Chapter 5
Detachment Filtration With Unregulated Rate

ABSTRACT

The depth detachment filtration with linear kinetics and an unregulated rate is considered in detail. A significant filtration rate is initially provided due to the suspension accumulation in the storage tank. The early and preparation stages are specially studied. The main interest is the final stage, during which the suspension is processed with a declining filtration flow rate. The technological analysis is carried out considering the limitation on the decrease in the filter performance. The hydraulic properties of the filter communications and variable head losses in them are taken into account. Mathematical modeling is significantly complicated due to the close relationship between the kinetic parameters and the filtration rate. An approximate solution is obtained with minimal errors for the general form of such relationship. An exact solution was obtained and a reliable calculation method developed based on it. The limiting storage tank height was evaluated, calculations of the filter run duration and applied optimization of the bed absorption properties were performed.

Along with the clarification of aqueous suspension on rapid filters, which is implemented at a constant filtration flow rate and thoroughly studied by analytical methods in the previous chapters, recently filtration with a variable flow rate is of considerable interest. The corresponding filtration rate mode is more and more widely used in the practice of water treatment due to a number of advantages and, first of all, simplicity of filter operation, greater reliability (Chaundry, 1987; Cleasby, 1993; Grabovsky & Gurinchyk, 2008; Poliakov, 2022; Saatci, 1990). In the process of the clogging of a filter media, its hydraulic resistance steadily increases, so that the filtration rate naturally decreases in the absence of special head losses compensators (rate regulators). At the same time, a short-term increase in the filtration rate is also possible, if a packed bed is unable to pass the entire amount of suspension fed to the filter in time. In this case, the initial suspension accumulates at the inlet to the medium, providing an additional reserve of mechanical energy. In order to maintain the high performance of the filter on a regular basis, it must be systematically washed at any rate mode. However, the time of the successive washing in the case of decreasing filtration rate should be set on the basis of the requirements for the filtrate quality and filtrate flow rate.

Below the mathematical modeling of the suspension separation in the second main rate mode (filtration), namely, at an unregulated filtration rate is performed. As a consequence, the performance of a filtration facility gradually decreases, and the hydraulic characteristics of the transportation system,

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storage tank acquire a non-stationary character. Consequences of jointly occurring clarification and hydrodynamic processes consistently studied with the use of exact and approximate methods at two varieties of the above-mentioned mode. The operation of a rapid filter in the second rate mode is schematically illustrated in Figure 2 from Chapter 1.

In the first variety of the unregulated rate filtration, the stability of the energy resource in a packing bed or in the entire facility is ensured by maintaining a constant differential head (pressure) at the boundaries of the respective physical region of motion. In the second variety, a suspension is fed to the filter at a significant constant flow rate. In both cases, part of the suspension fed to the facility is retained in the storage tank due to the insufficient flow capacity of the clean and even more so of the clogged bed. However, in the first variety of the second rate mode, the rise of the initial suspension level in the storage tank is limited physically (head in the raw water collector), and in the second variety – structurally (overflow chute mark). In the first instance, the separation of a suspension was purposefully studied and, therefore, a constant differential head was set at the boundaries of the operating medium in Section 5.1. Numerous dependencies are derived and widely illustrated here, which allow to carry out the predictive and technological calculations with a high accuracy on the basis of two (approximate and special reference) solutions, in fact, the basic mathematical problem of the suspension filtration with a monotonically decreasing rate. Taking into account the proportionality of the head losses in the active porous bed and the transportation system of the filtration facility, and at the same time the significance of changes in the flow characteristics, Section 5.2 additionally considered the hydraulic aspects of the operation of the supply and offtake communications at constant head losses throughout the facility (the first type). The technological process is implemented at fixed heads at the collectors of a suspension (raw water) and filtrate (disposable or effective head). Finally, the theoretical studies of the filtration facility operation in the second variety of the second filtration rate mode (Section 4.3) were carried out in full (predictions, technological and design analysis). At the beginning of each operating period (filter run) due to a relatively high hydraulic resistance of the layer of a filtering material the surface layer of an initial suspension is formed above it. The characteristic time of its formation is significantly less than the similar time of the suspension clarification, which justifies the isolation of special (early) stages from the general technological process. At these stages, due to their short duration and, as a consequence, small amounts of the suspension and suspended matter entering the bed, it is reasonable to limit modeling only the hydrodynamics of the water flow in a clean porous medium and pipelines serving it, with emphasis on the dynamics of the suspension level in the storage tank. The porous material of the bed is saturated with the initial suspension in the shortest first stage. Nevertheless, this stage deserves a separate consideration, because quite a large amount of fluid can accumulate above the bed surface by its end. At the second stage, the main volume of the untreated suspension accumulates at the inlet of the bed and the offtake communications are activated. Therefore, the entire filter run at a variable filtration rate was conventionally divided into three stages, succeeding one another. The general approximate and particular exact solutions of the problems describing the fluid motion not only in the layer of a filtering material, but also in supply and offtake communications were found. The accuracy of all obtained approximate solutions was estimated.

The detailed technological analysis was based on two (first variety) or three (second variety) criteria of the clarification efficiency by filtration, the meeting of which guarantees the high quality of filtrate and economical operation of the facility. The hydraulic criterion (1.36) was no longer necessary. Instead of it the criterion was used, which provides control over the filter performance and prevents its excessive