

Lecture 17

Filtration for Trickle Irrigation Systems

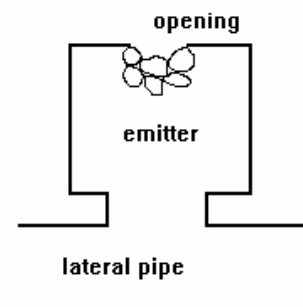
I. Introduction

- Water for trickle irrigation systems can come from open reservoirs, canals, rivers, groundwater, municipal systems, and other sources
- Solid contaminants can include both organic and inorganic matter
- Examples of inorganic matter are sand, silt and clay (soil particles), and trash floating in the water
- Examples of organic matter are bacteria, algae, moss, weeds & weed seeds, small fish, insect larvae, snails, and others (see the figure below)



- Solid contaminants need to be removed from trickle irrigation systems because they:
 1. Cause clogging of emitters, which can lead to serious water deficits and non-uniformity of the applied water
 2. May cause wear on pump impellers, emitter outlets, and other hardware

3. Can provide nutrients which support the growth of bacteria in the pipes
 4. Can accumulate at the ends of pipelines and clog valves
 5. Can contain weed seeds which aggravate weed control in the irrigated area
 6. Cost the farmer money
- All of the above problems translate to direct costs to the farmer
 - These filters do not remove salts from the irrigation water (unless reverse osmosis membranes are used, which are very uncommon in irrigation systems and are not covered here)
 - Groundwater usually requires less filtration than surface water, but even groundwater should be filtered
 - The maximum allowable particle size in trickle irrigation water is usually between 0.075 mm and 0.2 mm, so the water must be quite clean
 - Filtration is almost always complemented by the injection of various chemicals into the water to help prevent clogging due to bacterial growth and precipitation of solids from the water
 - Solid particles smaller than emitter outlets can cause clogging when they bridge at the opening (see the figure above)
 - Some consultants recommend the removal of all particles larger than 1/10 of the minimum outlet diameter for drip emitters, or about 1/7 of the minimum outlet diameter for spitters, misters, and microsprayers
 - Larger particles may be allowed with spitters, misters, and microsprayers because of “shorter pathways” and sometimes larger openings



II. Types of Filtration

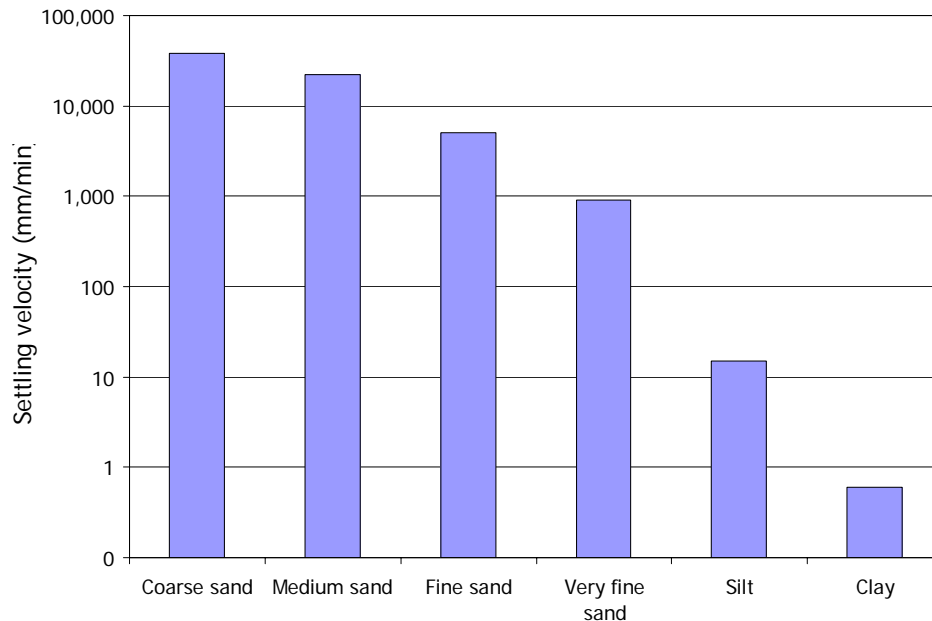
- The basic types of filtration used in trickle systems are:
 1. Reservoirs (settling ponds)
 2. Pre-screening devices
 3. Sand separators
 4. Sand (*media*) tanks
 5. Gravity overflow screens
 6. Tubular screens
 7. Disc filters

III. Use of Reservoirs in pre-Filtration

- Some of the benefits of an open reservoir upstream of the pumps in a trickle irrigation system are:
 1. To buffer differences in supply and demand rates. The supply from a canal or well seldom coincides exactly with the system requirements (flow rate and duration), and the system requirements can change due to different numbers of stations in operation, “down time”, and duration of sets.
 2. To allow for settling of some of the suspended particles. In these cases the reservoir serves as a “settling basin”. Precipitated sediment can be periodically removed from the reservoir with equipment or manual labor.

| Soil Texture | Particle Size (microns) | Vertical Settling Velocity (mm/min) |
|----------------|-------------------------|-------------------------------------|
| Coarse sand | > 500 | 38,000 (1½ mph) |
| Medium sand | 250 - 500 | 22,000 |
| Fine sand | 100 - 250 | 5,000 |
| Very fine sand | 50 - 100 | 900 |
| Silt | 2 - 50 | 15 |
| Clay | < 2 | 0.6 (very slow!!) |

The barchart below has a logarithmic scale on the ordinate:

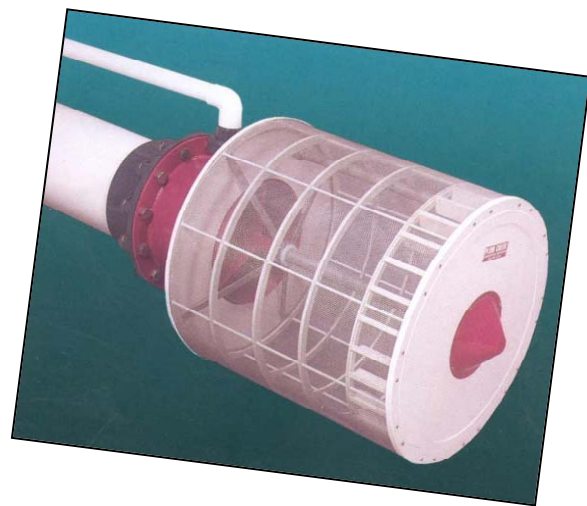


Longer settling basins will allow more time for suspended particles to fall to the bottom before arriving at the pump intake.

3. To aerate water pumped from wells, thereby oxidizing and precipitating manganese and iron out of the water (some groundwater has manganese and iron, and these can cause plugging of emitters). Only 1.5 ppm of either manganese or iron can cause severe clogging problems in trickle laterals and emitters (see Table 18.1 in the textbook).
4. To allow for air to escape when the water comes from a “cascading” well, in which air becomes entrained into the water. Air in pipelines can dampen the effects of water hammer, but also causes surges and blockages of flow.
5. To allow oils to collect on the water surface. Oils can cause rapid clogging of most types of filters, requiring special cleaning with solvents and possible replacement of sand media. When pumping from a reservoir the inlet is below the water, and oil does not enter.

IV. Pre-Screening Devices

- These screens are intended to prevent fish, large debris and trash from entering the pipe system, upstream of the other filtration devices
- Pre-screening is not necessary for groundwater or municipal water supplies
- Pre-screening devices often have “self-cleaning” features, otherwise they can clog up rapidly

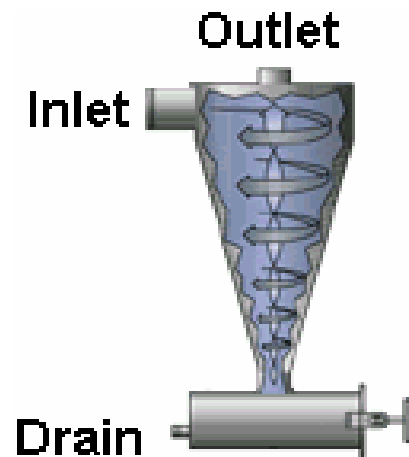


- Horizontal grills
 - Screen plates
 - Rotating and self-cleaning screens
 - Gravity screen filters
- If the inlet line upstream of a pre-screening device is pressurized, you will lose all of the pressure and have to repressurize downstream of the screens – this is a major disadvantage to pre-screening in such cases

V. Sand Separators

- Sand separators are used to remove sand (but not organic matter) from the water
- Most work by spinning the water in an enclosed column (or cone) to remove sand through a centrifuge-type action
- There are no moving parts
- Solid particles with a density of approximately 1.5 g/cm^3 can be removed by these devices (most sand has a density of about 2.65 gm/cm^3)

- Can remove from 70 to 95% of dense particles
- Periodic purging of accumulated sand (manual or automatic) is necessary to maintain performance
- Must have the correct flow rate through the sand separator for proper operation, otherwise less sand will be removed from the water
- Most sand separators have a pressure loss of between 5 and 12 psi, from inlet to outlet. This pressure loss does not change with time, only with flow rate.
- Some sand separators are designed to fit down into wells to protect the impellers and pump bowls, but they are not as efficient as above-ground sand separators
- Sand separators cannot remove all of the sand, and may pass large amounts when the system is starting or stopping
- Therefore, screen filters should be installed downstream
- Sand separators are available but are not used as much as they were in the past because people are using media tanks and other filters instead
- When taking water from a deep well, an alternative to using a sand separator is to properly develop the well and use a good quality well screen



VI. Sand Media Filters

1. Introduction

- This type of filter is filled with sand, or some other particles such as crushed (makes it angular, traps debris better) granite, crushed silica material (e.g. garnet)
- Some designers go by a uniformity coefficient for the media, defined as the ratio of 40% retained size (larger) to the 90% retained size (smaller) from a sieve analysis
- This uniformity should usually be between 1.0 (perfect!) and 1.5
- In most media filters the water passes through vertically, from top to bottom
- A drain screen (of which there are various types) at the bottom allows clean water to exit, but prevents the media from leaving the filter tank.
- Many media filters have a layer of gravel around the bottom drain
- The inside top of the tank usually has some kind of “diffuser” to help spread the dirty water evenly over the media surface
- Standard tank sizes are 24, 36 and 48 inches in diameter, with a media depth of about 30 to 40 cm
- Tank walls are usually 3 - 5 mm thick, depending on the brand



- The tanks are often made out of carbon steel, type 304 stainless steel, or type 316 stainless steel (if water has high salt content)
- Every installation should have at least two tanks so that back-flushing can occur during operation, but many designers recommend at least three tanks in which only one is back-flushed at a time
- New media should be rinsed with clean water before placing it in the tanks because it may have dust and other particles in it
- Some tanks have not performed well when the installers failed to rinse the media first (resulting in fine particles passing into the irrigation system when the tanks are first put into use)

2. Applicability of Media Filters

- These filters are very good for removing relatively large amounts of organic and inorganic matter, but some pre-screening is usually necessary with surface water supplies
- High volume filtration at 20 to 30 gpm/ft² (1.3 to 2.0 cm/s)
- Some silt and clay particles can also be removed by sand media filters, but not by most screen-type filters. However, much silt and clay can pass through a media filter too.
- Large volumes of particle contaminants can be collected in the sand media before the media must be cleaned, or “back-flushed”
- In some cases the water must be pre-cleaned before entering the sand tanks to prevent rapid accumulation of particle contaminants
- Media filters can also remove some sand from the supply water, but this sand cannot always be effectively back-flushed from the media -- for large amounts of sand, there should be a sand separator upstream of the media tanks
- Industrial media filters are often five feet deep (or more), but have smaller flow rates and less frequent back-flushing than agricultural media filters, which may be only 14 inches deep
- Many of the particles captured by agricultural media filters stay within the upper few inches of the sand because they are back-flushed frequently

3. Back-Flushing the Tanks

- Back-flushing is required to clean the tanks
- Back-flushing can be performed manually or automatically, based on elapsed time and or on a pressure differential limit across the tanks
- Typical pressure differential triggers are 5 to 10 psi (35 to 70 kPa) greater than the pressure differential when the media is clean (clean media typically has a pressure differential of 3 to 5 psi, or 20 to 35 kPa)
- Often, a timer is set to back-flush at least one time per day, even if the pressure differential criteria (for flushing) is not met

- Automatic back-flushing is recommendable, because labor is not always reliable
- Some installations have view ports on the back-flush pipes so that an operator can see if the water is clean (to know if the duration of the back-flush is sufficient) and to see if any of the sand media is escaping during back-flush
- The pressure differential during a backflush operation should be 7 - 10 psi (50 - 70 kPa) – if it is greater than 10 psi, the flow rate is too high

VII. Secondary Filters

1. Tubular Screen Filters

- These are conventional screen filters, with two-dimensional surfaces and little capacity to accumulate debris
- There are many different kinds and variations of these filters
- Primarily used as backup (safety) filters downstream of the primary filters
- If the screen becomes dirty and is not cleaned, the pressure differential can become great enough to burst the screen. Or, the screen may stretch until the openings expand enough to pass some of the debris (which is not desirable)



- Flow through the filter is usually from inside to outside (debris is trapped on the inside surface during operation) to prevent collapse of the screens
- Cleaning can be manual or automatic, and there are many varieties of automatic cleaning methods

- Some filter designs have a rotating suction mechanism to clean the dirty (inner) side of the screen element
- Manually-cleaned filters can have slow or quick release cover latches -- the slow release latches are preferred because the quick release version can “explode” if opened while the system is at operating pressure (dangerous to personnel)

2. Disc Filters

- Similar to a tubular screen filter, but using tightly packed plastic disks for the filter media, with a deeper filter area
- Holds more contaminants than a regular screen filter without clogging
- Often installed in banks (several filters in parallel)
- Often have automatic back-flushing features, requiring higher pressure (about 45 psi minimum pressure) than normally available for system operation, so there is a special booster pump for cleaning
- Cleaning is often performed when the pressure differential across the filter reaches 6 psi
- The pressure differential for a clean filter should be about 1 to 4 psi (unless too much water is being pumped through the filter)
- These filters are not designed to remove sand from the water (sand gets stuck in the grooves)
- These filters can have clogging problems with some kinds of stringy algae



VIII. Chemical Injection for System Maintenance

- It is usually necessary to use chemicals to maintain a trickle irrigation system -- if not, the system will eventually become clogged
- Some chemicals are for the addition of plant nutrients, or fertilizers; this is called “fertigation”
- Different chemicals may be used for pest control: herbicides, insecticides, fungicides
- Other chemicals are used to kill bacteria and other organic contaminants, and maintain a sufficiently low pH
- The uniformity at which chemicals are applied to the field can be assumed to be equal to the emission uniformity of the emitters (assuming the chemicals are water soluble, which they should be if injected into the irrigation system)
- Following are guidelines for clogging hazard of irrigation water in trickle systems with emitter flow rates of 2 to 8 lph (after Bucks and Nakayama 1980):

| Kind of Problem | Hazard Level | | |
|------------------|--------------|---------------------|----------------|
| | low | moderate | severe |
| suspended solids | 50 ppm | 50-100 ppm | > 100 ppm |
| pH | 7.0 | 7.0-8.0 | > 8.0 |
| salts | 500 ppm | 500-2,000 ppm | > 2,000 ppm |
| bicarbonate | -- | 100 ppm | -- |
| manganese | 0.1 ppm | 0.1-1.5 ppm | > 1.5 ppm |
| total iron | 0.2 ppm | 0.2-1.5 ppm | > 1.5 ppm |
| hydrogen sulfide | 0.2 ppm | 0.2-2.0 ppm | > 2.0 ppm |
| bacteria count | 10,000/liter | 10,000-50,000/liter | > 50,000/liter |

- Types of clogging in trickle systems that can be managed through the injection of chemicals:

- Slimy bacteria

These can grow inside pipes and inside emitters. The chemicals used to kill this bacteria are chlorine, ozone, and acids.



- Iron and manganese oxides

Some kinds of bacteria can oxidize iron and manganese. Only small amounts of iron or manganese are necessary to support bacterial growth in the water. This can be treated with chlorine injection, acid and chlorine injection, linear phosphate injection, and aeration in a pond.

- Iron and manganese sulfides

These are problematic with some groundwater. Dissolved iron and manganese form a black, insoluble material. Manganese is toxic to most plants in small concentrations, and this may become a problem before clogging occurs. This can be treated by aeration, chlorination, and acid injection.

- Precipitation of calcium and magnesium carbonates

These are typically quantified by SAR (or adjusted SAR). You can use a dropper to put some hydrochloric or muriatic acid on selected drip emitters to test for the presence of carbonates and bicarbonates. If present, the acid will react and cause a “fizzing” sound and bubbles. One method to control precipitation of carbonates is to continuously inject carbon dioxide gas into the system, creating carbonic acid and lowering the pH. Sulfuric and phosphoric acids are also used, as are SO₂ generators. All of these are designed to maintain the pH near (or slightly below) 7.0.

5. Plant root entry into underground emitters

This is mainly a problem in permanent (several years) buried trickle irrigation laterals. Can use acid injection at end of each season for perennials to kill roots that are in the buried drip tubing. Or, use herbicides to kill roots in the tubing without damaging the plants. Some emitters and plastic drainage pipe have herbicide in the plastic to discourage roots from entering.

- It is dangerous to experiment with chemical mixtures in trickle systems, because some mixtures can cause clogging of the emitters
- Test the mixture in a glass container first, checking it after several hours or more, and determining whether the chemical mixture is water soluble
- Injection of chemicals should be after the system starts, and stopping before the system is turned off
- As a rule of thumb, one can assume an average pipe flow velocity of 1 fps, or 0.3 m/s, divide this into the longest pipe distance in the system (from pump to farthest emitter), and determine the time
- This is the time to wait after starting the pump, and the time to allow for flushing before turning the pump off

For example, if the farthest emitter is 600 ft from the pump, the travel time can be estimated at 600 s, or 10 min. Thus, you should wait 10 min before beginning chemical injection, and discontinue chemical injection 10 min before stopping the system, or before changing stations.

- Chemicals should be injected on a mass basis per set, not time. Thus, one would want to apply a certain number of lbs or kg of a chemical in an irrigation set, and it does not matter that it is all applied quickly or over a long time (provided that the starting and stopping delay discussed above is adhered to)
- The minimum injection rate can be put into equation form:

$$q_c = \frac{F_r A}{c t_r T_a} = \frac{(\text{kg/ha})(\text{ha})}{(\text{kg/liter})(0.8)(\text{hrs/set})} = \text{lph} \quad (332)$$

where F_r is the mass application rate per unit area; A is the area irrigated per set; c is the concentration of the chemical; t_r is some kind of uniformity ratio, taken to be 0.8; and T_a is the hours per set, or hours of chemical injection, if shorter than the set time