing of the unit by the National Sanitation Foundation, a national independent testing agency.

The aerobic treatment unit described here treats the primary effluent by extended aeration in a mechanically aerated contact chamber. The aerated wastewater in the contact chamber is well mixed to provide optimum exposure of the microorganism to the waste material. There is also a significant reduction of pathogenic bacteria during this process. After approximately 24 hours of aerobic contact, the activated wastewater is clarified in a settling chamber and the settled solids returned to the aeration chamber. The settled and clarified effluent is discharged from the settling chamber through an improved design discharge assembly to minimize solids carryover .

Aerobic treatment of domestic wastewater can be accomplished in other ways. Sand filtration is a process sometimes used whereby the domestic wastewater is first given primary treatment in a septic tank to reduce solids

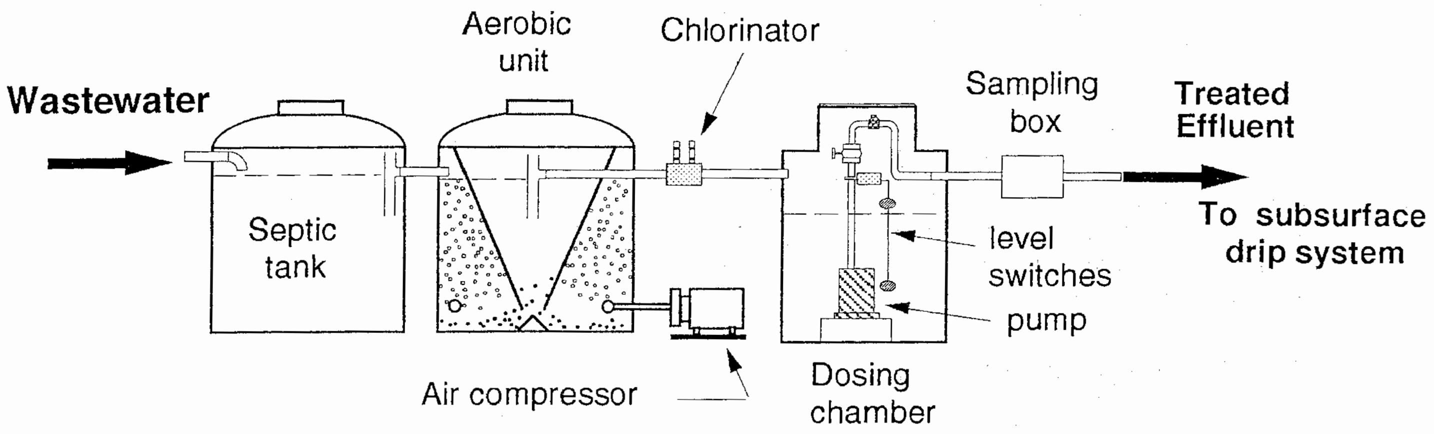

Figure 1. Pretreatment System

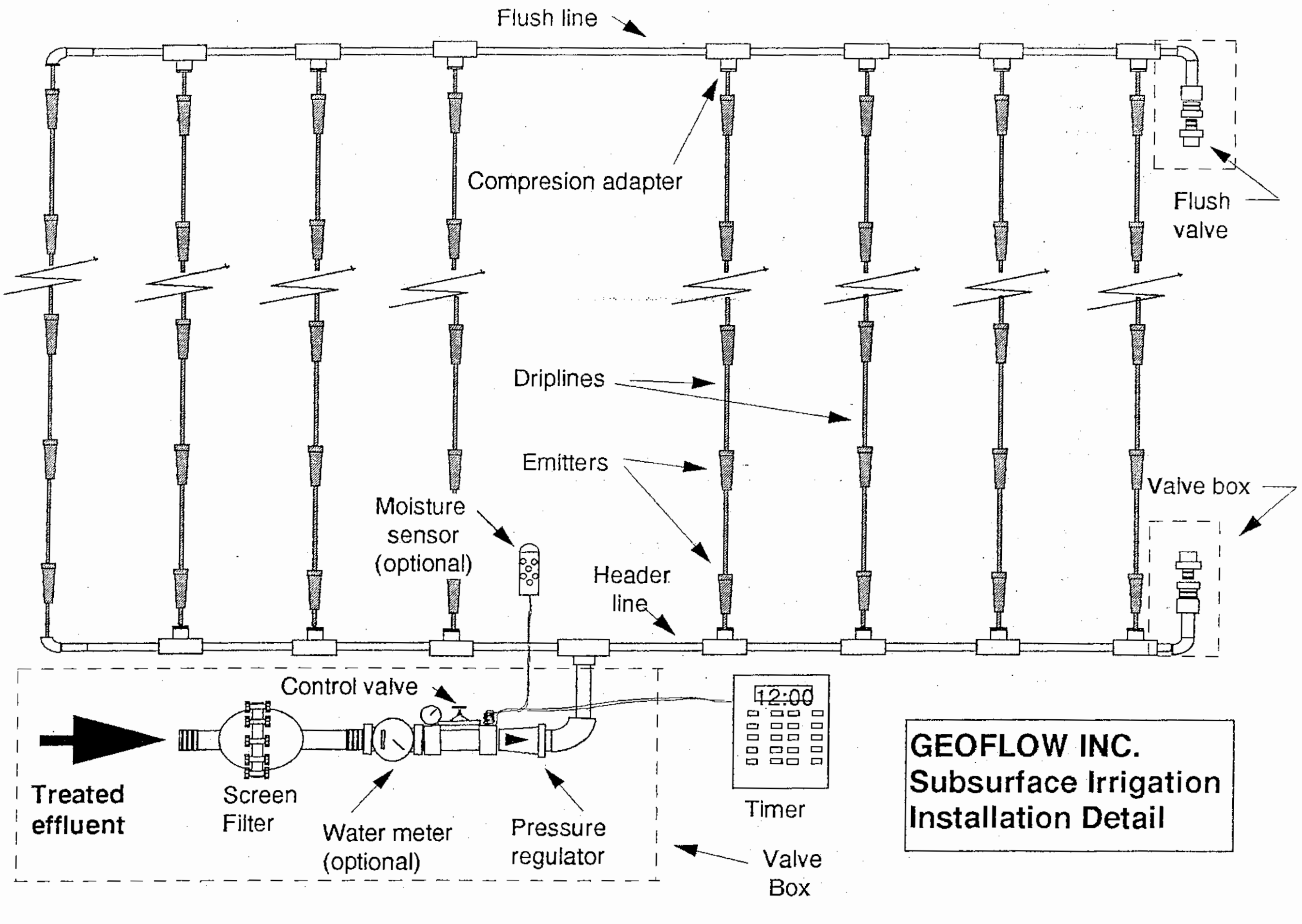

Figure 2. Subsurface irrigation system

and then applied intermittently to the surface of a sand bed of 2.5 to 3 foot depth. The most efficient sand filtration method is the recirculating sand filter (RSF). The RSF offers a high degree of treatment with a minimum of maintenance or nuisance problems compared to the standard intermittent sand filter . The RSF when loaded at a raw waste hydraulic loading of 2.5-3.0 gal/ft2 per day produces a high quality effluent of similar characteristics to that of the better aerobic treatment units.

Table 1. Typical field data of effluent quality from Clearstream* Home Aerobic Treatment Units.

No of Units	Location	Sam ples	BOD (mg/l)	TSS (mg/l)	pH	Fecal colif. /100ml
6	Orlando, FL	8	5.5	5.1	6.7	.-
1	Rockwall, TX (Note 1)	3	3	10	7.5	21
1	Rockwall, TX (Note 2)	3	<3.0	<1	7.5	<3
1	NSF testing	120	5 - 10	5- 10	7.2	.-

Note 1) Before Ozonation
Note 2) After Ozonation

The slow rate, intermittent sand filter, when designed at an hydraulic loading of 1.5 to 2 gal/ ft2 per day of septic tank effluent can also produce a high quality effluent, but will require more frequent maintenance than the RSF system. Frequent raking of the sand surface and periodic replacement of the top few inches of filter sand are periodically required. Odor problems are also a frequent complaint of the intermittent sand filter unless the septic tank effluent is dosed on the filter in a subsurface gravel bed . SInce the RSF system is dosed with an aerobic mixture of 4 parts filter effluent and 1 part septic effluent, odors are not a serious problem.

While sand filters can produce an effluent of equivalent quality to the better aerobic treatment units, the initial high cost of installation is the only downside of this system. Installation costs often run at two or more times that of the mechanically aerated system . Operational costs of the sand filter will be slightly less but will require several years of operations to recover the difference in costs.

B. Disinfection

The treatment by chlorination, ozonation, or UV radiation of the effluent discharged from the aerobic cell represents the final step of a "safe" pre-treatment system designed to allow maximum reuse of the wastewater in a landscape mode. The potential of ozonation for deactivating viruses and bacteria, detoxifying organic compounds and oxidizing any odorous components make it the logical choice for systems installed in lake shore settings or in extremely high groundwater conditions.

* Clearstream Wastewater Systems,. P.O. Box 705, Silsbee, TX 77656

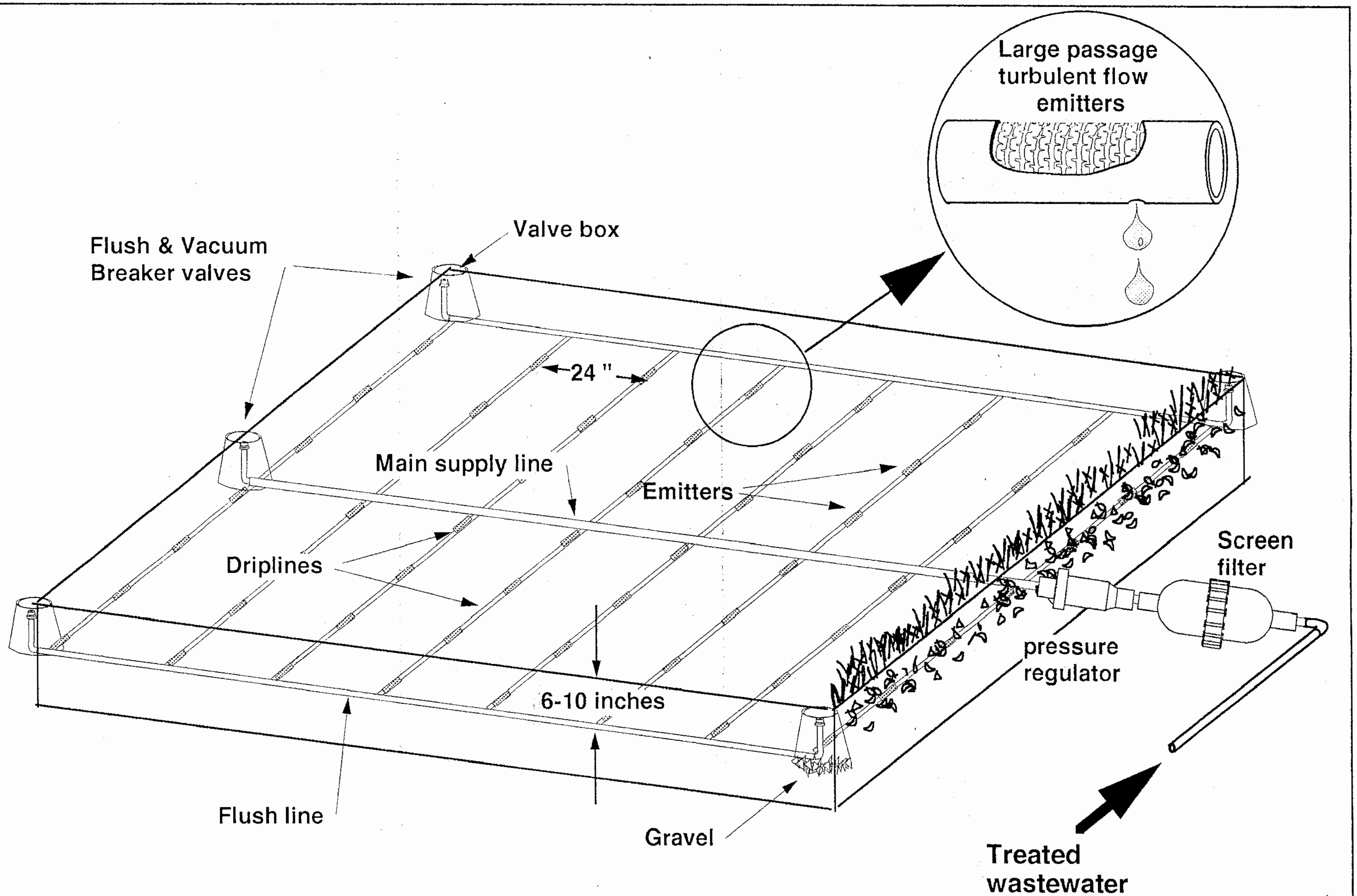

Figure 3. Subsurface drip installation diagram.

Ozone concentration in very low amounts and at very short contact time is capable of disinfecting and deodorizing the effluent. This process has only recently been utilized for home waste treatment due to the high installation and operation costs of previous ozonation systems. However, recent breakthrough in small ozonation equipment and generation by UV methods have resulted in small home units very economical to install and operate. These units provide safe, dependable and economical disinfection of home wastewater without the concerns or management problems associated with chlorine disinfection.

C. Final Treatment and Reuse by Subsurface Irrigation

Decentralizing the treatment process and producing a safe effluent at the point of generation makes reuse an attractive activity. Reusing aerobic, disinfected wastewater instead of potable water for non-potable uses like flower-bed and shrubbery sub-irrigation reduces the effective cost of the system and can lead to significant reduction in per capita demands for potable water supplies. Applying wastewater to the soil is in itself a very effective treatment process. There are many chemical, biological and physical processes that occur in the soil that substantially improve the quality of wastewater (1, 11, 12).

Trickle Emitter Design

A reliable subsurface trickle irrigation system for wastewater combines the advantages of high irrigation efficiency and water economy with that of safe underground application.

The major concern and problem with drip or trickle irrigation has always been the risk of clogging of emitters, even when using clean well-water. This has resulted in the design and use of relatively larger diameter outlets in the emitters. However, by using larger outlet emitters in subsurface drip systems, root intrusion became the main constraint. Roots seeking moisture and nutrients have been shown to enter drip irrigation lines and block them in the same manner they enter sewer pipes (2).

Because of the amount of impurities associated with wastewater and the potential for bacterial growth in the lines, the constraints of emitter blockage is quite real and must be addressed. To minimize this problem, the emitters should have relatively large diameter outlets. GEOFLOW™ has developed an emitter with "turbulent flow long path" design that has the largest flow area for a given flow rate of any emitters in use today. These emitters operate at a flow rate of 1 to 2 GPH with 0.06 to 0.07 inch orifices.

To solve the problem of root intrusion, the ROOTGUARD® [1] process was developed. This is an exclusive GEOFLOW™ process by which an environmentally safe herbicide (TREFLAN®[2])is compounded into the emitters to protect them from root intrusion for many years. The quantities of herbicide used are very small since only a small area around the emitter orifice has to be

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[1] ROOTGUARD® is a registered Agrifim Irrigation trade mark. The ROOTGUARD technology is used under license from the Battelle Memorial Institute.

[2] TREFLAN®is a trademark of Dow- Elanco

protected. Because of the very limited movement of ROOTGUARD in the soil and its virtual insolubility in water, only the roots that try to enter the emitter orifice will be inhibited. The herbicide used is environmentally safe since it does not move in the soil or dissolve in water and is not absorbed by the plants, ROOTGUARD has been registered by the Environmental Protection Agency for use in landscaping and food crop irrigation (EPA registration no. 1471-70).

The turbulent flow emitters used by GEOFLOW in the proposed wastewater systems are made out of polypropylene and polyethylene and are resistant to most acids and substances likely to be found in domestic wastewater. The pre-treatment unit with disinfection designed in conjunction with the system should keep the bacterial slimes under control in the system and the 150 mesh disc filter installed in-line of the header should remove any extraneous solids which might be of size to plug the emitter orifice.

All these components integrated into a reliable sub-irrigation system makes this a unique process for domestic waste disposal. Other systems of a similar nature are being promoted and used in some southeastern states. One such system called Mo-Dad-1 system utilizes the RAM drip emitter, a rubber diaphragm pressure compensating emitter. The rubber diaphragm reduces the outlet orifice during operation, making it highly susceptible to clogging. Even though the orifice opens when pressure is off, the chances of intermittent plugging with bacterial slimes are quite high.

A rubber diaphragm is susceptible to attack by oil, gasoline products and oxidizing agents, resulting in a likely change in the physical characteristics of the rubber over time and thus affecting the uniformity of flow in the emitters. Deposits also tend to build up at the seat of the diaphragm over time, changing the flow characteristics of the emitter.

The RAM type emitter is not protected against root intrusion and is susceptible to plugging by roots (2). Only the GEOFLOW emitter protected by ROOTGUARD® can offer positive protection against a very serious threat of root plugging.

Soil Application Design

The instantaneous water application rate of the system must not exceed the water absorption capacity of the soil. A determination of the instantaneous water absorption capacity of the soil is difficult, however, since the value varies with the water content of the soil. As the soil approaches saturation with water, the absorption rate reduces to an equilibrium rate called the "saturated hydraulic conductivity." Wastewater application rates should be less that 10 percent of this saturated equilibrium

Even though the trickle irrigation system maximizes the soil absorption rate through the low rate of application, thus keeping the soil below saturation, there will be times when the soil is at or near saturation from rainfall events. The design must account for these periods and assume the worst case condition of soil saturation. By designing for a safety factor of 10 or 12, based on the saturated hydraulic conductivity, the system will be under-loaded most of the time but should function without surface failure during extreme wet periods.

Using a safety factor of 12, a suitable design criteria would be to load the system at the estimated hydraulic conductivity but apply water for only a total of

2 hours per day out of the available 24 hours. By applying wastewater for a total of 2 hour per day, particularly if applied in "pulses" or short doses several times per day near the soil surface were the soil dries the quickest, this would keep the soil absorption rate at the highest value and minimize the potential of water surfacing on poor soil conditions.

As stated previously, this design criteria will under-load the system at all times except when the soil is at or near saturation from rainfall. If designing for an efficient irrigation system, the water supply may not be sufficient to meet the demands of a lawn or landscaped area during peak water demand months. This problem can be overcome by either of two solutions: add additional fresh-water make-up to the system during the growing season to supply the needed water for plants in question; or split the system into two or more fields with necessary valves and only use one of the fields during the peak water demand months and alternate the fields during winter months or extremely wet periods

Table 2 shows the recommended hydraulic loading rates for various soil conditions, using a safety factor of 12 with regard to the equilibrium saturated hydraulic conductivity rate of the soil.These loading rates assumes a treated, disinfected effluent with BOD and TSS values of less than 20 mg/l is produced in the pre treatment system.

Table 2. Minimum surface area required to dispose of 100 gpd

Soil type	Soil absorption rates: Est.Soil Perc. rate min/in	Soil absorption rates: Hydraulic. Conduc-tivity. in/hr	Design Hydraulic Loading rate gal / ft2-day	Total Area required ft2 / 100gal per day
Coarse- sand	<5	>2	2.0	52
Fine sand	5-10	1.5-2	1.6	65
Sandy loam	10-20	1.0-1.5	1.3	80
loam	20-30	0.75-1.0	0.9	115
Clay loam	30-45	0.5-0.75	0.6	175
Silt-clay loam	45-60	0.3-0.5	0.4	260
Clay non-swell	60-90	0.2-0.3	0.2	520
Clay - swell	90-120	0.1-0.2	0.1	1040
Poor clay	>120	<0.1	0.075	1380

System Installation

Pre-treatment System

For individual home systems, a 500 gallon septic tank and an aerobic treatment system of 500 gallons per day capacity is generally used for homes of 4 bedrooms or less. For larger homes, a 600 - 750 gallon per day aerobic unit should be used.

After primary and secondary treatment, disinfection is the next step to reduce pathogen levels in the effluent and minimize bacterial growth in the field lines and emitters. The usual treatment to control bacterial slime growth is chlorination on a continuous basis to achieve a residual concentration of 1-2 mg/l. If ozone or UV disinfection is used, which have no residual effect in the lines, then chlorine should be applied on an intermittent basis at a rate of 10-20 mg/l just before the system is finished dosing the last dose of the day.

Chlorine may be introduced into the system either as liquid, solid or gas forms. For home systems, the liquid or solid form is more appropriate. Since calcium hypochlorite tablets may flake when dissolving and chlorine may cause some iron and manganese precipitation, it is better to chlorinate ahead of the final filter so that any particulates are removed.

Pump Tank and Controls

Dosing and irrigation supply will be by a submersible effluent pump located in a 150-300 gallon storage tank. The operation of the pump will be by a simple float on-off level switch in the tank. The "on" level switch will activate the pump when the tank reaches a high water mark and the low level switch will turn the pump off when the tank reaches a predetermined minimum water level. For a typical system this volume would be 50-100 gallons. For a 250 to 500 GPD system, this results in 3 to 10 irrigation pulses per day. For systems on sloping ground where water drains from the pipes to the lower points of the system after each pulse or dose, larger doses and fewer pulses per day would be more suitable. Irrigation uniformity is best maintained with irrigation pulses of 10 minutes or more.

Filter Requirements

The recommended disc filter uses a 150 mesh screen that filters out particles larger than about 100 microns. The type of emitter used in GEOFLOW trickle systems will not have problems with this particular size since the diameter of the flow path is 14 to 17 times larger, or 0.056 inches (1400 microns) for the 1 GPH emitter to 0.08 inches (2,000 microns) for the 2 GPH emitter. To maintain the proper water quality for the drip system, the filters are easily backwashed manually or equipped with automatic back flush triggered by a timer or a pressure differential switch. The installation schematic of the in-line filter is shown in the typical system lay-out.

Flow Regulator

Under normal conditions, the pressure in the trickle lines should be maintained between 20 and 25 psi during operations. This is controlled by a pressure regulator located in-line following the filter. The emitter lines are connected at each end by a PVC header line and flush line to allow optimum pressure equilibrium in the system. Flush /vacuum release valves are located at each end of these lines to allow a small amount of water to be automatically flushed from the system every time it is started and avoid dirt suck back when the system is switched off. This is important to prevent solids from accumulating at the ends of these lines and to prevent dirt from entering the lines.

The schematic of a typical field layout of the trickle irrigation system shows only a single field. For systems over 2000 ft in size or having over 500 emitters, the system would be split into 2 or more fields of equal size. Flow for a dual field system would be alternated through the use of a mechanical valve which automatically switches fields each time the pump is activated.

For systems with more than 2 fields, the operation of each field is controlled with an irrigation controller utilizing electric solenoid valves for each field station. By separating the system into several fields, smaller pumps and more uniform distribution can be achieved. Where soil conditions vary, some fields may be programmed to receive less water than other fields of the system .

<u>Trickle Emitter Lines</u>

A normal home system would have emitter lines placed on 2 foot centers with a 2 foot emitter spacing such that each emitter supplies a 4 ft area (Fig. 3). These lines are best placed at depths of 6-10 inches below the surface. This is a typical design for systems on sandy and loamy soils which will have a cover crop of lawn grass. Other line spacing may be used for special use situations such as for landscape beds where shrubs and trees are to be watered and are planted on an irregular spacing. Closer line spacings of 15 to 18 inches can be used on clay soils where lateral movement of water is restricted.

The shallow depth of installation is an advantage of the trickle irrigation system since the topsoil or surface soil is generally the most permeable soil for accepting water. The topsoil also dries the fastest after a rainfall event and will maintain the highest water absorption rate. Where restrictive horizons such as hardpans or claypans are present or sites with seasonal high water tables near the surface, shallow placement allows the dispersement of water above these zones. Where fill material is used to increase the soil depth on such problem sites, the trickle emitter lines can be laid on the original soil surface and the fill material carefully placed over the lines.

Table 3. Water application table for a 1 Gallon/hour emitter

Water application (inches of water per hour)

Emitter	Drip line spacing (inches)						
spacing (in)	12	15	18	24	36	48	60
12	1.60	1.28	1.07	0.80	0.53	0.40	0.32
15	1.28	1.03	0.86	0.64	0.43	0.32	0.26
18	1.07	0.86	0.71	0.53	0.36	0.27	0.21
24	0.80	0.64	0.53	0.40	0.27	0.20	0.16
36	0.53	0.43	0.36	0.27	0.18	0.13	0.11
48	0.40	0.32	0.27	0.20	0.13	0.10	0.08
60	0.32	0.26	0.21	0.16	0.11	0.08	0.06

All trickle irrigation systems are dependent on a good vegetative cover to prevent erosion from the field and utilize the water applied to the rooting zone. Sites should be quickly sodded or seeded and mulched with appropriate lawn grasses immediately after installation. Most lawn grasses will use 0.25 to 0.35 inches of water per day during the peak growing season. This calculates to be about 0.16 to 0.22 gal/ft /day, a significant part of the daily effluent loading. By overseeding lawns with winter ryegrass, this use efficiency can be continued through much of the year.

For vegetation using 0.16 to 0.22 gal/ft2 /day by evapo-transpiration, the typical home sewage flow of 250 gallons per day would supply the water needs of a landscaped area of 1150 to 1600 sq. ft. without having to add fresh make-up water. For systems larger than this, the plants will suffer water stress during the hot dry months unless additional fresh water is applied.

To determine the rate of water application from various trickle irrigation designs, Table 3 gives the rate for a 1 gph emitter at various line and emitter spacings. These values assume the water is equally distributed between the emitters.

Calculation Example

As a sample calculation, a 450 GPD home system has to be designed. The system is to be located on a silty clay loam soil with an estimated saturated hydraulic conductivity of 0.4 in/hr Turf grass will be grown on the site with a peak evapotranspiration of 0.25 inches per day. The site is a level site.

a) Field area required (Table 2)
    260 ft /100 gpd x 4.5 = 1170 ft2
b) Emitter line spacing = 24"
    Emitter line required = 1170 ft2 / 2ft = 585 ft
c) Emitter spacing = 24"
d) Total number emitters = 585ft/2ft=293 emitters
e) Emitter flow rate = 1.13 GPH
f) Total flow = 293 x 1.13 GPH = 331 GPH
g) Daily irrigation time = 0.25 in/day / (0.40 x 1.13))= 0.55 hours/ day (Table 3)
h) Pumping rate required = 331 GPH/ No. of sectors= 331 GPH / 1 or 5.5 GPM
i) System operating pressure = 20 psi = 46 ft
j) Pumping Head
    Pressure H = 46
    Friction H = 5
    Elev. H = 4' (pump depth below grade)
    Total = 55'
k) Pump Selection - Meyers E3, submersible
    Effluent pump - 5.8 GPM @ 55' head
l) The water depth applied at 450 GPD over 1170 ft 2 (there are 231 cu. inches per gallon)
    450 / 1170 = 0.38 gal / ft2 . Or x ·(231 cu. in / gal) / (144 in/ ft2) = 0.61 in/day
m) Water depth applied if only typical household waste flow of 300 GPD were available = 0.40 in
n) Irrigation area required to apply 300 GPD at a peak water use rate of 0.25 in/day
    = 1170 ft2 x 0.40 /0.25 = 1875 ft2

To get most efficient use of the average daily wastewater supply, an area of 1875 ft2 would be selected.

o) If a 75 gallon dosing volume were used for an average flow of 300 gallons per day, about 4 irrigation cycles per day would be made, lasting about 14 minutes each.
p) If 1875 ft 2 are selected so that the maximum area is irrigated, then to keep the same small pump, it would be convenient to divide the plot into two sectors of 940 ft 2each. Following the same calculation procedure, the flow per sector will be 4.47 GPM, and the time to dispose of 75 gallons will be 17 minutes. To dispose of 300 GPD it will take four irrigation cycles. Irrigation to the sectors will be alternated.

<u>Design Summary</u>

Design flow rate = 450 GPD
Normal flow rate = 300 GPD
Minimum irrigation area required = 1170 ft2
Most efficient irrigation area = 1875 ft2
Daily irrigation time 0.86 - 1.4 hr/d

Design Layout
(see Fig. 3)

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