# Effective Transport Parameters Determination for Dry Anaerobic Process


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Nowadays, several different techniques exist to deal with anaerobic digestion of waste. If many of them use dry conditions, we will focus here on dry processes. Thus, the main issue will be to deal with the water content and its distribution in the waste. As a matter of fact, this will be dependent on several parameters, such as materials, density, porosity and of course permeability. In this study, an experimental set up will be presented. Based on simple measurements, we will be able to determine some of the effective parameters for the porous media composed with rape straw. Depending on the solid density, we will give informations about their dependence on the bed density but also on the characteristic time needed to fill the heterogeneous medium with water.

According to Shewani *et al.* (2015), and based on Barenblatt *et al.* (1960), a two equation model might be used when large contrasts of transport properties exist. A macro porosity region (denoted M) will ease the flow of water within the porous media structure, whereas a micro porosity domain (denoted m) will slow down the flow by "pumping" partly the water. This could be expressed according to the following simplified system of equations

$$\nabla.\mathbf{U_L} + \nabla.\mathbf{U_G} = -q_{L,M\rightarrow m}$$

$$\varphi_M \frac{\partial S_M}{\partial t} + \nabla.\mathbf{U_L} = -q_{L,M\rightarrow m}$$

$$\varphi_m \frac{\partial S_m}{\partial t} = q_{L,M\rightarrow m}$$

where $\mathbf{U_L}$and $\mathbf{U_G}$ are respectively, the liquid and the gas velocities. $\varphi_{i=m,M}$ are the micro porosity and the macro porosity of the medium, $S_{i=m,M}$ are the saturations of water in the two regions and $q_{L,M\rightarrow m}$ is the water exchange term. To determine all of these terms and the dependence on the bed density, we have developed a column represented in Figure 1. The column dimensions are 15cm diameter and 30 cm height between the two shelfs. The water is injected using a peristatic pump with a maximum flow rate of 300l/h/m². Considering that the generalized Darcy's law is valid (see Muskat *et al.* (1937)), we have:

$$\mathbf{U_i} = -\frac{KK_{r,i}}{\mu_i}(\nabla P_i - \rho_i g)$$

with $K$ the absolute permeability $K_{r,i}$ the relative permeability, $\rho_i$ the density. Injecting the water along the z-axis and assuming no increase in the gas pressure, we could determine the effective permeability along the vertical direction according to $\mathbf{U_L} = \frac{K_z K_{r,L}}{\mu_L}(\rho_L g)$. Defining the apparent permeability, $K_L = K_z K_{r,L}$, we have a direct relation between the permeability and the measured flow rate at the water outlet $K_L = \frac{\mu_L Q_L}{\rho_L g S}$.

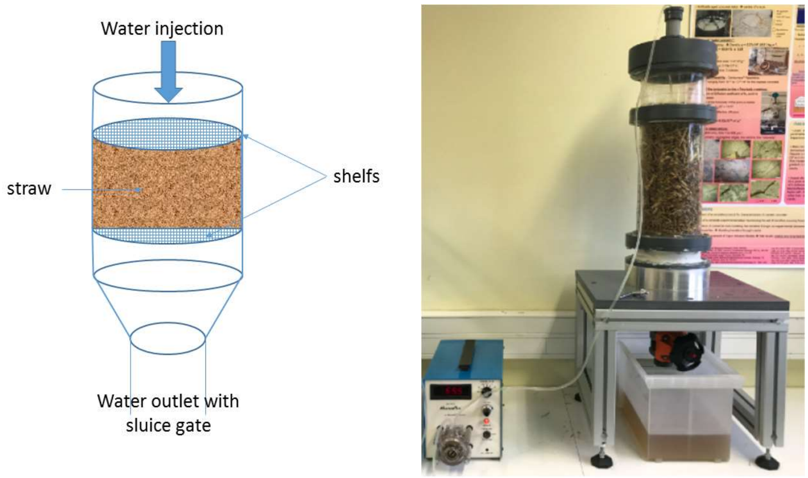


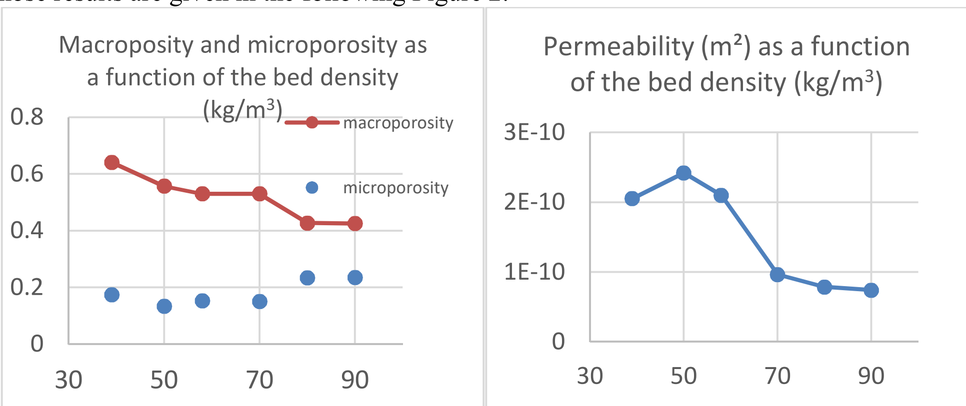

**Figure 1 :** Sketch of the experimental device on the left hand side. The experimental set up in use on the right hand side.

We have performed a set of experiments in order to determine the values of micro and macro porosity, the total porosity and the permeability. Two replica of each experiments have been done in order to ensure the reproducibility of the results. In the next table we give a short and brief summary of the results obtained.

Table 1. set of experiments

| Density ($kg/m^3$) | macro porosity | micro porosity | porosity | Hydraulic conductivity (m/s) | Permeability ($m^2$) | Exchange time (min) |
|---|---|---|---|---|---|---|
| 39 | 0.641 | 0.174 | 0.815 | 0.002 | $2.052\ 10^{-10}$ | 17.45 |
| 50 | 0.557 | 0.134 | 0.691 | 0.0024 | $2.42\ 10^{-10}$ | 11.7 |
| 58 | 0.6 | 0.153 | 0.753 | 0.0036 | $3.9\ 10^{-10}$ | 9.3 |
| 70 | 0.564 | 0.179 | 0.743 | 0.00095 | $9.65\ 10^{-11}$ | 10.1 |
| 80 | 0.427 | 0.234 | 0.661 | 0.00077 | $7.85\ 10^{-11}$ | 14.6 |
| 90 | 0.425 | 0.235 | 0.66 | 0.00072 | $7.39\ 10^{-11}$ | 15.3 |

As a first evidence, the bed density has a strong influence on the effective properties. Increasing the density leads to a macro porosity decrease (up to 33%) and an increase in the micro porosity (25%). The permeability is reduced (~70%). This is easily understood as the macro porosity is lowered by the density increase. Those results are given in the following Figure 2.




a b

Figure 2. (a) Macroporosity and microporosity dependence on the bed density and (b) permeability.

We have also monitored the time to reach the equilibrium state for the water content in the micro porosity. This has been done previously by Shewani *et al.* (2015). The water exchange term is usually expressed using a difference between macro and micro saturations, such as:

$q_{L,M\rightarrow m} = C(S_M - S_m)^{\alpha}$ , with C and α constants to be determined and depending on the porous media structure.

In table 1, we report the results for $C^{-1}$, i.e. the characteristic exchange time. This exhibits a non-monotonic behavior. For low density, the time to reach the equilibrium is large (~20 min). This could be explained by the presence of large void spaces, limiting the surface in contact between the macro and micro porosity. But, increasing the bed density, the porous media structure changes, and the contact between the straw and the macro porosity seems to be more efficient. For larger values of the bed density, the exchange time increases. A possible explanation, is the conversion of part of the macro porosity to micro porosity, insulating partly some regions.

This new experimental set up allows to study a wide range of materials. The density is known to be an important parameter, and this has been investigated for one possible substrate used in Dry Anaerobic process.

***References***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