Ontario Onsite Wastewater Association

OOWA's Best Practices Series:

Sand Filter Bed Design and Installation

Produced by the OOWA Onsite Technical Committee

Version 1.0
BP 2: Sand Filter Bed Guidance Document

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1.0 Objective

The requirements of the Ontario Building Code (OBC) 8.7.5 are not being applied consistently throughout the Province, both in terms of design and installation practices. In 2013, OOWA solicited input from the industry with respect to these inconsistencies, and general issues and challenges associated with the use of Filter Beds. Based on the feedback received, six primary issues were identified, as follows:

1. Filter Sand Compliance
2. Even Distribution
3. Loading Rates
4. 75% Rule
5. Proper Backfilling Practices
6. Life Expectancy

This document has been prepared to discuss these issues, the ways in which the OBC is being inconsistently applied, and provide a best practice approach as to how the OBC should be applied and as to other considerations that would constitute best practices.

2.0 Background

The Filter Bed is a commonly used type of leaching bed in Ontario, as permitted within Subsection 8.7.5 of the Ontario Building Code (OBC). The Filter Bed originated from a study conducted by the Ministry of the Environment (MOE) by Chowdhry which was published in 1974. Design guidelines for Filter Beds were then incorporated in the 1982 MOE Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems, and were subsequently incorporated into 8.7.5 of the OBC.

The Filter Bed consists of a 750 mm depth of filter sand. A vertical separation of 900 mm is required between the base of the stone distribution layer in the Filter Bed, and any underlying rock, water table, or soil with a T time greater than 50 min/cm. Loading rates in the OBC vary from 50 L/m2 to 100 L/m2 depending on the daily design flow and the level of pre-treatment provided. Specifications for filter sand gradation limits are also provided in the OBC and are based on the Chowdhry study and 1982 MOE Guidelines.

The Chowdhry study investigated different loading rates (49 L/m² per day and 73 L/m² per day), as well as five different grades of filter sand. All sand filters were tested for at least 12 months at 49 L/m2 before the loading rate was increased to 73 L/m2. This study showed that 750 mm of filter sand, under-drained with a stone-pipe layer, can be an effective treatment unit, delivering a final effluent of < 10 mg/L BOD5 and TSS (tertiary quality). The coarsest fraction of filter sand investigated however released up to 250,000 cfu/100 mL of fecal coliforms. The average fecal coliform counts at the bottom of the under-drained Filter Beds dosed at these loading rates were 12,000 and 44,000 cfu/100 mL respectively.

These results demonstrate that the Filter Bed achieves a higher level of performance when a lower loading rate is applied and a finer fraction of filter sand is used. All Filter Beds tested by Chowdhry were tested at 50 L/m^2 for the first year. They were all under-drained with a crushed stone-pipe layer keeping the filter sand free-draining and aerobic – a necessary condition for proper wastewater treatment. There are however no provisions in the Code that prescribe Filter Beds be installed in the field with an under-drain or collection system, therefore the actual in-situ field performance is expected to be lower than found in the study. Since the Chowdhry study in 1974, no additional testing has been performed on filter beds, and there is limited field performance data available.

3.0 Current Filter Bed Practices

3.1 Filter Sand Compliance

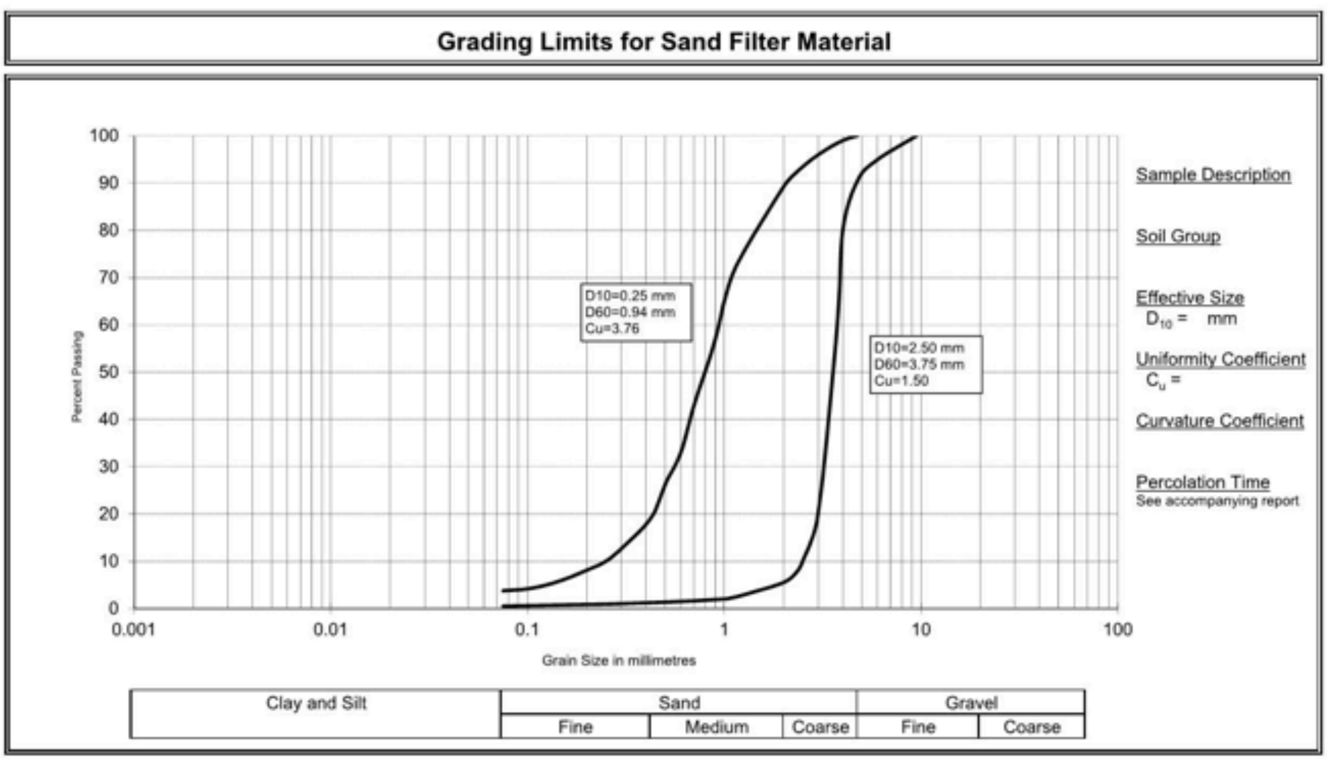
The function of a sand filter bed is directly related to the quality of the sand material used. The quality of the sand must be within a narrow range of specifications in order to be appropriate for use in a sand filter bed. Filter sand is typically a medium to coarse sand which must be poorly graded (i.e. the particles are approximately the same size), with little to no fines (i.e. silt/clay particles), and it will be visibly granular. If the sand is too coarse, the effluent will not receive adequate treatment, as it will percolate through the bed too quickly. If there are too many fine particles in the sand, the filter has the potential to clog. It is also important to ensure even distribution of effluent over the surface of the filter sand in the bed. Having the properly graded sand provides better potential for even flow distribution.

Most natural sand deposits will not meet the specifications for filter sand, and the material is typically manufactured. The specifications for filter sand were originally developed by the Ministry of the Environment and were contained in the Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems (1982), which has been superseded by the Ontario Building Code. The same material specifications are now included within the OBC under 8.7.5.3 (3), which specifies that the filter medium shall be clean sand comprised of particles ranging in size between the limits of:

a) An effective size of 0.25 mm with a uniformity coefficient not less than 3.5,
b) An effective size of 2.5 mm with a uniformity coefficient not greater than 1.5, and
c) Having a uniformity coefficient not greater than 4.5.

These size specifications are shown graphically in Figure 1. In order to ensure that a material meets these specifications, a grain size analysis should be performed on a representative sample from the pit. The resulting grain size curve should be plotted on a graph that shows the permissible limits for filter sand material. This analysis must be performed regularly to ensure that a consistent quality of filter material is being produced, ideally every six months.

Figure 1: Filter Sand Specification



It is recommended that the installing contractor request from the sand supplier, the results of a grain size analysis performed within the last six months. If this is not available, it is highly recommended that the contractor request an updated test, or make arrangements to have the sand tested at his own expense prior to importing any material to the site. Engineers, designers and regulators should be requesting the sand material specifications prior to providing any authorization to the installing contractor to begin hauling material to the site.

The sand supplier should provide a sand "spec" sheet showing that each load has been approved. The quality of the filter sand is best maintained by limiting the number of times that quantities are moved or handled to avoid degradation of the material. In addition, stockpiling filter sand for significant lengths of time should be avoided.

3.2 Even Distribution

In order to provide an adequate level of treatment of effluent before it enters the natural environment it is important that the septic tank effluent applied to filter beds be evenly distributed over the entire volume of filter sand. This helps to prevent preferential flow paths (short circuiting) from forming which can allow untreated effluent to reach the environment. Short circuiting of untreated effluent is most pronounced when filter beds are constructed using the coarsest fractions of filter sands for which pore sizes are largest, but can occur with all grades of filter sand allowed under the OBC.

Article 8.7.5.3.(2) of the OBC requires that the lines of distribution piping be evenly spaced over the surface of the filter medium. Further guidance is provided in the Appendix to the OBC, which states that the maximum spacing of distribution pipes should be 1.2 m. There are also limitations placed on the maximum design flow and maximum size of a filter bed, because as the size of the filter bed increases, the likelihood of achieving even distribution decreases.

Effluent can be distributed over the surface of the filter bed using gravity or pressurized distribution. While dosing a filter bed via a gravity trickle distribution system is acceptable by the Code, this method of effluent distribution highly dependent on the quality of the installation. If the distribution system is no properly installed and level, this which can result in significant point loading of effluent over the front end of the lowest elevation lateral within the bed. This results in one portion of the filter bed being heavily loaded and little to no load on the rest of the bed. In such cases the treatment performance of the filter bed will be poor, the chances of surface breakout are increased, and the life expectancy of the bed will be reduced. Gravity distribution systems rely solely on the formation of biological clogging mats (biomats) to achieve even distribution. When gravity trickle distribution is used it is recommended that the spacing between distribution pipes be limited to a maximum of 900 mm (as compared to the 1,200 mm maximum required by the OBC).

Biological clogging mats operate as a system of fine pores over the larger pores of the filter sand, helping to distribute water more evenly. However, clogging mats are nearly impossible to manage; they may take several years to form and until such time there will be a high point loading of effluent in gravity distribution systems. Clogging mats are also cyclical in nature – with little to no mat forming in summer periods, and mat forming in winter. When clogging mats remain in place year round they may no longer accept the total wastewater load. Since the formation of biological clogging mats is not consistent or predictable, and their presence cannot be confirmed, they should not be relied on as the sole method of achieving even distribution in the filter bed.

At a minimum, consideration should be given to dosing filter beds via a pumped to gravity system. In this system, wastewater is pumped to a distribution box or header which portions the flow evenly between the filter bed laterals. Wastewater then flows via gravity down the laterals to the rest of the bed. While not as pronounced as in a gravity-trickle system, there will still be point loading of effluent at the front end of each lateral until a biological clogging mat has formed. However, once a pump is introduced to the system consideration can also be given to using a fully pressurized distribution system which provides superior performance to a system that pump to gravity distribution.

A fully pressurized distribution system is the most effective method of achieving even distribution to the filter bed. These systems apply wastewater to the sand in controlled doses at certain times and to specific locations within the bed. Demand dosed systems apply wastewater to the filter bed as it is generated, while timed dosed systems apply wastewater the filter bed evenly over a 24 hour period. For large systems or applications where flow is expected to be highly variable (e.g. a church, a cottage, a rental home) a timed dosed approach is recommended. The closer the spacing of orifice holes in the distribution pipes, the more evenly the wastewater will be distributed within the bed. However, orifice holes that are too closely spaced require larger pumps and more maintenance. Orifice holes should be shielded to prevent scouring of the filter sand once in use.

3.3 Loading Rates for Filter Basal Area and Extended Contact Area

The original loading rate requirements are very clear in the Ministry of the Environment's Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems (1982), as part of the Filter Type Leaching Beds. The intent behind the loading rate requirements is to make sure that Filter Bed final dispersal area is based on loading rates that properly reflect the ability of the underlying soil to absorb the applied effluent on a continuous basis and over the entire life of the system without a breakout to ground surface, and to limit the probability that the soil component will be sized without proper consideration of soil characteristics and its absorption capabilities which could lead to system malfunction or failure.

The filter bed final dispersal area is composed of two elements:

a) The contact area of the base of the filter media,

b) The loading area, which includes the 15 metre extension that compose the loading area, commonly referred to as the mantle.

Contact Area means the area of the base of the sand filter bed, which is required to absorb the treated effluent into the underlying native soil or fill after it has passed through the sand media. The contact area does not include the area where the mantle, if required, comes into contact with the native soil. The contact area, if larger than the effective area (top of the filter media) shall extend horizontally at a minimum thickness of 0.25 m to cover an area equal to A=QT/850, where A is the area of contact in m2, Q is the daily sewage flow in litres, and T is the percolation time of the underlying soil in min/cm. For low T-times, this calculation may yield an area smaller than the top of the filter media (i.e. the required stone area calculated in accordance with 8.7.5.2). In these cases the contact area should be increased to be at least equal to the stone area.

Loading Area means the area required to move the treated effluent out of the filter media into the underlying native soils. It is sized based on the Loading Rates given in Table 8.7.4.1.(A) as per the requirements of Sentence 8.7.5.2.(2) and 8.7.5.3.(1). These Loading Rates properly reflect the ability of the soil, throughout the loading area, to absorb the applied effluent in a continuous basis without any breakout to ground surface. The loading area may be comprised of native soils if the T-Time of the underlying soil is less than 15 min/cm, or of fill material if the native soils has a T-time in excess of 15 min/cm, and must meet the requirements of the 75% rule (see section 3.4). For examples of filter bed construction in sandy soils refer to Appendix A.

The loading area includes the mantle, which is the lateral extension of the loading area. The mantle must extend 15 m down gradient from the point of effluent application (distribution pipes) in any direction in which the effluent will move horizontally.

The Loading area, which includes the mantle, must be provided for all filter bed installations according to Sentence 8.7.5.3.(1). For filter beds installed in sandy soils with a T-time less than 15 min/cm, the loading area and mantle may be comprised of the native soil, provided vertical separation distances to limiting layers can be maintained. For these installations, designers must show that the loading area sized according to the loading rates in Table 8.7.4.1 including a 15 m mantle extension are available on the site and have a minimum depth of 0.25 m. However no excavation or placement of material is required for this part of the system. It is important to conduct a thorough site and soil assessment when using native soils for the Loading area and mantle extension. Additional test pits and bore holes may be required to ensure that the soils are consistent and suitable for use over the total area.

The loading area must be constructed of imported fill material when:

a) The T time of the native soil exceeds 15 min/cm;
b) There is insufficient soil depth (0.25m) extending for at least 15 m beyond the outer distribution pipe in any direction in which the effluent will move laterally;
c) The percolation time of the filter media will not satisfy the requirements of Sentence 8.7.4.2.(2).(the 75% rule explained in section 3.4 below).

In all cases, the material used for the loading area must meet the 75% rule. Since the T-time of filter sand is generally between 4 – 8 min/cm, imported material for the loading area with a maximum of 10 min/cm is required.

Filter beds installed with an imported loading area should be at least partially or fully raised. In cases where there is insufficient vertical separation to rock or water table, a filter bed would typically need to be partially raised regardless of whether the T-time of the native soil is 15 min/cm or less. In all cases it is important that end of the mantle extension meet the natural grade in order to avoid saturation of the mantle material. This is especially important in lower permeability soils where infiltration into the underlying soils may be difficult. Section 3.5 contains additional construction and backfilling recommendations that are particularly relevant in low permeability soils.

Figure 2 below presents a schematic of the loading rate area for a fully raised filter bed. For more examples of inground, partially raised and fully raised filter bed installations in different

Figure 2 below presents a schematic of the loading rate area for a fully raised filter bed. For more examples of inground, partially raised and fully raised filter bed installations in different soil types refer to Appendix A.

Figure 2: Fully Raised Filter Bed Components

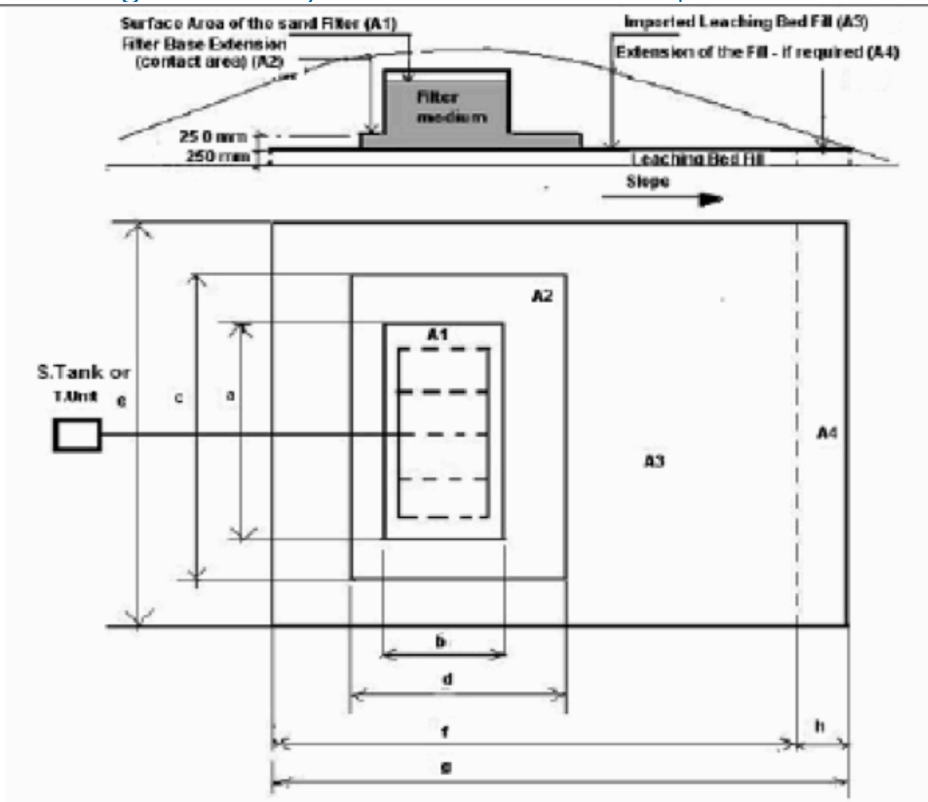


Figure 14 RAISED FILTER BED CONSTRUCTION

NOTES

The areas shown above represent the following elements

A1 The surface area of the filter medium (axb)

Sized based on the requirements of Article 8.7.5.3 (should not be less than 10 m2 or more than 50 m2)

A2 The extension of the Base of the filter (cxd)

Sized based on the formula A = QT/ 850 stipulated in Sentence 8.7.5.4.(6)

A3 The area covered by the imported leaching bed fill (loading area) (fxe)

Sized based on the loading rates given in Table 8.7.4.1.(A) as per the requirements of Sentence 8.7.5.2.2.

A4 The extension of the loading area to 15 m beyond the outer distribution pipe in the direction of flow (If needed) to satisfy the requirement of 8.7.4.2.(1). (exh)

3.4 The 75% Rule

The original "75% Rule" was contained in the Ministry of the Environment's Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems, as part of the requirements for raised leaching beds. The rules surrounding raised beds and mantle requirements are intended to prevent a very coarse fill material (and therefore a small leaching bed) from being placed directly on low permeability soils or rock, which could lead to effluent breakout around the bed. The 75% rule basically states that any fill material used in the portion of the bed containing absorption trenches shall not be less than 75% of the T-time of the soil used in the mantle. For example, if a site had native soils that consisted of a silty sand with a T-time of 20 min/cm, this native soil could be used to provide the mantle for a raised leaching bed, if a suitable depth of this material (minimum 0.25 m) extends at least 15 m beyond the piping in the bed. However, in order to use the native material with a T-time of 20 min/cm for the mantle, this would mean any imported fill used for the portion of the bed containing absorption trenches would have to have a T-time of at least 15 min/cm.

The 75% rule is contained in the Ontario Building Code under 8.7.4.2(2), and applies to both absorption trench leaching beds and filter beds, requiring that if the mantle sand has a T-time of greater than 15 min/cm, any leaching bed fill material used to form the leaching bed shall percolation time not less than 75% of any soil or leaching bed fill material used to construct the 15 m mantle. In the case of a filter bed, because the specifications for filter sand are within such a narrow range, the T-time will generally be 10 min/cm or less. Any soil used for the construction of a mantle for a filter bed should be limited to a granular material, with a T-time not more than 15 min/cm.

This means that if native soils on the site have a low enough T-time (i.e. less than 15 min), they could be used as the mantle, provided there is a suitable depth (0.25 m) extending at least 15 m beyond the piping in the filter bed. In most cases, imported sand would be required to meet the specifications for the mantle sand.

The 1982 MOE Manual specifically states for Filter Beds that "A soil mantle of T not greater than 15 min/cm and at least 0.25 m in depth is required to extend at least 15 m beyond the outer distribution pipes in any direction in which the effluent from the bed will move laterally. It must be added if the soil in or on which the filter bed is to be constructed has a T value exceeding 15 min/cm." This is a more clearly defined requirement for the filter bed mantle than the current OBC requirements regarding the 75% rule.

3.5 Proper Backfilling Practices

OBC requires that filter beds be backfilled with leaching bed fill so as to ensure that, after the leaching bed fill settles, the surface of the leaching bed will not form any depressions. The Code requires the depth of cover to be a minimum of 300 mm and a maximum of 600 mm over the stone in any leaching bed system, whether it is an absorption trench bed, filter bed or area bed (the only exception to this requirement is shallow buried trench).

After placing the stone and distribution piping, the stone layer should be covered with a layer of geotextile to prevent backfill soil from entering the stone layer. It is recommended that Filter beds be completely backfilled with septic sand (T < 15 min/cm, which is typically the same sand as used for the mantle), then subsequently covered with a thin layer of topsoil (e.g. 100 to 150 mm).

In the case of a raised filter bed, complete the side slopes (berm) and cover the separation layer with 300 mm of backfill soil. The berm around the perimeter of the mound should extend at least 900 mm outward in all directions from the top of the aggregate layer. The berm should have a 3(H):1(V) side slope and consist of clean topsoil free of rocks, rubble and vegetation in order to maintain aerobic conditions in the bed and protect side slopes from erosion. Several system failures are attributed to the backfill having too much clay content. If the cover is too thick or clay content too high, then after the soil settles it will seal the bed and can result in failure.

Additional recommendations:

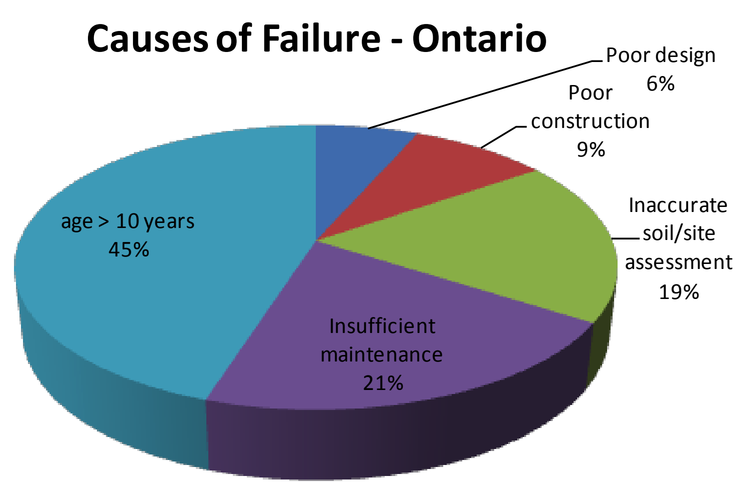
- Avoid construction on wet soil to reduce compaction and smearing.
- Use low-load, tracked construction vehicles and always keep sand between the vehicle and soil during construction.
- Add the sand, berm soil and aggregate from the upslope side.
- Keep all equipment and vehicles off the absorption area at all times.
- Keep all equipment and vehicles off the undisturbed area down slope of the raised sand bed at all times.
- Lightly compact the berm to limit lateral flow.

3.6 Life Expectancy

The leading causes of septic system failures in Ontario are due to old age and lack of maintenance (refer to Figure 3 on the next page). All septic systems, including filter beds, are biological systems and require periodic maintenance to ensure they function in their intended manner. Typical maintenance activities include removal of solids from the septic tank, cleaning of effluent filters, inspection of any electrical components, and inspection of the bed for uneven wet spots or grass discoloration that could be caused by uneven distribution of effluent within the bed. Proper maintenance of filter bed systems improves system performance, reduces health and safety risks, and increases system longevity.

When properly designed, installed, and maintained in areas of good permeable native soils, filter beds have a life expectancy similar to other conventional septic systems and can last for upwards of 20 years. Special consideration should be given however to raised filter bed systems in areas of low permeability native clay soils. In raised filter bed systems sand is placed on top of the low permeability clay soils and installed without an underdrain to keep the system free-draining. The underlying clay soils remain almost permanently wetted and are now buried deeply enough to prevent meaningful oxygen transfer with the surface. This smothers the clay soil and greatly reduces its ability to accept water, increasing the chances of surface breakout and failure. The effectiveness of such filter bed systems is especially limited during winter and spring months, during periods of extended rainfall, and during periods of heavy water use in the building being serviced. When fully raised filter bed systems are installed on heavy clay soils experience has shown that life expectancy can be substantially reduced (less than 5 years).

Figure 3: Causes of Failure for Private Sewage Disposal Systems in Ontario



Life expectancy of filter beds can also be greatly reduced when:

- Constructed using compromised bed materials (e.g. sand with too many fine particles)
- Systems are undersized to meet setback or footprint constraints
- Systems experience heavy use or abuse by homeowners
- There is a lack of maintenance
- Systems are installed too deep in the ground to allow efficient oxygen transfer
- Improper backfill material is used
- Even distribution of effluent is not achieved
- Other methods of cutting corners are implemented in order to reduce installation costs

Designers should consider the permeability and burial depth of the native soils before designing filter bed systems. A list of Do's and Don'ts for proper septic system health should be given to property owners. It is highly recommended that all septic system have annual maintenance contracts with a qualified provider to increase environmental protection and system longevity.

4.0 References

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