Chapter 6
Transport and Sorption

6.1 Interphase Exchange

Aside from advection, diffusion and dispersion, which can be formulated separately for the solid and the fluid phases, the interaction between the phases is another process which is relevant in many environmental systems. Under certain conditions, particles in the pore space are attracted by the surface of the porous medium where some chemical processes tend to bind them in various ways. Different processes like electrical attraction and repulsion, complexation or chemical reaction can be distinguished in a detailed look, gathered under the general term sorption.

In multiphase environments, sorption denotes processes that affect an exchange of components between phases. One can speak of interphase exchange. In porous media there is the exchange between solid and fluid phase, i.e. between the water in the pore space and the solid matrix. Adsorption denotes fluxes from the fluid to the solid phase, while desorption is the opposite process, in which there is a flux from the solid to the fluid phase. In the following the term mobilization is used frequently. A pollutant particle which has been fixed at the surface of the solid matrix in a first time period, may be re-mobilized and freed for dispersion and advection processes in a second time period.

A schematic view on adsorption and desorption in the pore space of a porous medium is given in Fig. 6.1. In the remainder of this chapter, we will mostly refer to that multi-phase set-up as it is the standard concept for environmental models concerning groundwater, seepage water and pore water in aquatic sediments.

In a first fundamental distinction, the speed of the processes governing inter-phase exchange in relation to the transport processes is of concern. One speaks of fast sorption if sorption is faster than the transport processes; and of slow sorption if sorption is slower than transport. Thus the characterization of sorption depends on the specific situation.

Let $c$ denote the fluid phase concentration and $c_s$ the solid phase concentration. Normally $c$ and $c_s$ are not independent but connected. High or low concentrations in
one phase are usually connected with high or low concentrations in the other phase. Such phenomenon can be formulated by a mathematical relationship. In the case of fast sorption, the relationship is mostly stated in the functional form

$$c_s(c)$$  \hspace{1cm} (6.1)

in which the solid phase concentration is given in dependency of the fluid phase concentration. This is called a (sorption-) isotherm\(^1\) and can be understood as an equilibrium, very much like the equilibrium in chemical reactions. The concentrations in one phase are adjusted if, for whatever reason, the concentration in the other phase is changing.

The simplest example is the linear isotherm

$$c_s = K_d c$$  \hspace{1cm} (6.2)

where the distribution coefficient \(K_d\) determines the ratio between solid phase and fluid phase concentrations. The physical unit [volume/mass] can be attributed to the fact that the concentrations in the fluid and solid phase are usually not measured in the same physical units. Strongly sorbing components have a high \(K_d\), while it is low for weakly sorbing components. Non-sorbing components do not interact

\(^1\)The notation ‘isotherm’ stems from the fact that such measurements are mostly performed for constant temperatures, i.e. isothermal conditions. In general the isotherm changes with temperature.