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PEOPLE AND SYSTEMS FOR WATER, SANITATION AND HEALTH

Determination of suitable sites for wastewater infiltration systems

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DURING THE PREPARATION of a European Standard for the disposal of domestic wastewater treated by a septic tank, it became apparent that there were wide variations in percolation tests and other methods for determining the suitability of infiltration sites. This paper describes the processes that were considered to draft a standard with worldwide applicability

Requirements of an infiltration system

Various wastewater and sanitation systems utilise the ability of soils to absorb and de-contaminate water. These include septic tank systems, rainwater soakaways and greywater disposal. Figure 1 shows a typical arrangement for a treated effluent infiltration system. The area of the disposal system is dependent upon the quality of the effluent and the properties of the soil.

Mechanisms of water percolation through soil

Infiltration systems are intended to be installed in unsaturated ground. The moisture level in the soil will be dependent upon its drainage ability, climatic conditions and frequency of discharge. As the moisture level determines the behaviour of infiltrated water, its variability makes realistic modelling difficult. However, models have been developed that simulate the behaviour of water in soils. Most of these are appropriate for homogeneous and isotropic soils (Baver et al 1972), but they provide an insight to the reasons for variability in results obtained from natural soils. Work by Healy and Laak in the 70s showed that the two basic mechanisms cause the flow of water through a soil; capillarity and gravity. The resultant flows due to these mechanisms are different and the dominant mechanism depends upon soil type. In all but sand and gravel, the capillarity effect controls the flow in dry soils. The flow patterns due to the different mechanisms are shown in figure 2.

The basic theory of water percolation through a permeable soil is provided by Darcy's Law; enabling hydraulic conductivity, k, to be determined. This, however, assumes a uniform porous medium and an inert fluid totally saturating

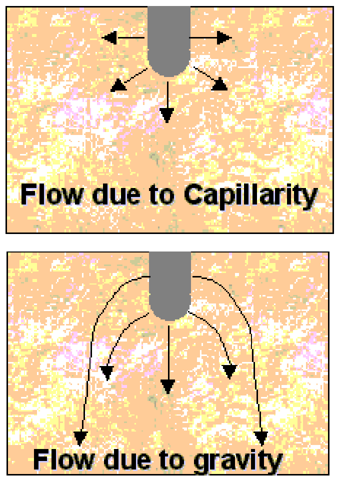

Figure 2. Mechanisms of water flow from a test hole

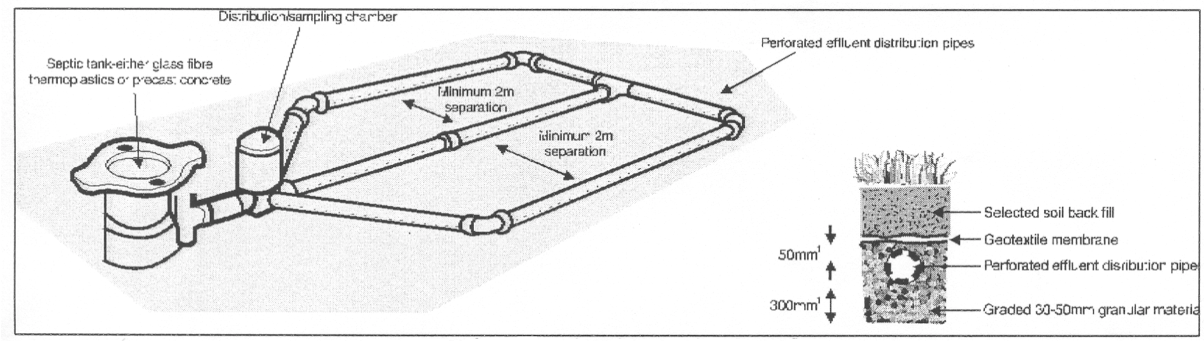

Figure 1. Septic tank and a typical drainage field

the medium. In practice, ion exchange in some soils (Reeve et al 1954) may create variations and the dispersion and migration of colloid particles, subsequently lodging in the soil pores, that can lead to reductions in the hydraulic conductivity in slightly sodic soils and/or where the percolating liquid has a low electrolyte concentration (Aringhieri and Capurro 1994). Hence all the factors need to be taken into account in determining the maximum loading that can be sustained for the life of the system; the long term acceptance rate (LTAR) (Laak 1980) for any soil and wastewater combination.

Current percolation rate determination methods

Determination methods are generally, fairly universal, simple and poorly specified, or extremely complicated and only applicable in very specific circumstances. Although there are exceptions, most determinations may be classified as;

- Falling head percolation tests,
- Constant head percolation tests, or
- Soil sample particle size distribution analyses.

The type of determination that is traditionally carried out in a particular country, or region, has usually been developed from practical experience with the local soil conditions. As different soils utilise different mechanisms of water adsorption and movement, the local determination that works in one area may be totally inappropriate for a different location. A typical laboratory percolation test apparatus is shown in figure 3.

Percolation tests

For all percolation tests, the soil should be totally saturated to obtain a true percolation rate. For in-situ tests, this requires the soil in the vicinity of the test hole to be sufficiently saturated so that the boundary between saturated and non-saturated soil is far enough away from the hole, so as not to influence the results. In practice, this is rarely achieved. Laboratory tests on extracted soil samples are very easy to saturate. However, care is needed to ensure that the samples are representative of the soil conditions in the proposed site.

Falling head percolation test

This is most appropriate for use in free draining soils where gravity is the predominant driving force. Filling the test hole and leaving it to soak overnight simulates saturation of the soil. The duration of the test depends upon the rate at which the water level drops in the test hole. A typical test hole specification is shown in Figure 4.

Constant head percolation test

For soils where capillary action is the predominant driving force, this is the more appropriate. By the constant introduction of water into the test hole, through a mechanical float operated valve, for a set period saturation of the surrounding soil is simulated. However, this process may require a prohibitively large quantity of water and depends on the performance of a mechanical valve. The duration of the test is not soil dependent and hence it is usually less than a falling head test. Typical test apparatus is shown in figure 5.

Soil Analyses

These are being used increasingly in civil engineering to assess ground conditions for foundations. Sieve analysis techniques are established in many countries and although the use of a soil laboratory may be required, the analysis is fast, reliable, repeatable and relatively inexpensive. In some cases existing data may be available that can be utilised to determine site suitability and system dimensions.

Variability of test results

In any real procedures there will be variations. However, percolation tests are subject to an unusually wide variation of results with some very large factors. For example the determined hydraulic conductivity or permeability coefficient, k, is subject to the following factors.

- Type of soil or grain size distribution (factor :10^{10})
- Discontinuities such as seams of sand or clay and root holes (factor :100)
- Compaction of the soil (factor: 5)
- Degree of saturation (factor: 3)

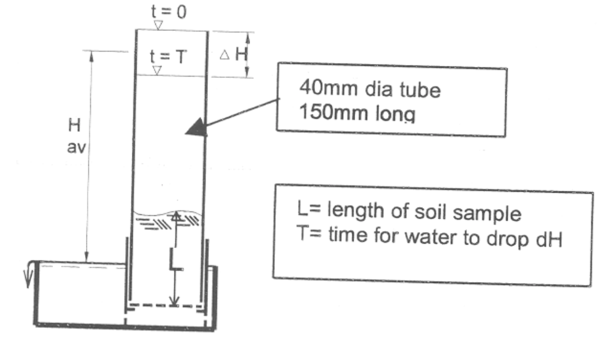

Figure 3. Tube Permeameter test apparatus

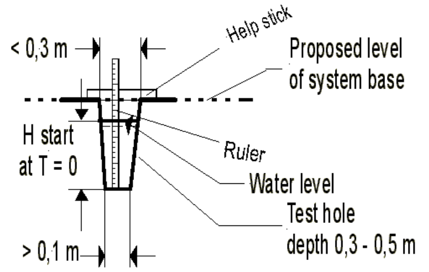

Figure 4. Example of test hole for falling head test

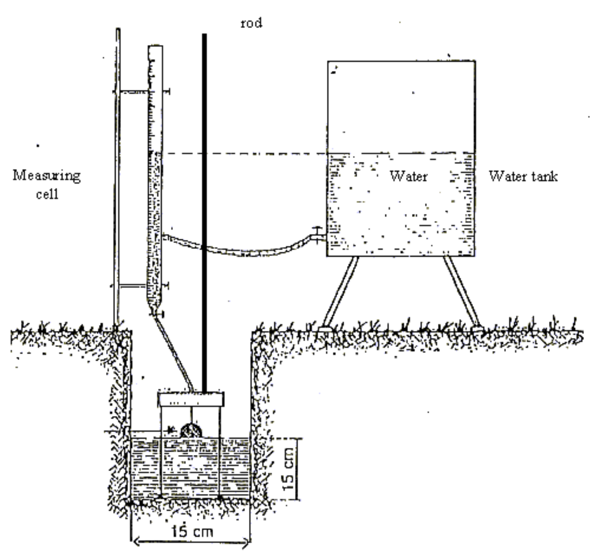

Figure 5. Example of constant head test apparatus

Climatic conditions and seasonal variations in groundwater levels will also affect the values obtained.

Due to the magnitude of the possible variation factors it is unreasonable to express the determined values in units that imply great accuracy. Although mm/s may be a justifiable SI unit for percolation, it is misleading. A more appropriate unit would be m/day.

Comparison of tests carried out in various countries

Recent tests were conducted in France, Scotland, England, Sweden and Finland to compare the results obtained using different generic tests and national variations. In most countries a wide variation of soil types possible was used. The results of these tests were broadly similar and were used to refine and simplify the tests that were used in the draft standard.

Other comparative tests in Ghana have been reported by Fekpe et al (1992). Although the results are similar they differ from the European tests in one significant finding. The Ghanaian tests showed no relationship between clay content and percolation rate, whereas the European tests showed that the clay content was very significant. The proportions of clay to sand in the different soils may explain the difference. The European soils had low ratios while the Ghanaian soils had very high ratios.

Physical aspects of a site that need to be considered

Although the percolation rate of the soil is an important parameter in designing an infiltration system it does not indicate the physical suitability of a site. To assess the site physically the topography and proximity of services and bodies of water must be considered. Figure 6 shows an example of how an infiltration site can affect groundwater.

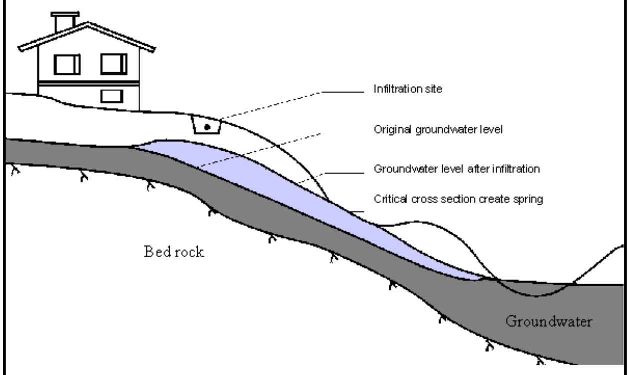

Figure 6. Possible effect on groundwater of an infiltration site

Implications of local flora and fauna

The expenditure on percolation tests and soil analysis may be reduced if the preliminary site investigation includes the consideration of visual surface clues to the conditions of the ground.

Significant informative can be obtained from the plants and trees growing in and around the proposed site. As many plants are dependent upon specific ground conditions for their existence, their presence can be used as indications of, amongst other things, the drainage properties of the soil. Table 1 is an extract from an annex of the draft European Standard describing various plants that indicate good, poor and variable drainage conditions. Although different countries may have different native plants, the principle can be applied universally.

Importance of groundwater levels

At least a soil depth of 0.6 m is needed to treat settled wastewater (Khanbilvardi + Long 1955).

To this minimum depth a convenient safety factor is normally added, so that it is normally specified that 1 m of soil should be between the base of any infiltration system and the highest level of any groundwater. This ensures treatment of the wastewater and protection of the groundwater. However, these depths only apply where biochemical oxygen demand (BOD) and suspended solids (SS) removal are required. For some other contaminants, far greater depths of soil and horizontal separation distances from bodies of water will be required. Although treated wastewater can contribute to groundwater recharge it may cause contamination that requires costly treatment to produce safe drinking water.

Factors that affect the long-term performance of any wastewater infiltration system.

The build up of biofilm and biomass within an infiltration system and the surrounding soil will lead to a reduction in the overall percolation rate. So that the build-up of the biological layer can be minimised, the loading rate should

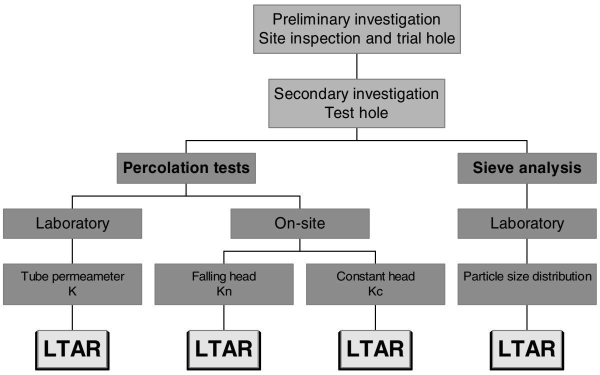

Figure 7. Site assessment procedure

be appropriate and the wastewater distributed evenly throughout the system. Fines in the wastewater may also blind some of the infiltration surfaces. Regular desludging of septic tanks and settlement chambers will prolong the system's life. Empirical relationships for LTAR and hydraulic conductivity have been developed over a number of years. These have been used in the European Standard to determine the design daily loading rates for septic systems.

Site assessment

To minimise cost and provide an effective investigation, the 'Site assessment procedure' should be followed. Depending upon the local soil, available equipment and services, the percolation rate for the infiltration area may be determined by the most suitable route. The use of an initial trial hole to determine local groundwater levels and soil variations will minimise costs, as it can be used to obtain soil samples and the test holes can be made in its base.

Conclusions

There are many factors that affect the selection of a suitable site for an infiltration system. Many of the tests are labour intensive, time consuming and the results can be ambiguous. The proposed European Standard procedure enables variations of soil conditions around the world to be accommodated in a simple systematic evaluation. Although the standard was originally drafted for septic tank effluent only, its principles can be applied to other effluents.

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Table 1. Plants which indicate good drainage conditions throughout the year

Common name	Latin name	Description	
Daisy	Bellis perennis	Height 3-4cm Small white flowers with yellow centres all through summer	
Bulbous buttercup	Ranunculus bulbosus	Height 40cm Bright yellow flowers from March to June