Design and realisation of a pilot site for monitoring Infiltrated soil water under a real on-site treatment system; evaluation of soil functions

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Abstract

The knowledge of soil and water movement in vadose zone is essential for a wide range of scientific and practical fields. One of the main but less studied media is the soil under the Undrained On-Site Treatment Systems (UOSTS). In situ monitoring is necessary to interpret most physical and hydric properties of soil and to determine the chemical composition of seepage water as a key aspect in sustainable management of soils. In this paper the design and instrumentation of different hydropedologic sensors in a real UOSTS, for the fist time in France, is presented. One of the main objectives is to extract the soil water samples in different stages of depth under the treatment system. Besides by performing the in situ hydraulic conductivity measurements, monitoring the recorded moisture and matrix potential data of the soil and determining soil physical properties in laboratory, we identify the existence of preferential flow in the heterogeneous soil of the site. As a main result, the executed pilot site is operational from March 2012. Soil water sample collecting and data recording are done regularly from this date. Also In situ permeameter tests give values of the conductivity which are averagely 135 times higher than values deduced from pedotransfer functions. This suggests that preferential flows occur within the soil via macropores shortcutting the matrix. Analysis of the recorded data shows the rapid reaction of the water table to the rainfall and the non-uniform reaction of the tensiometers according to their position. These results together suggest the existence of preferential pathway flux through the sand pack and the underlying soil.

Keywords

Water sampling; On-Site Treatment; preferential flow; soil; hydraulic conductivity

INTRODUCTION

On-Site Treatment is a management way (in French, ANC: assainissement non collectif) which relies on a system to be chosen according to local conditions of each case among a series of standard agreed systems and ensures independently the collection, treatment and evacuation of domestic wastewater, near the house. This mode of wastewater purification concerns about 5.4 million homes, nearly 15% of the French population (SIARV, 2006). In general, the OSTS shall be designed, installed and maintained so as to present no risk of soil contamination or water pollution, especially no risk to withdrawal waters which would be used for human alimentation or particular usages such as shellfish farming, fishing on foot or swimming (BRIGAND and LESIEUR, 2008).

The ANCRES project (ANC – Retention and Purification by Soils) aims to develop a socio-technical indicator to manage the depurator potential of the soil which is subjected to the infiltration of treated domestic wastewater in OSTS. An undrained gravel pack system (UOSTS) has been instrumented and installed in the garden of a private house in the Yonne Department in France. It is currently in the follow-up phase since the beginning of March 2012.

Pollutants in the vadose zone does not necessarily move at the same rate as water, but the transit time of water represents a lower limit for the transport time of certain pollutants. Otherwise, it is important to know and describe the terms of water flow in soil in order to characterize the soil's capacity as a vehicle for transport of dissolved and suspended substances (CALVET, 2003).

There has long been speculation that large continuous openings in field soils (macropores) may be very important in the movement of water. Such voids are readily visible, and it is known that they may be continuous for distances of at least several meters in both vertical and lateral directions. These voids allow rapid movement of water, solutes and pollutions through the soil (BEVEN, 1982). The permeability of a soil during infiltration is mainly controlled by big pores, in which the water is not held under the influence of capillary forces (SCHMEACHER, 1864).

There is no doubt that water will move through large voids under saturated conditions and that they have a very important influence on the saturated hydraulic conductivity of soils, even though they may contribute only a very small amount to the total porosity of a soil.

Porosity can be classified with respect to the hydraulic conductivity of the soil, where data on the change of conductivity with soil moisture are available. When the structural pores are large in relation to those in the surrounding soil, the movement of water through the macropores, once initiated, may be much faster than equilibration of potentials in a respective volume of soil matrix. If this is so, the potential gradients associated with the two systems will be different. In heavy soils, channel drainage will in most cases precede general drainage; a portion of the water escaping by the open channels before the body of the soil has become saturated; this will especially be the case if the rain fell rapidly, and water accumulates on the surface (LAWES et al., 1982).The possibility of such discontinuous behaviour can be appear as there is a amount of stone fragments in the fine soil which could increases the flow rate in the soil by their size and the condition of the connectivity of the macropores and the effects of capillary tension within the macropores become smaller. Other terms such as preferential flow pathways for macrochannels have been suggested to emphasize the importance of structure on flow dynamics. We try to identify the preferential flow in a stony soil with a fine clay matrix by using the measured and estimated saturated hydraulic conductivity and monitoring the soil moisture and capillary potential by regard to the variations of water table and rainfall.

Stony soils are soils containing over 35% or 40% in volume of soil particles larger than 2 mm: the rock fragments (FAO, 2006; Soil Survey Staff, 2010). These soils are composed of several fractions (Corti et al., 1998): fine soil matrix (particle diameter<2 mm), gravels (2<particle diameter<20 mm), pebbles (20<particle diameter<50 mm), stones (50<particle diameter<200 mm) and blocks (particle diameter> 200 mm). The stony soils, often shallow, cover about 30% of areas of Western Europe, and up to 60% in Mediterranean areas (POESEN and LAVEE, 1994). The wide distribution of this type of soil generates interest in its functioning, but the characterization of stony soils remains difficult. Since the founding works of BERGER (1976), COILE (1953) and GRAS (1994), the rock fragments, that we define here as the “stony phase”, are usually recognised as non inert and are taken into account when some physical or chemical properties of these soils are characterised. Stones play a role in soil by modifying the pore space. In natural soils, an increase in the content of rock fragments is correlated with a decrease in the bulk density of the fine soil matrix (TORRI et al., 1994). This decrease is due to extra porosity resulting from contact between the stones and the fine soil matrix, which in turn arises because the space between the stones is incompletely filled by fine soil matrix or because the larger particles prevent the smaller ones from packing (STEWART et al., 1970; POESEN and LAVEE, 1994). Stones can affect water retention if they are porous, but their release of water depends on the fine soil matrix in which they are embedded (GRAS, 1994). More generally, the effect of stones on the hydraulic properties of the soil is associated with arrangement of soil particles. The stones and the soil add their own respective porosities in granular media (SHARMA et al., 1993), but the porosity of these media and the associated water properties can be modified by compaction (RAVINA and MAGIER, 1984).

POSITION OF THE PROBLEM

Rock fragment content, size and position in the soil, may both increase and decrease infiltration. The presence of rock fragments usually results in a decrease in the infiltration rate (CHILDS and FLINT, 1990; MA et al., 2010; MA and SHAO, 2008) since they reduce the surface available for the flow transport in soil. Nevertheless, rock fragment can also increase the infiltration rate, by the creation of preferential flow (PF) pathways at the fine soil matrix-stone interface, the latter being active only at high water contents.

URBANEK and SHAKESBY (2009) argued that with large stone contents flow pathways develop along sand–stone interfaces and a continuous preferential flow path can form provided there are sufficient stone-to-stone connections. The distribution and alignment of the stones, especially at intermediate stone contents, are important for promoting water movement. ZHOU et al. (2009) studied the effects of different gravimetric rock fragment contents in a soil on infiltration, saturated hydraulic conductivity (Ks) and solute transport. The in-situ tests showed that both infiltration rates and the saturated hydraulic conductivity initially decreased with increasing rock fragment content to minimum values and then increased. Verbist et al. (2008) demonstrated that stone fragment content correlated significantly with both saturated and unsaturated conductivities, probably due to a positive correlation between stone content and coarse lacunar pore space. COUSIN et al. (2003), in calcareous soils, found that the percolation was underestimated when the rock fragments were neglected and the soil was considered only as fine earth, while percolation was overestimated when the rock fragments were considered as non-porous stones.

An additional source of variability when considering infiltration measurements is the measurement method and the subsequent data analysis. REYNOLDS et al. (2000) compared three methods (pressure infiltrometer, tension infiltrometer, and the constant-head soil core method to determine the saturated hydraulic conductivity and found very little correlation among the methods used. MOHANTY et al. (1994) observed similar differences when comparing the constant-head well (Guelph) permeameter, falling-head well permeameter, tension infiltrometer, concentric ring infiltrometer, and constant-head soil core methods. GOMEZ et al. (2001) found better correlations among four different measurement methods (falling-head well permeameter, pressure infiltrometer, tension infiltrometer, and rainfall simulator) and were able to detect significant differences in infiltration rates between and under olive trees in southern Spain with each of the methods used.

Techniques for describing, inferring, or quantifying preferential flow (PF) can be classified into different groups: (i) observation and quantification of structures susceptible to cause PF; (ii) measurement of water distribution or water movement; (iii) investigation of gas movement. For solutes and particles either already in the environment or applied as tracers, methods with (iv) breakthrough curves are widely used. Dyes can be used for breakthrough curves, but they are often associated to (v) image analysis approaches. Different techniques in each group can be described with different advantages and disadvantages. Each of them corresponds to a given group of techniques for estimating PF at small scale and larger scale. An extended description of each technique has been discussed by ALLAIRE et al. (2009).

Current recommendations for the design and management of infiltration structures of treated wastewater and storm water runoff are mainly based on hydraulic criteria. So far, few data are available with regard to the intensity of the disturbance caused to the functioning of the underlying aquifers.

The analysis of the signals of water content and matrix potential of soil recorded by the data loggers allows understanding the influence of an undrained on-site treatment system with a sand filter and distribution drains on the spatial distribution of soil infiltration.

The objective of this study was to evaluate infiltration imposed by an on-site treatment system in the heterogeneous stony soils of centre of France and to answer the following questions:

- Is it possible to clearly identify the effect of embedded stone fragments of soil on soil hydraulic conductivity?
- What variability in infiltration rates can be expected under an on-site treatment system which is characterized by heterogeneous, stony soils, but with a fine soil matrix between the rock fragments (identification of preferential flow)?
- What is the influence of the performance of the on-site treatment system on the spatial distribution of the infiltration rate in the soil?

MATERIAL & METHODS

Field site

The field site considered in this study is located in a valley in the centre of France (03°26′28.3″ E, 47°39′52.8″ N) and consist of a soil with a fine matrix containing rock fragments (maximum size of 20 cm) which was developed on calcareous parent material (Rendzic Leptosol), which are common in the central part of France. In this area there are two broad sets of plates, one with chalk foundations, another sitting on limestone and other natural Marne. These "surfaces perched" tabular or wavy, are deeply incised by a large valleys. In term of lithology, the rock fragments of the site are of the Jurassic limestone. Because of the relatively steep slope at two sides and the site is located at the foot of this slope, it seems that the soil is a colluvion which is the result of the movement and accumulation of Portlandien limestones and Marnes of the Upper and Middle Jurassic (J9) on Kimmeridgian calcareous marnes of Lower Jurassic (J8) and so the colluvion of a clay loam soil with the calcareous fragments has been accumulated at the interface of these two geologic layers (Figure 1).

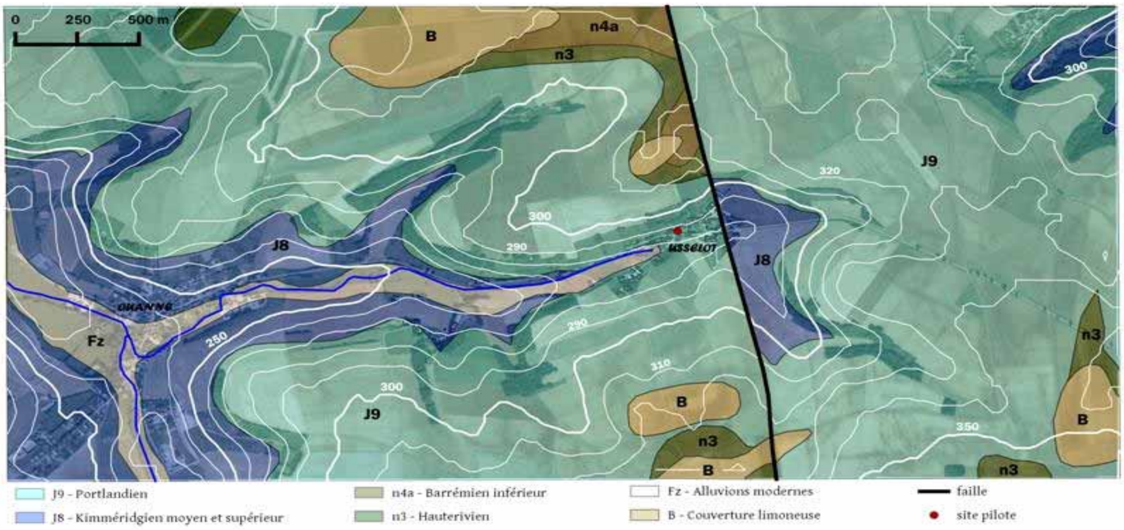


Figure 1: The geologic view of the Field site

The bottom of the excavation of a new undrained on-site treatment system (OSTS) in the yard of a house was considered to collect the soil samples, do the permeability tests and install the hydrodynamic monitoring probes. The OSTS is a management way which ensures independently the collection, treatment and evacuation of domestic wastewater, near the house (Brigand and LESIEUR, 2008) by spreading the pretreated wastewater in five drains on a sand pack and then the treated wastewater percolate in the soil under the system (Figure 2).

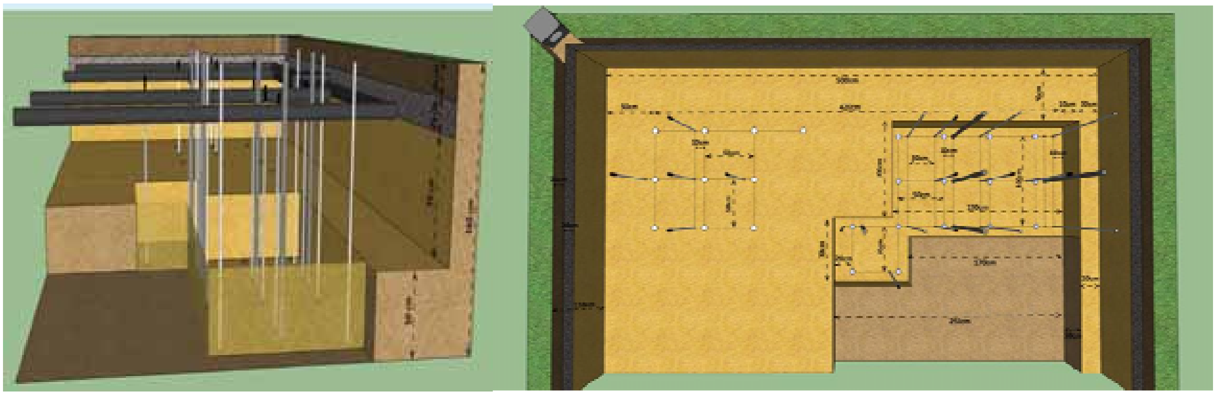


Figure 2: The cross section and plan of implantation of the instruments in the pilot UOSTS.

Selection of the soil water sampler

Sampling devices differ in the type of information they collect, in their resolution in space and time, cost, and maintenance needs. To choose the appropriate type of sampler and specify the appropriate experimental protocol, the exact definition of the target of the study is necessary. In order of priority for the ANCRES project, the objectives of soil water sampling are to evaluate:

- Solute concentration (mg.L-1)
- Mass balance (mg.m-2.year-1)
- Solute transport (g.cm-2.day-1)

Considering the objectives of the project and the method that was proposed by WEIHERMULLER et al. (2007), a device of porous plates was chosen for this research project (Figure 3).

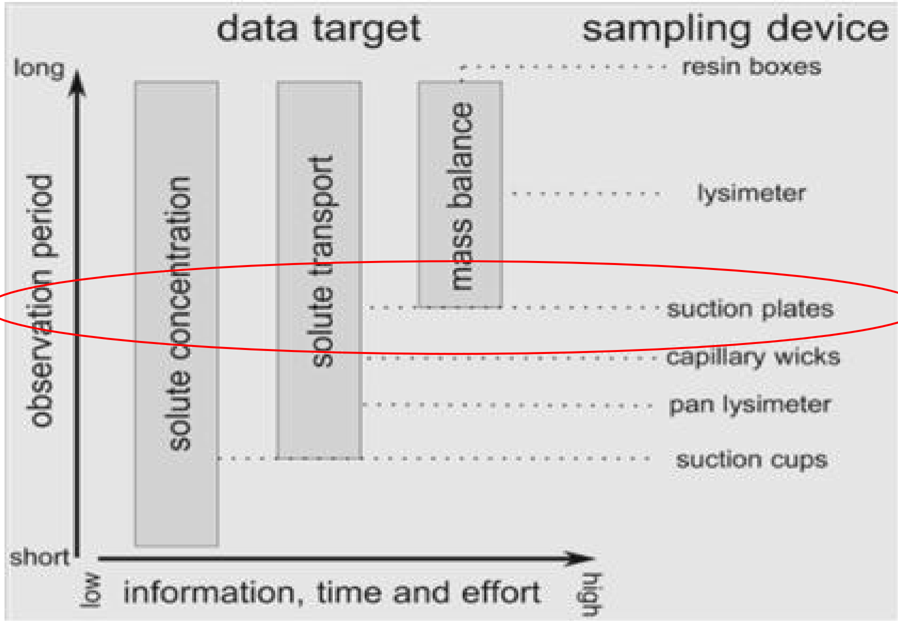


Figure 3: The data target determines the observation period, level of information, time and effort, and selects the optimal sampling device.

The porous plates (round, 7 cm in diameter, flat plates, "2D") were chosen because they have the following advantages, those with a (*) being compared to the porous cups:

- Suitable for detecting the organic matter and heavy metals in the soil ;
- No retention of phosphorus, total organic carbon or other elements ;
- 50% of quartz (no swelling no shrinkage) ensures stable and sufficient hydraulic conductivity ;
- Minimal risk of clogging the plates ;
- Can be used in all soil types and at any depth (*) ;
- Does not create vertical preferential flow in soil (*) ;
- Possibility of detection of events or preferential flow (*) ;
- More representative samples (*) ;
- Applicable to estimating the mass balance (4).

By applying suction on the plates by two vacuum pumps, soil water is collected in two polypropylene bottles (2 liter capacity) via Teflon tubes. A rough calculation of the recoverable amount of water leads to a conservative value of 1.2 l / day / resident. This value is for low matrix potential of soil between 0 and 100 mbar. Then the storage and transport of samples are performed in a cooler.

Field and laboratory measurements

At the beginning of installing the undrained OSTS, the bottom of the excavation (120 cm depth) has been gridded into 25 square meshes of 1 m² and then 15 soil samples of collected from the first 15 m² of the excavation (1 samples of averagely 10 kg for each m²). Simultaneously, in the middle of the each m², 15 permeability tests were done with a Guelph Permeameter (GP) device in order to measure the local saturated hydraulic conductivity of the soil (Figure 4).

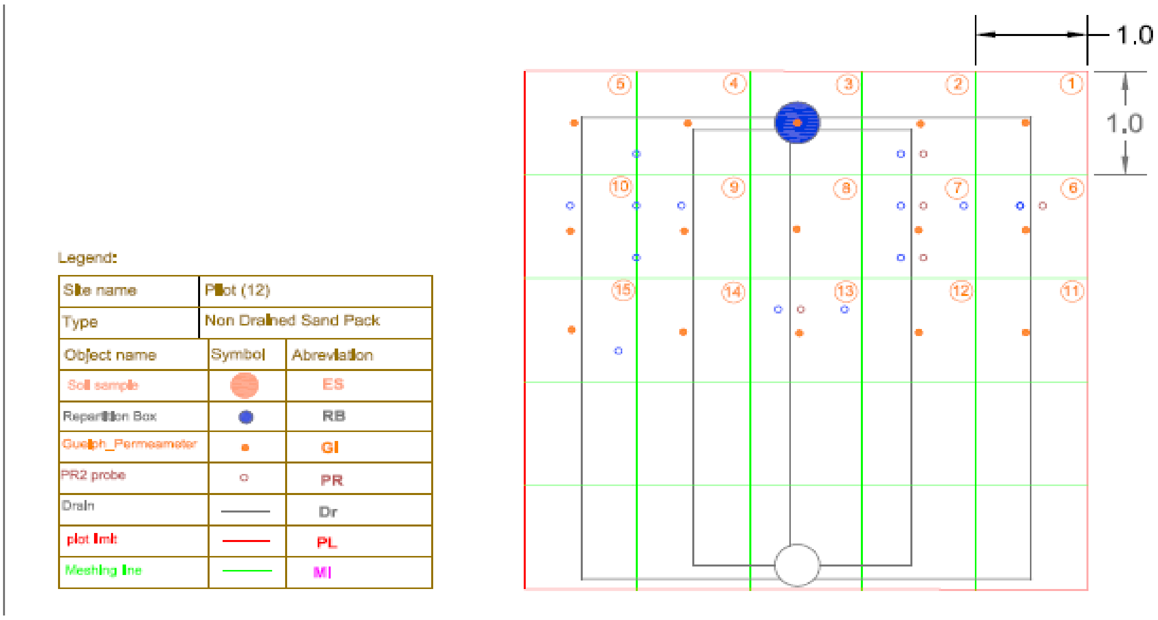


Figure 4: Plan of 15 permeameter test and the implantation of the probes in the plot.

After ELRICK et al. (1898) the Hydraulic conductivity by Guelph permeameter is calculated by the following equation:

$$K_{fs} = Q/(A + (B/\alpha^*)) = CQ/\left[2\pi H^2 + \pi a^2 C + 2\pi H/\alpha^*\right] \quad (1)$$

where $Q(L^3T^{-1})$ is the steady intake rate of water; $H(L)$ is the constant height of the ponded water in the well; and a^* which take on specific forms for specific solutions; $K_{fs}(LT^{-1})$ is the field saturated hydraulic conductivity; C is a dimensionless shape factor and A and B are the coefficients.

It is clear form this expression that if α^* is measured or estimated independently, then only one ponded head (H) need be used.

In this study the "one-ponded height technique" was applied to measure 15 saturated hydraulic conductivities in each m². For all the measurements in a augered well the constant height of the ponded water in the well $H(L) = 5cm$ and the radius of the well $a(L) = 3cm$. The procedure employed for the single height measurement as follows:

(i) Estimate α^* from a site evaluation

(ii) Using α^* from (i) calculate K_{fs} using equation 1

The "Achilles heel" in the preceding approach is the choice of α^*. α values measured in situ from ponded infiltration tend to fall between about 1 m^{-1} and 100 m^{-1}. REYNOLDS and Elrick (1989) obtained α values for Guelph loam ranging from 15 to 20 m^{-1}, and SMETTEN (1986) found $\alpha = 5$ to 7.9 m^{-1} for a red-brown earth in South Australia. SCOTTER et al. (1982) measured values between 2 and 90 m^{-1}, and HENDRICKX et al. (1988) found the α values of 0.6 m^{-1} for "greasy" fine sand and 9.5 m^{-1} for fine sand. In light of these field results, the following choices, for α^*, were suggested (ELRICK et al. 1989) on the basis of structural/textural considerations (ZHANG, et al. 1998).

This classification is the final attempt at establishing several categories for α^*. ELRICK (1985) noted that the $\alpha^* = 12$ m^{-1} is the first choice for most soils. Actually, according to the results of laboratory tests on soil samples (stony calcareous soil with a clay loam matrix) value $\alpha^* = 12$ m^{-1} was considered in the calculations of K_{fs} by the Guelph permeameter (Figure 5).

In the geotechnical laboratory of CNAM in Paris the 15 soil samples have been oven dried 105°C for 24 h. The fine earth fraction (soil matrix) was separated from the rock fragments by softly brushing and grinding. Soil matrix has been passed from the 0.08 mm sieve. For each of the samples, according to the French NORMES, the hydrometery tests have been done for the particles lower than 0.08 mm. Following the particles size distribution curve derived for each soil sample, soil texture of the samples have determined by using the USDA soil texture triangle (Figure 6).

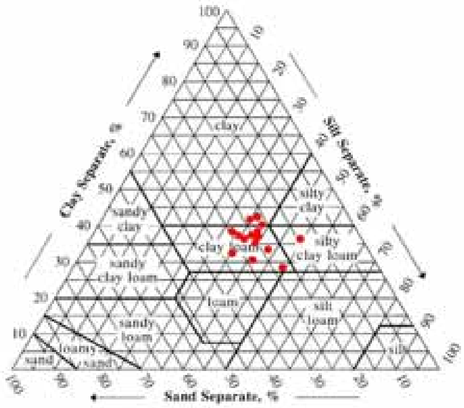


Figure 5. Variation in clay (0–2 µm), silt (2–50 µm), and sand (50–2000 µm) contents at the 15 measurement points.

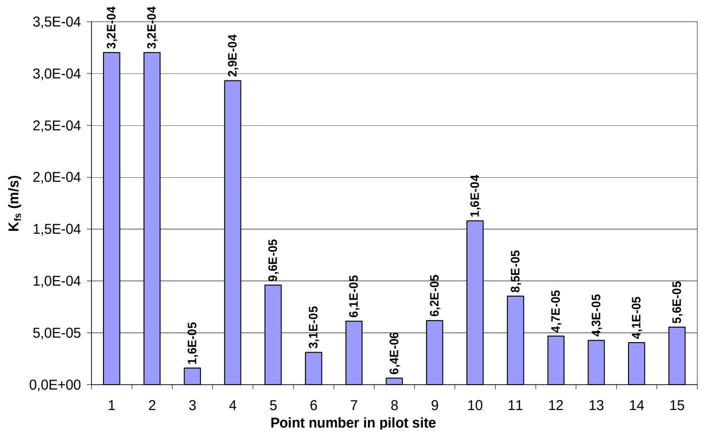


Figure 6: Variation of Kfs values measured by Guelph permeameter at 120 cm depth

By using these textural data and applying a pedotransfer function hydraulic conductivity have been estimated for each soil sample. In the field of soil science, the pedotransfer functions (PTF) are the tools based on statistical relationships, which are used to estimate and predict the properties and behaviour of soil which are difficult to measure directly, from other soil characteristics which are readily observable in the field or determined by routine soil samples. Hydraulic conductivity of the soil matrix estimated by the pedotransfer equation developed by SAXTON et al. (1986):

$$K_s = 2.778 \times 10^{-6} \exp(X) \tag{2}$$

in which:

$$X = 12.012 - 0.0755s + \frac{(-3.895 + 0.03671s - 0.1103c + 8.7546 \times 10^{-4} c^2)}{1 - (\rho_b / 2.65)} \tag{3}$$

where K_s is the saturated hydraulic conductivity, s (%) and c (%) are percentages of sand and clay soil, is the bulk density of the soil.

Installation of hydrodynamic detecting devices in the field site

In order to characterise the hydrodynamic evolution of soil, under the on-site treatment system because of infiltrating rain water and treated waster water, the spatial distribution of water content and the matrix potential of the soil were monitored at the bottom of the excavation at two depths (120 and 160 cm). The system is composed of 12 electronic tensiometers (5 at 120 cm and 7 at 160 cm) (SDEC-France company; model: STCP 850) and 5 water content profiling probes which transmit an electromagnetic field extending about 100 mm into the soil as a ring in a definitive depth (Delta-T Devices Co; model PR2/6-FDR). Twelve electronic tensiometers provide longitudinal and transversal profiles across the soil. The probes give us the temporal and spatial distribution of volumetric water content of soil at 70, 80, 90, 100, 120 and 160 cm of depth from soil surface. A pressure sensor of free water table (Eijkelkamp company; model: Minidiver) was installed in a well downstream of the plot. This device is completed by a meteorological station (Watchdog 2900ET) implanted near the plot. The data are continuously recorded (time step of 30 min for rain, 10 min for soil tension and water content and 1 hour for the water table) (Figure 2).

Among the different techniques to describe and infer the preferential flow in this site, we use three major techniques: (i) Observation the excavation; (ii) Field saturated hydraulic conductivity in multiple points. (iii) Water content and tension distribution.

The observation of soil structure range from very expensive (e.g., scanning) to inexpensive (e.g., photo of soil surface) but the direct observation of the excavation in a rainy period was selected to visible water trickles and rock fragments. The field saturated hydraulic conductivity measurements in 15 points were done by a Guelph Permeameter (GP) device under the following approach; the GP instrumentation was installed in an augered hole at the soil surface, a constant head of 5 cm was maintained in the hole, the K was calculated. The K with an order of magnitude higher than the homogeneous soil matrix indicates PF, the spatial distribution of Ks indicates the distribution of macropores. The water content and tension distribution technique is a simple, easy to measure but difficult to interpret and install technique which was done by the FDR probes and the tensiometers. By a graphical interpretation of treated data, we estimated the heterogeneity and the PF interpreted from this heterogeneous distribution.

RESULTS AND DISCUSSION

Measured and estimated hydraulic conductivity

Table 1 shows the soil texture, estimated (K_{SE}) by the Saxton's pedotransfer function and measured (K_{GP}) hydraulic conductivities of 15 point in the field site. According to the results of the identification of soil texture, the majority of the soil sample has a clay loam texture for the soil fine matrix. Average clay content is 37% which results to soil shrinkage of the fine soil matrix. So shrinkage of the fine phase leads to the formation of coarse lacunar pores due to cracking between the fine phase and the calcareous stones. The maximum, minimum values of (K_{SE}) are 1.36×10^{-6} and 6.11×10^{-7} m/s respectively with an average of 8.06×10^{-7} m/s. The similar values for (K_{GP}) are 3.2×10^{-4}, 6.41×10^{-6} and 1.09×10^{-4} m/s. The average of the (K_{GP}) is 135 times higher than the average of (K_{SE}). The variation of (K_{GP}) in the field follows no pattern and this is directly related to the amount of rock fragments and their alignment in the soil matrix.

Table 1: Summary of the field and laboratory results for the soil texture and hydraulic conductivity

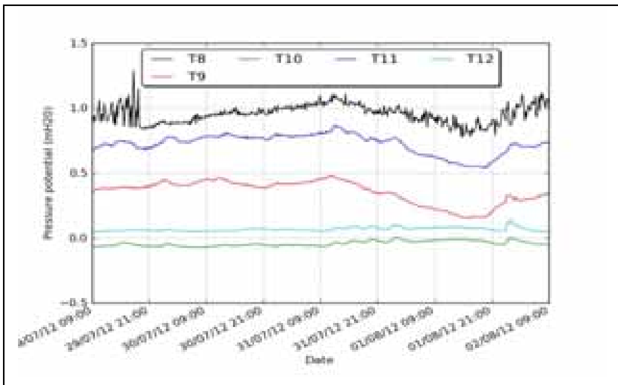
Soil point number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
textural Class (USDA triangle)	Clay loam	Clay	Clay loam	Clay loam	Clay	Clay loam	Clay	Clay loam	Clay loam	Clay loam	Silty clay loam	Clay loam	Clay loam	Clay loam	Clay loam
Estimated Ks by Saxton's PTF m/s (KSE)	7,5E-07	6,7E-07	6,4E-07	8,6E-07	6,1E-07	9,4E-07	6,1E-07	8,1E-07	6,7E-07	7,2E-07	9,4E-07	1,4E-06	1,1E-06	7,2E-07	7,2E-07
Field measured Kfs (Guelph) m/s (KGP) (α*=12 m-1)	3,2E-04	3,2E-04	1,6E-05	2,9E-04	9,6E-05	3,1E-05	6,1E-05	6,4E-06	6,2E-05	1,6E-04	8,5E-05	4,7E-05	4,3E-05	4,1E-05	5,6E-05

Monitoring the hydrodynamic parameters

The figures 7 to 10 are the graphical presentation of variation of the volumetric water content (%), soil tension (m_water) for a dry period and water table (m) and rainfall (mm) for a very short wet period.

Figure 7 is the illustration of the soil water tension for the 5 tensiometers installed at 120 cm. from July 29th to August 2nd. They are located at the interface of sand-soil. The tension values of T8, T9 and T11 are highly positive and T10 and T12 are almost near-zero tensions. . It means that the porous media at this interface is relatively saturated. For all the tensiometers there is daily cycle with 2 principles peaks at 13:00 and 23:00 which are compatible with the peak time consummation of water at home by the inhabitants. As well the identical temporal behaviour of T10 and T12 together and T8, T9 and T12 indicates that they receive the same sequences of water with different amounts. The spatial variation of the pressure in this part is due to, the non-equilibrium repartition of treated wastewater in the drains but the spatial distribution is complicated and it can be because of the heterogeneous vegetal soil on the drains which cause the heterogeneous evaporation from the soil. The range of variation of pressure, among the tensiometers, is averagely between 0 and 1 m-water.

Methods - a brief description of the methods/techniques used (the principles of these methods should not be described if readers can be directed to easily accessible references or standard texts).



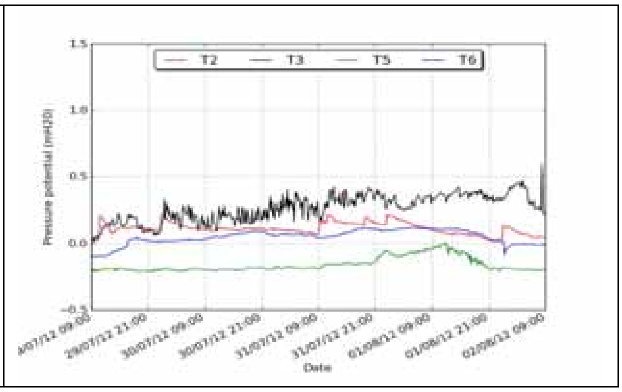


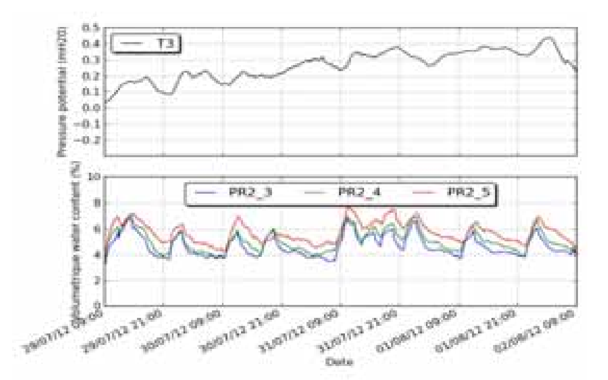
Figure 7: pressure potential variation of tensiometers at 120 cm depth (Left).
Figure 8: pressure potential variation of tensiometers at 120 cm depth (Right).

Figure 8 is the same graphic as Figure 7; just it is for the variation of 4 tensiometers (T2, T3, T5 and T6) at 160 cm in the soil. The pressure values of T2, T3 and T4 are positives or near zero (T6). The daily cycles can be observed for this party too. But the range of the variation of the pressure is between -0.25 and 0.5 m-water which less than the part of 120 cm. it has several reasons at this phenomenon. The drains at left contain much treated wastewater as the drains at the right party of the plot and it is because of the installation of the drains. On the other hand the results of the soil hydraulic conductivity measurements shows that the permeability of the soil is at the same order of magnitude which for sand by the literature $(10^{-4}\ m/s)$. The general difference among the pressure of the tensiometers is because of the heterogeneity of soil.

The non uniform spatial distribution of pressure potential for all tensiometers and their daily cycle oscillation, which are almost positive for all of them, show that the saturation is controlled by infiltration from the upper layer (infiltration controlled saturation" and this in not due to the rise of water table which create a flat free surface with a homogenous water heads in different depths.

The evolution of soil water content (PR2) at 3 depths (90 and 100 cm in the sand pack and 120 cm at the sand-soil interface) and soil's water tension (the nearby implanted tensiometer, T3) was illustrated in Figure 9. The two devices have been implanted side by side (20 cm of distance at mesh n° 2). The 2 daily peaks of water content due to infiltration of treated wastewater are observable in the PR2 curve which correspond the variation of water tension of the soil recorded by T3 for the same time period. According to the three curves of water content variation, the vertical gradient in 3 depths shows that water content varies between 4 and 7.5 present each day and water content increase in the depth.

By using the water table variation data and the rainfall data for a pluvial period which has been illustrated in figure 10. We can see a clear reaction of water table to the rain with a progressive rise of water table and a delay which is due to the time that water needs to flux in the soil and arrive in water table from the surface.



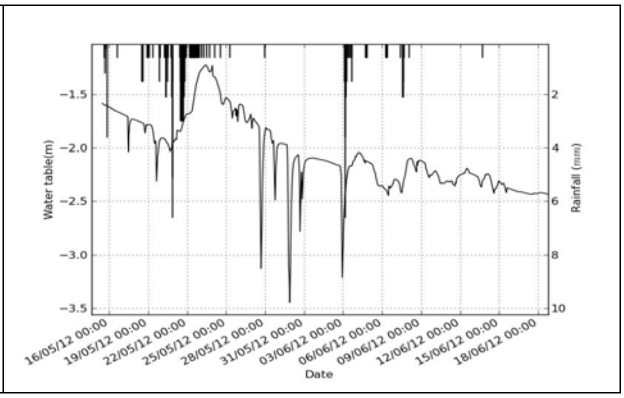


Figure 9: Temporal evolution of soil tension (T3) and water content (PR2) at mesh number 2 (Left).
Figure 10: Variation of the water table and rainfall for a period of one month (Right)

CONCLUSIONS

The observations of 2 trickles of water flow at the bottom of the excavation before filling with the sand and the remarkable difference between the in situ measured hydraulic conductivity and which derived from soil texture approves the existence of preferential pathways in the soil. The influence of the stoniness on hydraulic conductivity is positive. The variability of hydraulic conductivities measured in 15 points proved to be significantly related to differences in the stone fragment content.

This leads to the overall conclusion that stone fragment content is possibly the most important factor influencing infiltration rates in the soils present in our experimental plot, the matrix of which exhibits only small textural differences. Our plot is representative of a large part of the soils in this area. This conclusion can probably be extended to stony soils of calcareous regions and beyond, to heterogeneous urban soils more or less anthropogenic. This implies that stone fragment content should be taken into account when hydrologic processes are evaluated and when developing pedotransfer functions to predict hydraulic properties.

The results of the analysis of the hydrodynamic data in this plot are helpful to monitor the performance of the on-site treatment system and detect amount and sequence of the infiltration of treated wastewater in the soil which influence the spatial distributing of water in the soil.

The results of the permeability tests can be coupled with the results of soil water samples which are collected in two levels (120 and 160 cm) by porous plates that have been installed in the bottom of the on-site treatment excavation, to evaluate the influence of the preferential flow on the quality of percolated water toward the water table.

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