OZONATION AND BIOFILTRATION IN WATER TREATMENT

Operational status and optimization issues

Introduction

In drinking water treatment, biofilters may be used alone for the treatment of polluted surface water. In most cases however, they are used in combination with ozonation. Ozonation are used for multiple purposes including disinfection, colour removal, odour and taste removal, iron and manganese oxidation, removal of micro pollutants, disinfection by-product control, and aid for coagulation. In these applications, ozone reacts with natural organic matter (NOM) and converts part of it into biodegradable organic matter (BOM). The aim of the biofilter is to remove this fraction of BOM as well as the background BOM present in raw water. There are no regulatory limits for the amount of BOM in drinking water and the design and operation of the biofilters may therefore be arbitrary. The largest water companies can afford extensive pilot testing while smaller plants are often designed on the basis of experience or rules of thumb. Since biofiltration is a seemingly simple process, little thought is usually given for operational issues once the biofilters are in place. The microbial processes taking place in the filters are, however, extremely complicated. The environment is extreme for microbial growth including low substrate and nutrient concentrations, sometimes very low temperatures, complicated substrate interactions, etc. Therefore it is likely that in many plants, the biofiltration process is not well understood and the operation may not be optimal.

Importance

Especially in Europe, there has been a trend towards avoidance of chlorination or use of reduced chlorine doses to avoid formation of chlorinated disinfection by-products and taste and odor problems. The required treatment barriers can be achieved by using alternative disinfectants like ozon and UV, or by extensive water treatment. As a result, many water works do not have residual disinfectant in their distribution network. Bacterial growth during distribution can be prevented by employing treatment processes that produce a biologically stable water quality. To achieve this, biofiltration is often used, at least as part of the process train. To prevent excessive microbial growth in water, optimal operation of biofiltration systems is of primary importance.

Approach

This report is based on review of literature published on biofiltration, mostly pilot- and full-scale studies. The report deals mostly with the application of biofilters for the removal of natural organic matter (NOM). Since the process is often used in combination with ozonation and these two processes are interlinked, some aspects of ozonation characteristics, especially formation of biodegradable organic matter, are included. The report concentrates on rapid biofiltration processes. Other drinking water processes that are classified as biological, like slow sand filtration and artificial ground water recharge, are not discussed.

Results

BOM contains large amounts of various organic compounds, most of which are not yet identified. In simple terms it can be divided into "fast" and "slow" BOM depending on biodegradation rates. Review of removal efficiencies in biofilters show that they are not able to achieve complete removal of BOM. Probably they are able to remove the "fast" fraction of BOM only. One of the challenges of biofilter operation is to achieve good removal also of the "slow" BOM. Raw water quality, ozone dose and seasonal changes of NOM may affect this. One strategy is adjustment of ozone dose, since it has a major impact on the types of BOM formed. Doing this without compromising other ozonation objectives like disinfection may require careful optimization.

One of the major problems in biofilter operation is that there are no available methods for rapid analysis of the major parameter – biodegradable organic matter. The analytical methods for direct measuring of BOM are typically time consuming taking from days to weeks before result is ready. Many of them are expensive and require analytical experience which is not available in many (smaller) waterworks. Thus they cannot be used for process control. There is therefore a need for rapid and simple methods which could allow measurements of changing BOM concentrations in biofilter feed and/or effluents. Biofiltration models have potential to be of great help in biofilter operation and several models have been developed. Mechanistic models can usually accurately predict the biofilter performance, but the amount of required parameters is high (usually around 10-20). These are typically site specific and calibration of the models requires intensive scientific investigations. Empirical models are simpler and much easier to use and calibrate, but they may not be able to predict accurately such a complicated process as microbial community in biofilters when the operational conditions are changed. There is a need for finding a compromise between these approaches.

One operational parameter which is easiest to control is backwash strategy. The purpose of the backwash is to remove accumulated particles and excess biofilm. The different studies agree that backwash with chlorinated water impairs biofilter performance. Otherwise different methods do not seem to decrease BOM removal efficiencies significantly but may affect ripening time, turbidity removal, etc. Most treatment plants seem to backwash on regular time intervals. This may cause excessive shear of biofilm and media or accumulation of particles which may cause diffusion limitation of substrates into biofilm.

Other factors which may influence biofilter performance, but are not very well studied and therefore poorly understood, include limiting phosphorus concentrations, oxygen supersaturation after ozonation, role and control of invertebrates, and control of the amount of microorganisms in the biofilter effluent.

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