CHAPTER V
SAMMARY AND CONCLUSION

The problem of non-equilibrium and/or preferential water flow and transport has received much attention in the soil and agricultural sciences because of its implications in accelerating the movement of agricultural contaminants (fertilizers, pesticides, pathogenic microorganisms and toxic trace elements) through the unsaturated zone to underlying groundwater. Non-equilibrium flow and transport are probably the most difficult processes in terms of control the accurate predictions of contaminant transport in soils and fractured rocks. Non-equilibrium or/and preferential flow, as opposed to uniform flow, results in irregular wetting of the soil profile as a direct consequence of water moving faster in certain parts of the soil profile than in others. Therefore, the objectives of the present work were to evaluate and comparison the physical and chemical non-equilibrium processes of potassium transport under the present experimental conditions using the last version of HYDRUD-1D **(Šimůnek *et al.*, 2008).**

To achieve the intended objectives, three surface soil samples (0-40 cm depth) were collected. The soil samples were taken from different locations as follows:

1- Sandy loam soil: collected from El-Hammam region, Matrouh Governorate (30° 48.814' N latitude, 29° 24.094' E longitude and 18 m above sea level).
2- Sandy soil: taken from Idko region, Behaira Governorate (31° 16.827' N latitude, 30° 15.484' E longitude and -2 m above sea level).
3- Sandy clay loamy soil: taken from Hammad village, Rashid region, Behaira Governorate (31° 19.694' N latitude, 30° 26.373'E longitude and 10 m above sea level).

All soil samples were prepared for determination of some physical and chemical properties. Soil hydraulic parameters and potassium sorption isotherms were determined according to the proper methods.

Polyvinyl chloride columns (PVC), 65 cm height and 19 cm diameter (283.5 cm^2 surface area) with closed bottoms, were used in the study. The base of the columns was tightly sealed with silicon adhesive. The bottom 1 cm layer, in the columns, was coarse gravel as drainage layer. A plastic tube of 1.0 cm diameter fitted into the drainage layer at 60 cm soil depth to collect the drainage water. The columns were hand-packed with air dried soil samples for length of 60 cm at constant bulk density by gently tapping. The arrangement of the experiment allows supplying a potassium solution at constant rate. The soil columns were subjected to water flux until steady state out flow at the bottom of soil column with solution of 12.5(control), 100 and 200 mg K/l as KCL. The KCL solution was added at constant rate and the leachate collected at the bottom end of each column was recorded. The leachate was monitored for volume and concentration values at corresponding time till the salt front has passed the lowest end of soil column, and then stopped recording data. The solute drained from the bottom of column was collected in glass bottle and then volume and K concentration were measured.

The obtained results can be summarized as follows:

1- **Water retention function**: Water retention function of the three tested soils used in the present study was expressed using two hydraulic models; van Genuchten-Mualem type function model and Durner's multimodal pore system.
2- **Potassium sorption isotherm**: Potassium sorption isotherm was done using linear sorption isotherm and two site sorption model
3- **Potassium transport with equilibrium and non-equilibrium models:** Potassium transport through the soil column for the three soils was done and applying some equilibrium and non-equilibrium transport models, i.e. dual porosity model (DPM), dual permeability with two site mode (DPTS), equilibrium model (EQ), one-site sorption model (OSM) and two site-sorption model (TSM).

The results show the same trend of moisture distribution that increasing in upper layer and then decreased gradually down to the bottom of soil column. Also, the results show that moisture content of experimental data was more than predicted one. The differences between experimental and predicted data may be due to the soil heterogeneity during packing of soil column under experimental setup.

The experimental data show higher values of sorbed and soluble K distribution through the soil column than the modeling data. This result may be due to the soil heterogeneity as results of macropores and preferential flow of water and solute. Preferential flow, as opposed to uniform flow, results in irregular wetting of the soil profile as a direct consequence of water moving faster in certain parts of the soil profile than in others.

The obtained results of the present study show that there are differences between experimental and predicted data according to HYDRUS-1D. The non-equilibrium simulation of potassium transport in the three soil textures did not fully represent the experimental data. These differences may be due to the heterogeneity of soil packing and also due to the macropores flow phenomena. Soil heterogeneity is responsible for the difficulty in predicting the movement of mass (solids, liquids and gases) in field situations at most scales. For example, it often results in faster movement of gas, water, solutes and particles than would be expected from the soil matrix properties. This more rapid mass transport is associated with processes such as flow through earthworm burrows, cracks in soil, or flow associated with soil layering and hydrophobicity. These processes, together, are called preferential flow (PF). Preferential flow (PF): refers to flow mechanisms where transport of water together with dissolved or suspended matter is primarily associated with a smaller fraction of the total pore network, at any scale much larger than the microscopic.

From the present study we need more basic research to cover the knowledge gaps according to the following points:

1. More research is clearly needed on the role and importance of long-term leaching in macropores and kinetic non-equilibrium sorption effects.
2. Further advances can be expected from researches that explain the combine geometric descriptions of soil macropores structure with continuous real-time measurements of solute transport.
3. One more working concept is that a coarser, more heterogeneous structure (associated with a decrease in macro-porosity) promotes strong non-equilibrium macropore flow but only until critical limit is reached when macropore

connectivity becomes limiting. These effects of pore volume and spectral dimension may be investigated for transport by diffusion, but not with gravity-driven convective processes such as macropore flow.

4. Since any model is simplification of reality and the underlying reality is never known exactly, model simulation results are inherently uncertain. One expression of this uncertainty is equifinality, characterized by multiple model structures and parameter sets yielding acceptable fits to observed data (Beven, 2006). To better understand the uncertainty and limitations of the model structure, the optimization problem can be formulated in a multi-objective context, where information contained in several data-sets is exploited simultaneously **(Gupta *et al.*, 1998; Vrugt *et al.*, 2003; Wohling and Vrugt, 2008; Köhne *et al.*, 2006).**

A general conclusion of the present study is that a model's success or failure to represent the flow and transport processes internal to the transport domain should not be judged solely by the response prediction at a single outlet point. Therefore, we need more experimental data and more thorough studies of many soil types to evaluate how much and what type of information is required to fully parameterize selected non-equilibrium models. Until measurement techniques are fully developed, inverse parameter identification is an indispensable means for the application of complex non-equilibrium models. To facilitate such applications, the objective function for the inverse problem in HYDRUS-1D can be formulated in terms of a large number of variables involving not only boundary concentration fluxes, but also water and solute distributions within the soil profile and in different phases.