A number of cement plants face problems in their compliance with the HCl emission regulations. This work is focused on the study of the mechanism of HCl absorption by cement raw meal at conditions similar to those of post-preheater tower units. The main goals of the project were the understanding of the mechanism of HCl absorption at industrial conditions and development of industrial models that are able to predict the HCl emission and optimize the control of HCl emission from cement plants.

The first four chapters provide the framework of this study and present the cement manufacturing process, available literature, and industrial data that are related to the HCl formation and absorption mechanisms. In particular, the HCl formation mechanism is not completely understood; however, industrial measurements showed the presence of two formation zones: one in the low temperature (360-600°C) preheater tower cyclones, and one in the rotary kiln. Furthermore, strong HCl scrubbing phenomena were detected in the particle filters and raw mill units. Therefore, the understanding of the mechanism of HCl absorption is a key issue for the optimization of HCl emission control and prediction of the HCl emission from cement plants.

Chapter 5 comprises the description of the used experimental set-ups, experimental procedures and materials characterization. A fixed-bed reactor - FTIR set-up and a standard TGA-FTIR system were used for the conduction of isothermal and ramping temperature tests, respectively. The fixed-bed set-up was used for the experimental study of the mechanism of HCl absorption by raw meal in the temperature range of 100-180°C, using gas phase HCl concentration between 52 ppmv and 200 ppmv. The effects of gas phase composition (0 or 5% v/v H₂O, 0 or 30% v/v CO₂, and 0 or 3% v/v O₂) and particle moisture content were also studied using fixed-bed tests. TGA-FTIR tests were conducted to study the effects of raw meal compounds on HCl absorption in the temperature range of 90-350°C, using reagent grade CaCO₃, simulated raw meal, two industrial raw meals, and the thermally degradable AlCl₃·6H₂O as HCl source. Furthermore, the TGA-FTIR tests were used for the fast screening of HCl absorption by different raw meals.

Chapter 6 presents the interpretation of the obtained experimental data. Fixed-bed tests showed that the HCl absorption by raw meal is consistent with a surface saturation phenomenon that is characterized by a certain HCl absorption capacity of raw meal and extremely low active compound conversion (less than 1%). Furthermore, HCl absorption tests using moist gas phase with 5% v/v H₂O showed increase of HCl absorption capacity of raw meal by 25% at 180°C and 61% at 100°C relative to the absorption capacity from dry gas phase tests. It is noteworthy that the raw meal moisture content strongly promotes the HCl absorption in the case of dry gas phase tests. On the other hand, it was concluded that the presence of 30% v/v CO₂ and 3% v/v O₂ in gas phase has no significant effect on HCl absorption in the range of operating temperatures of post-preheater tower units. Agglomeration of the raw meal particles and flow channeling significantly decrease the apparent HCl absorption capacity. The HCl absorption capacity of raw meals increased almost 10 times when raw meal samples were diluted using inert material with larger particles size, due to breaking up of agglomerates and elimination of flow channeling. TGA-FTIR tests showed that the industrial raw meals have higher HCl absorption capacity than reagent grade CaCO₃ and simulated raw meal. Furthermore, they indicated that Fe₂O₃ promotes CaCO₃ chlorination. The obtained results showed that TGA-FTIR system is probably inappropriate for the fast screening of HCl absorption by different raw meals.

Chapter 7 comprises the modelling work on fixed-bed experimental data. The fixed-bed model assumes that the HCl absorption is a surface saturation phenomenon characterized by a specific HCl absorption capacity that depends on temperature, gas phase moisture content and raw meal moisture content. HCl absorption is controlled by HCl mass transfer to the particle surfaces (through the gas film) and active surface conversion. The use of an appropriate Sherwood number expression for multiparticle fixed-beds (mixtures of active and inert particles) and a numerical solution method for the model equations allowed the simulation of the experimental data.

Chapter 8 presents the HCl absorption industrial models for the post-preheater tower units. These models simulate the mechanism of HCl absorption using the same principles, e.g., surface saturation phenomenon, as the aforementioned fixed-bed model. The applied modelling approach for particle filters assumes that the HCl absorption occurs in the dispersion before filtration bags and not in the dust layer on filtration bags. This claim is based on the lab results (fixed-bed tests) which showed that the HCl absorption is a very fast reaction and raw meal particles tend to be strongly agglomerated when they form cake layers (low apparent HCl saturation capacity). Furthermore, the developed model assumes that the HCl absorption approximates a reaction in entrained flow reactor similar to plug flow reactor (PFR) characterized by gas phase residence time equal to 1.9s. The entrained flow reactor model was also used in the simulation of HCl absorption in the raw mill. The application of the entrained flow reactor model to the raw mill showed complete HCl absorption in the raw mill. Generally, it is concluded that the industrial models can simulate the HCl scrubbing phenomena in particle filters and raw mill sufficiently well. The entrained flow reactor model was not evaluated in the case of gas conditioning tower due to the lack of industrial data.