USING OF NANOFIBER FILTER FOR AIR FILTRATION IN WATER SUPPLY FACILITIES

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Abstract

The air is a medium that is commonly used for various water treatment methods or it is in very close touch with treated water. Untreated air can content significant amount of pollutants. Contact of polluted air with treated water causes interactions of both media which results in water contamination.

Nanofiber filter has numerous prerequisites for high quality and efficiency of air treatment. Testing of nanofiber filter efficiency, analyses of proper filter type for different air filtration purposes and measure of disinfection effects was researched and compared with commonly used filter. Functionality of the filters was verified on prototype unit.

The test of passive contamination corresponded to interaction in water tanks. Physical parameters such as velocity, flow, temperature and pressure difference of the filters were measured for the test. Also microbiological samples of examined filters, filtrated air and saturated water were evaluated. Analyses of measured values confirmed effectiveness of nanofiber filters in air treatment and determined advantages and borders of their application.

Key words:

Nanofiber filter, air treatment, water supply facilities

1. INTRODUCTION

The air is a medium which is commonly used for water treatment. It is applied for radon, iron and manganese removal systems, deacidification and also other treatment processes. These processes take advance of bringing the air amount against water falling stream. [1] It means that air is a tool for water treatment and influence a quality of treated water. If the air is contaminated and no measures are implemented (i.e. filtration), pollutants are entering the system and can be brought to accumulation tanks or water supply system. This process of contaminant transfer is called active contamination. It occurs during water treatment processes. [2]

Other type of contaminant transfer appears in water storages during ventilation. If ventilation system is not protected by efficient filter, pervaded air get to a contact with treated water which can be subsequently contaminated. This process is called passive contamination. The air can be medium which brings animal and vegetable parts and residues. These residues do not have to be injurious to health but it can be used as transport base or a substrate for reproduction of spores and microorganisms. [3]

Revival of microorganism cells is manifested by growth of biomass structure on the walls of basins and transport pipeline. Higher frequency of washing the basins is needed then. Other effect of aeration is also disruption of carbon dioxide equilibrium. Calcium carbonate is precipitated and influence frequency of sludge removal. [1]

Rate of air contamination is highly influenced by surrounding environment of water supply facility, i.e. according to the research of Rihova the vicinity of frequented roads, agriculture facilities and also pasture influence the occurrence of air contaminants. [3]

Nanofiber materials have been developed in last decades. Filters made of nanofiber aim to be effective solution for protection of water supply facilities. The motivation of this research is to verify possible application of these filters.

The article aims to knowledge enhancement of air filtration and evaluation of its influence on environment in water supply facilities through pilot unit realization. The unit enables to examine and evaluate hypothesis that are related to the decrease of microbial loads and to the catching of contaminants with higher effectiveness than by means of currently used filters.

The article is focused on passive contamination topic. The main aim is to verify positive influence of filtration by means of nanofiber filters in environment of water supply facilities.

2. EXPERIMENTAL

Experimental part is focused on comparison of results achieved during tests by means of pilot unit. It is compared the difference between nanofiber filter and commonly used filter. The filters are put into the pilot unit and tested under the same methodology. Samples are taken and results are compared.

2.1 Characteristics of nanofiber filter

Nanofiber filters provide marked increase in filtration efficiency at relatively small decreases in permeability. The filters have both important properties – small diameter of fibres and big amount of small pores. Particular pore has very small dimension. But total sum of air volume is big due to high pore concentration. This means that the rate of caught contaminants is higher while airflow losses are lower. [4]

Filters used for testing are products of company SPUR a.s. Filters are processed by electrospinning when solution of polymer goes through electric field and is affected by high voltage system. Completed nanofibers are collected in a collector.

Used filters are multi-layered. Nanofiber layers are always placed in the middle layer.

Fig. 1 The composition of nanofiber filter (left) and microscopic picture of nanofiber layer (right)

The tests were performed with two types of nanofiber filters to compare effectiveness and suitability for water supply facilities. Their structures are similar but different materials are used for nanofiber layers. The most important parameters of filters are summarized in Table 1. The other criteria for filter choice were high rate of caught contaminants and low airflow losses. Both nanofiber filters were fixed in the frame only in one layer – no multilayering was used.

2.2 Characteristic of commonly used filter

Currently, the ventilation of water supply facilities is protected by standard non-woven textiles. It was chosen non-woven textile of producer after discussion with water supply providers. It is used as comparative equivalent to nanofiber filters. Properties of the textile are summarized in Table 1. The textile was fixed in the frame and folded up – 8 layers of filter were fixed in the frame.

2.3 Methodology of testing

Testing was performed with using of pilot unit which was placed outdoor. Two fans connected in series were sucking the air which went through the filter. The filters were fixed in plastic frame of dimensions 400 x 400 mm. The outlet of the unit was directed to outside environment. The test is simulating the air flow in ventilation system.

Flow velocity, temperature, humidity and pressure difference before and after filter were continuously measured for each test. Data were recorded and average value was calculated.

Every test took 20 minutes. Three samples of deposited air pollutants were taken after each 20 minutes. The samples were taken before filter, after filter and outside the pilot unit. 20-minute cycle was repeated three times. Then the filter was taken out and 4 samples were withdrawn. These samples were sent to microbiological analysis – for elution test.

The testing was divided to 2 phases due to time demands. The first phase was named Attempt 1 and nanofiber filter 1, commonly used filter and pilot unit without filter were tested. The second phase was called Attempt 2 and nanofiber filter 2, commonly used filter and pilot unit without filter were tested. Both fans were set on maximum operating power that is ca. 800 m^3/h for one piece (without any losses on a filter).

2.4 Sampling methodology

2.4.1 Deposition of air pollutants

Pollutants entering the pilot unit were caught in sterile Petri´s plated during the testing. Time of exposition was always 20 minutes. The plates were equipped with culture medium Plate Count Agar (PCA, Biokar Diagnostics, France). The plates were incubated in thermostat under temperature 22 °C for 72 hours. The amount of colony forming unit (CFU) was found after the end of incubation.

The level of contamination was evaluated for total amount of microorganisms and for amount of moulds. The methodology of measurement was based on official announcement of Ministry of Health Care, Act No. 6/2003 Coll. where hygienic limits of chemical, physical and biological indicators were set for indoor environment of some buildings. [5]

2.4.2 Elution test of filters

Samples of filters were put into sterile cover. The square size of every sample was 25 cm^2 (50 x 50 mm). These samples were used for leachate preparation. The sample was dipped in 50 ml of sterile physiologic solution. The mixture is shaken for 2 minutes in homogenizer (type STOMACHER). The volume of 1 ml was taken to Petri´s plate and poured with sterile nutrient solution.

These two groups of microorganisms are evaluated:

- Total count of microorganisms (CPM) in medium of agar PCA (Biokar Diabnostics, Francie) under temperature 22 °C in 72 hours.
- Count of microfungi (moulds and yeasts) in medium of agar Chloramphenicol Glucose Agar (Biokar Diabnostics, Francie) under temperature 25 °C in 120 hours.

The amounts of colony forming units were counted after incubation. The results were correlated to area of filter sample (25 cm^2).

2.5 Pilot unit

Pilot unit is designed for testing filter properties and their effectiveness. The unit is equipped with measurement equipment for monitoring characteristic indicators of environment – airflow velocity, pressure difference before and after filter, temperature. All sensors are placed in main filtration chamber. The scheme of the unit is described in Fig. 2, left part.

Fig. 2 Pilot unit – scheme (left) and realization (middle, right)

2.6 Testing results and discussion

The results of air pollutant deposition are summarized in Fig. 3 for Attempt 1 and Fig. 4 for Attempt 2. The amount of particles caught before nanofiber filters and commonly used filters is similar. But the filters differ in amount of particles caught after filter. The rates of total microorganisms are in size of CFU units for both nanofiber filters while the same number for commonly used filter is in range of 24 – 50 CFU. The effectiveness of air pollutant deposition is very significant and corresponds to findings of Barhate. [6]. The difference of deposited total microorganisms between nanofiber filter 1 and commonly used filter is 75 %, or 65 % for nanofiber filter 2. These results correspond also to findings of Sundarrajan [7] who described separation of airborne bacterial contaminates and volatile organic compounds nanofiber filter

Various pollutants are transported by the air. Unprotected facility is contaminated as it was defined in the article of Rihova. [5] The amount of caught microorganisms significantly and irregularly raised in application without filter. The increase was reported only for Attempt 2. Possible reason is a consequence of actual concentration of pollutant in the environment.

All samples are measured as time dependant values. Number of pollutant caught before nanofiber filter corresponds to commonly used filter (55 CFU vs. 56 CFU) for Attempt 1 while airflow differs 4 times (215 m^3/h vs. 869 m^3/h). The same ratio is different for Attempt 2 (28 CFU vs. 36 CFU) where average airflow differs also 4 times (227 m^3/h vs. 905 m^3/h). The hypothesis of more caught pollutants during higher airflow could not been proved – the differences are not significant.

The air flow is strongly dependant on resistance of filters. It is significant for nanofiber filters where resistance (ca. 12 mbar) and lowest airflow (ca. 220 m^3/h) were measured. The application without any filter is characterised with the highest air flow (1667 m^3/h).

Elution tests of filters showed strong dependence on choice of sample intake place. The differences are in wide range for nanofiber filters and also for commonly used filter. It varied also for commonly used filter in Attempt 1 and Attempt 2. The reason for such differences could be actual weather state where various types of microorganisms are presented in the air. This effect can be observed in amount of yields whose measured amount in Attempt 1 significantly surpassed the amount in Attempt 2, for commonly used filter (45748 CFU vs. 1693 CFU) and partly also for nanofiber filters (41760 CFU vs. 26287 CFU).

Generally, it can be noted that amount of particles caught by nanofiber filter is demonstrably equal or higher to commonly used filter for all measured microbiological indicators.

Table 1 Summary of filter characteristic and results

Attribute	Nanofiber filter 1	Nanofiber filter 2	Commonly used filter		No filter application
			Attempt 1	Attempt 2	
Name of the filter (producer)	PL1023+PL1082 (SPUR)	PL 624+PL626 (SPUR)	PP- textile (Producer A)		-
Number of layers inside the filter	4	4	1		-
Type of upper cover layer	PP SB (30 g/m^2)	PP SB (30 g/m^2)	PP (17 g/m^2)		-
Type of upper nanofiber layer	nNT PVDF_HFB (0,3 g/m^2)	nNT PU-SAN (0,45 g/m^2)	-		-
Type of lower nanofiber layer	nNT PU 918 (0,2 g/m^2)	nNT PU-SAN (0,45g/m^2)	-		-
Type of lower cover layer	VS SB (30 g/m^2)	VS SB (30 g/m^2)	-		-
Layers in frame	1	1	8		-
Difference pressure (max. vent. power)	11.8 mbar	12.1 mbar	7.2 mbar	7.4 mbar	0.1 mbar
Average flow (max. ventilation power)	215 m^3/h	227 m^3/h	869 m^3/h	905 m^3/h	1667 m^3/h
Average deposition – before filter	55 CFU (CPM_{22})	28 CFU (CPM_{22})	56 CFU (CPM_{22})	36 CFU (CPM_{22})	72 CFU/128 CFU (CPM_{22})
Average deposition – after filter	9 CFU (CPM_{22})	3 CFU (CPM_{22})	51 CFU (CPM_{22})	28 CFU (CPM_{22})	-
Average efficiency - deposition	**84 %**	**89 %**	**9 %**	**22 %**	-
Aver. filter extraction - microorganism	5034.3 CFU/50 ml	1283.5 CFU/50ml	10448.5 CFU/50 ml	98.8 CFU/50 ml	-
Average filter extraction - moulds	223.3 CFU/50 ml	2579.8 CFU/50ml	168.8 CFU/50 ml	1340.8 CFU/50 ml	-
Average filter extraction - yeast	41760.0 CFU/50 ml	26287.0 CFU/50 ml	45748.0 CFU/50 ml	1693.8 CFU/50 ml	-

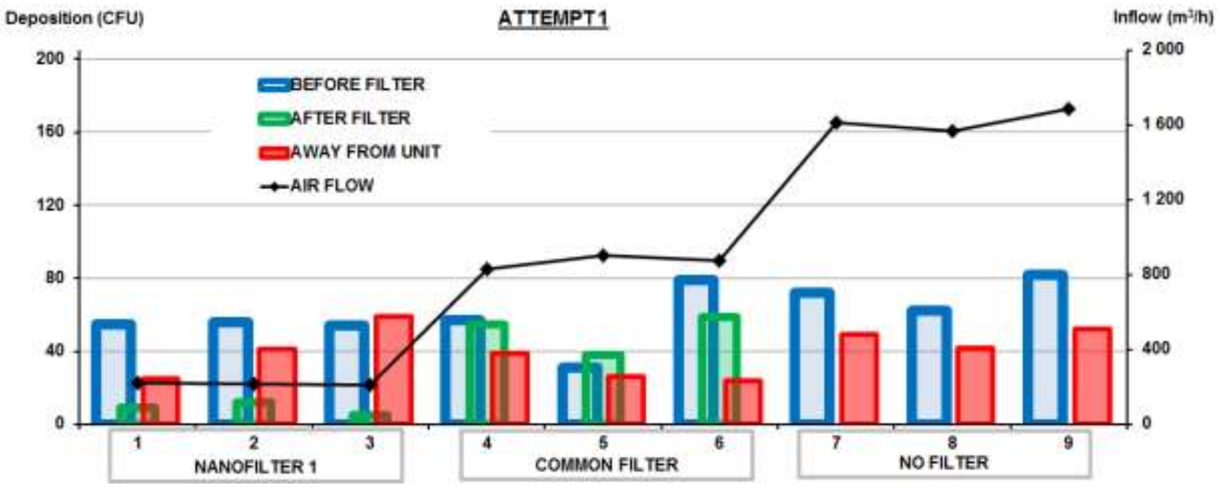

Fig. 3 Attempt 1 – deposition results

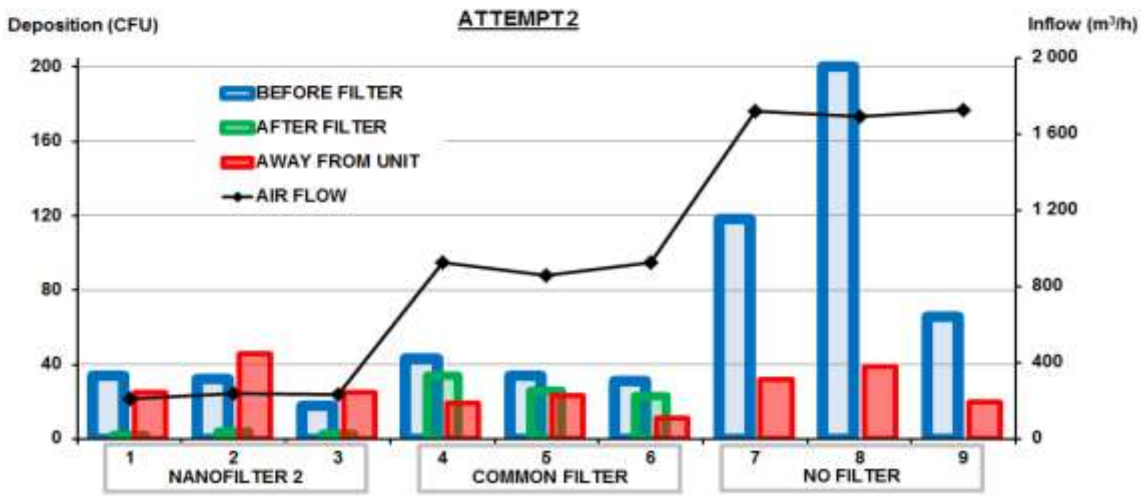

Fig. 4 Attempt 2 – deposition results

3. CONCLUSIONS

Nanofiber filters are applicable for protection of water supply facilities. They proved higher efficiency during the pilot testing in comparison with commonly used filters. Different types of nanofiber filter material did not have an effect on efficiency of air treatment which was similar. Higher resistance of nanofiber filter does not have to be taken into consideration due to future passive using of the filter and no energy requirements. Nevertheless a verification of the effectivity in long-term view under changing external and the confirmation of filter´s effectivity in real environment of operating water supply facility is needed.

Next phase of a research should be focused on deeper review of effectiveness of nanofiber filters with lower resistance. This resistance should be closer to commonly used filter. Also a research of active contamination application is needed to establish applicability of nanofiber filter for this part of air treatment processes.

4. ACKNOWLEDGEMENT

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