

Chapter 3

Applied Aspects of Constant Rate Filtration

ABSTRACT

The thorough technological and also design analysis of the rapid filters operation with a constant rate is carried out in Chapter 3. It is based on the solutions of the mathematical problems from the previous chapter, as well as sanitary and hydraulic criteria. The procedure for determining the duration of the filter run (operation period) is shown for similar conditions. This procedure is implemented for the purpose of applied optimization of the filter bed height, the most important design parameter. The consequences of the unavoidable sorting of the granular filtering material due to intensive washing are studied. Filtration is considered with a strict restriction of the impurity accumulation in the pores and, accordingly, the formation of two zones with complete and incomplete deposit saturation in the clogged bed. The technique of the filtration intensification by splitting a single suspension flow into two or more smaller flows is analyzed. The evaluation of the sensitivity of the technological parameters relatively temperature and deposit composition has been carried out.

The chapter focuses on the applied aspects of the theory of the detachment deep bed filtration. In general, the development of the filtration theory, first of all, implies the study of new processes and effects in connection with the increasing requirements of water treatment practice. At the same time, fundamental knowledge about the patterns of changes in the filtration characteristic can be acquired through in-depth analysis of the fundamental knowledge about the patterns of changes in the filtration characteristic can be acquired through in-depth analysis of the validated mathematical models. Indeed, the analytical solutions and the numerous theoretical dependencies arising from them, which are contained in the previous chapter and will also be presented in most of the subsequent chapters of the monograph, can provide a reliable prediction of spatial and temporal changes in all the filtration characteristics involved in the basic models and initially unknown. And nevertheless, not a system solution of the classes of correct mathematical problems of various contaminants removal in special porous media became the main purpose of the monograph. From the practical point of view it is even more important to realize the full potential of the significant opportunities of new solutions as a basis for the technological and design calculations of filtration facilities. Therefore, the efficiency of the operation of the mentioned facilities (actually the economics of filtration) will constantly be in the focus of attention in the future, and the results of the mathematical modeling of the clarification process will logically culminate in the (applied) optimization of the technological and design parameters. In principle, analytical dependences for the

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concentrations of dispersed impurity, head losses, derived in case of a constant filtration rate at linear mass exchange kinetics and detachment filtration (Chapter 2), at nonlinear kinetics and non-detachment filtration (Chapter 4), and in case of the controlled head differential for the impurity concentrations and filtration rate also at linear kinetics and detachment filtration (Chapter 5), etc. are suitable for realization of applied optimization procedure. At the same time, however, they need to be adapted using efficiency criteria to the technological requirements for the filtrate quality, the expenses of mechanical energy for filtration flow process, water flow rate.

Therefore, the analytical solutions of four problems of the detachment filtration of aqueous suspension with a constant rate obtained in Chapter 2 allow to predict reliably the increase in the outlet concentration of contaminants and head losses in the packed bed over time, and at given values of C_e , Δh to determine the time for which they are reached. The calculation dependences resulting from these solutions, in essence, serve as computational tools, which in combination with the principles of the applied optimization and technological modeling make it possible to theoretically substantiate rational design of a filtration facility and its control algorithm for the appropriate conditions of filtration.

If restrictions on the filtrate quality and mechanical energy expenditure are set in advance based on the sanitary and economic requirements (normative values C_* , Δh_*), then the expressions for $C_e(t)$, $S(z,t)$, $\Delta h(t)$ given in Chapter 2 are transformed into transcendental equations with respect to the required technological times. As a result, systems of such equations are formulated, which are not difficult to solve by fitting. The procedure for finding a unique solution, and in fact a set of suitable values of the technological times t_p , t_h , t_f is described in detail and implemented by characteristic examples in Section 3.1 and (Poliakov, 2009a). The filter run duration calculated in this way corresponds to a strictly explicit bed height and an equivalent grain diameter. If it is practically possible to vary them, the design analysis, which is the subject of Section 3.2, becomes important. At the same time, of particular interest for practice is the alternate establishment of the values of these design parameters (optimal L and d_g), at which the duration of the filter run is maximized. Possible consequences for a high-rate filtration of regular changes in the mechanical composition of granular material (grain grading) along the height of the filter media, caused by its intensive mixing during washing, are specially analyzed. The peculiarities of the suspension clarification at stable high-rate mode are considered in detail. The possibilities of the intensification of filtration facilities operation by increasing a hydraulic load are discussed on concrete examples. In individual cases, e.g. in case of the accelerated clogging of a filtering material, it is suggested to reduce the rate of medium fouling to supply the necessary amount of water into the filter at different levels, splitting into several flows. Section 3.5 develops a theoretical basis for the substantiation of such separation and establishment of rational technological parameters. The temperature of water being treated in warm and cold seasons differs significantly. As a consequence, physical, chemical, biological processes, which significantly depend on temperature, proceed in water treatment filters throughout the year at different rates. Obviously, the purification effect of (bio)filtration can also have a pronounced seasonal nature. Analytical methods have been used to evaluate the effect of temperature instability in the environment on suspension filtration, and at the same time the active water binding by the deposited contaminants, which significantly accelerates clogging of a bed and frequently noticeably reduces the time of continuous operation of the filter.

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