The subsurface water movement is an important step of the water cycle which fully understanding is not yet achieved. Groundwater is defined as water contained in soil pores and in the fractures of rocks. It is not stopped, it slowly moves downwards recharging rivers, sustaining ecosystems and yielding water to wells. Indeed, subsurface water is often preferred as water source for human uses because it is usually cheaper to make drinkable and less vulnerable to pollution than surface water. On the other hand, when it is polluted, it is difficult to timely notice and to clean up. Its flow strongly depends on encountered geological underground formations and it is difficult to reproduce not being directly observable.

Many tests and models are applied to determine formation properties' averages and, therefore, the average response of the field to water movement. Usually they are time-consuming and assume a homogeneous field, or only vertically heterogeneous. Therefore heterogeneity gets characterized very approximatively . Indeed, this way they do not consider the possible presence of fast pathways which considerably influence contaminant movement.

Therefore, this paper proposes to use the steady-periodic model for oscillatory pumping test in a Monte Carlo framework in order to characterize hydrogeological formations evaluating local properties: conductivity and storativity, concentrating on their heterogeneity. The oscillatory pumping test stimulates aquifers with several periodic signals of different frequencies, then the model elaborates data by a modified Bayesian inversion and the pilot point approach in which governing equations of subsurface movement are used in the Fourier space. The model proposed in this paper provides a deep understanding of the spatial distribution of hydraulic properties that is generally needed, for example, in contaminant transport studies at the local scale.

After that a preliminary sensitivity analysis is carried out to determine best parameters to us, different typology of results and simulations are carried out in order to assess capability to infer hydraulic properties variations with limited prior information. Nine simulations are carried out, starting from a simple one and concluding with a random field characterized by high variances.

In conclusion, from this paper it is possible to see how local properties in the field are approximatively reproduced giving an indicative idea of their heterogeneity . The average of Monte Carlo simulations is able to infer the heterogeneity pattern of both properties but it does not correctly evaluates extreme values. While, the best simulation captures local properties' values and their statistics with acceptable but variable accuracy.

For situations of pollutant spreading, contaminant transport on the field is crucial but difficult to infer even with the model proposed in this study. Breakthrough curves usually have not been correctly reproduced by simulated fields. On the other hand, connectivity functions are often reproduced quite precisely by the best simulation. It is a good result because it is a relevant indication of the presence of fast pathways where contaminant particles can move. Even if arrival times of particles are wrongly inferred, the connectivity function gives an idea about the possibility for particles to move fast and therefore it is an indication of contaminant spreading risk. This approximate information could be very useful for sensible areas.

Another useful information regards the regards the size of as input ranges of data where the PSO algorithm searches statistical parameters of the field. Large ranges on the PSO algorithm allow the inferred field to adapt to the available observations about the area of interest, even if the computational time increase.

Finally, the most important observation is the higher sensibility of the model to storativity than to conductivity. This is understandable given that the model is applied to an oscillatory pumping test and therefore it works in transient conditions. Indeed, it is widely known that in steady conditions conductivity is the relevant parameter, while in transient conditions storativity turns into the main parameter even if conductivity still influences. Models currently used usually focus on conductivity and storativity is not accurately reproduced. While this work provides a sensible measurement for this lacking property of the field.