THE INFLUENCE OF THE SIZE DISTRIBUTION AND PARTICLE PROPERTIES ON THE FILTRATION PERFORMANCES IN TECHNICAL WATER

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Abstract

When analyzing the experimental data related to technical water quality, the most commonly is used method for determination of particle size distribution. It is needed, also, to derive an adequate approach which can describe model under the study. In order to design adequate filter system, information's about the particle size distribution are crucial. This paper presents results of examining the size distribution of solid contaminants found in technical cooling water, and influence of particles properties on filtration performances.

Keywords: Particles distribution, filtration, technical water, granulometric composition.

1. Introduction

Water which is used for industrial purposes has the main place in production, although role of water in cooling and heating system, and usage of water for removal of excess heat, or heating up by using steam should not be left out. Water sources from which water is supplied are mostly not satisfying required quality for direct usage in industrial application. Because of that, it is necessary to treat water in different ways in order to achieve the set quality requirements which correspond to different application for later utilization in the process.

Preparation and treatment of industrial water begins with purification. On the first place filters need to be free of solids found in the water, after which commonly, by using the chemicals are treated solved matters in water. List of chemicals which are used in these kinds of treatments is long, and mostly are used mixtures of different chemicals, not just one. [1] Water used in production as part of the product is necessary to be suitable for technical use and that is fulfilling demands required for the end product. If water is, for example, used in production of chemicals where water is base product, it is demanded that water is clean and without possibility to find dirtiness in final product. In production in pharmacy, solutions which will later be used as drugs for humans and animals, should have only active substances, and must not be contaminated with other ingredients. Technical water in factory for manufacture of tires, which is used as cooling medium, is considered in paper [2].

When talking about water which is used for cooling or heating (utility water), requirements for purity are not very high, but treatment is necessary. With treating this kind of water, goal is to decrease and avoid technical problems which can occur in a cooling water system, or a heating loop. [3] Possible contamination of utility water is formation of biofilm, biofouling and growth of algae, on the first place if cooling systems are open. Microorganisms are spreading in water and forming biofilm on pipes and in machines, which is affecting heat transfer in system, or it may even clog it. Industries which are dealing with heat-transfer equipment are facing problems with economic loss, due to appearance of fouling. Ensuring the anti-fouling technology on the surfaces of heat exchange systems is of great importance, in order to use effectively energy and reduce production of carbon dioxide. [4] That degree of water contamination is determined with indicators of contamination, and it represents concentration of the substance in milligram per 1 dm^3 of water.

Feed of the water in manufacturing process is constantly composed of particles in different sizes (size distribution), and regarding to the smallest particles in the distribution, many aspects of filtration cycle is controlled. These smallest particles are easily passing through filter material in the beginning stages of filtration, they are accumulating in cake layers nearest to the filter material, and they most intensively interact with ions and other substances, creating the compressibility effect. These particles also affect the most surface and specific resistance of filter cake. When observing the distribution of particles, significant particles for characterization of filtration are rarely the ones which are 50% f size. Filtration is usually controlled by finer particles in the distribution, because even small increase in the number of finer particles can reduce filtration rates. [5]

2. Method

Particles are defined as "any relatively small subdivision of matter, ranging in diameter from a few Angstroms to a few millimeters". Composition and consistence of particles can be very different, concerning the fact that particles can have different shape, may be isotropic or anisotropic, also particles can be molecularly homogenous or inhomogeneous, or composed of organic or inorganic molecules, or they can be suspended in versatile media. Devices

which are measuring sizes of particles are under the influence of various parameters, i.e. homogeneity, shape of particles, state, molecular structure, isotropy, or medium in which particles are suspended. [6]

In this research was examined water from the well in municipality Novi Beograd, which is used for heating and cooling in system of heat pump. Raw well water was filtered with 30 μm filter (Profimat, Judo Wasseraufberaitung GmbH, Germany) (figure 1).

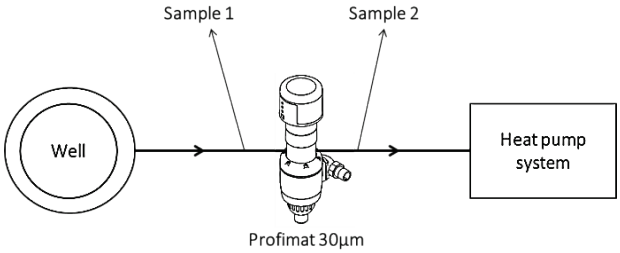

Figure 1. Installment for pumping and filtration of well water showing where samples were taken.

It was noticed that fouling formed on the heat exchangers which are placed in system of heating and cooling, with which is decreased efficiency of system functioning (figure 2).

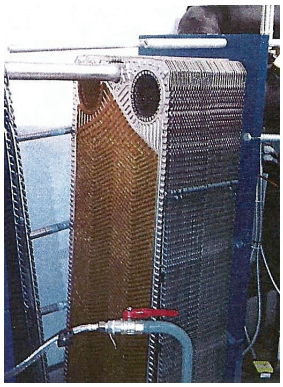

Figure 2. Contaminated heat-exchanger.

Observed process takes place at constant pressure which is meant by type of filtration process. Defining of complete filtration process comprise analysis of media which should be filtered, defining the operation conditions, determination of filtration steps, and filter constructions.

Research comprised examination of water and examination of contaminants in water. For both samples were done physical-chemical examinations of water and granulometric composition of solid particles in ware.

Granulometric composition represents an important characteristic of structure and physical properties of natural and artificial material. It represents the content of granules of different sizes in artificial product, rock, or soil, expressed in percentage of the bulk, or the quantity of granules of examined sample. Data of granulometric composition are not generally classified because of different purposes of examination and different objects for which it should be done.

Samples for testing of Granulometric composition were taken before and after the filter. Technique of granulometric examination of particles firmness in water consisted of sieving on places with retention grade of 125 μm and 63 μm. On that manner are obtained fractions of particles in range of < 63 μm, 63-125 μm and >125 μm. Fraction in range of 0-5 μm was obtained with pipette method.

Granulometric composition of the material from filter is determined with standard laboratory method of sedimentation for fine-grained particles smaller than 0,075 mm, according to SRPS U.B1.018: 2005. Specific weight of the material was determined with standard laboratory method with picometer, according to SRPS U.B1.014:1988.

3. Results

Observed medium, well water, with all its characteristics interacts with already implemented filter, and dependent of characteristics of filter material, there is possibility of filters effect on water.

Standard physical-chemical examination of samples is shown in table 1.

Table 1. Granulometric composition - Material washed out from the filter of 5 microns.

Sample	Unit of	Sample 1	Sample
Electrolytic	μS/cm	870	857
Chlorides	mg/l	24,09	24,14
Sulphates	mg/l	32,17	30,32
Total hardness	mg $CaCO_3$/l	372,2	374,9
Suspended	mg/l	<1	<1
Calcium	mg/l	57,46	61,59
Magnesia	mg/l	55,54	53,70
Iron	mg/l	0,32	1,47
Manganese	mg/l	0,046	0,016
Zink	μg/l	20,1	30,6
Copper	μg/l	<2	<2
Lead	μg/l	<2	<2
Nickel	μg/l	23,8	20,4
Cadmium	μg/l	<0,8	<0,8
Arsenic	μg/l	<20	<20
Mercury	μg/l	<1	<1

It is noticed that iron increased in water in Sample 2 (after filter) which can lead to forming of ferruginous bacteria's, which are very damaging for this kind of closed system.

Specific weight of the material is 3,25, which is not usual for natural ground (value for natural ground is 2,60-2,80). This imply that content of metal (iron or manganese) is increased.

Examined granulometric compositions of hardness of constituents in water before filter have shown that noticed fractions in observed sample are distributed as it is shown on image 3.

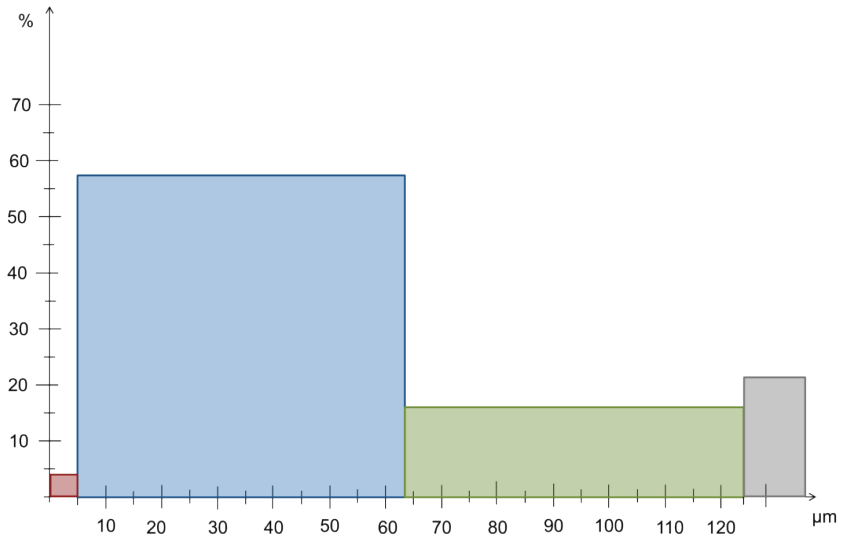

Figure 3. Granulometric composition of hardness of constituents in water.

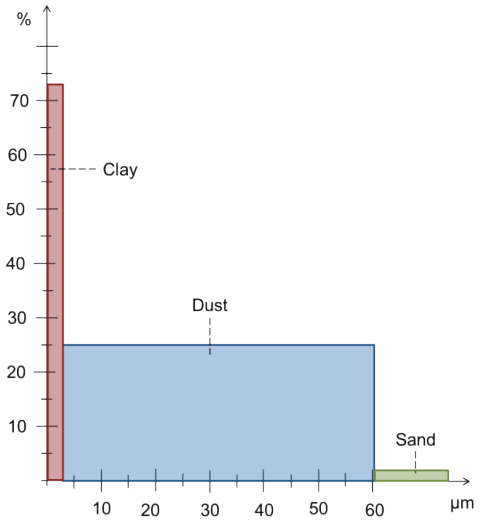

Figure 4. Illustration showing presence of classes in the sample of residue from heat exchanger cover.

Granulometric composition of solid constituents after filters show merely 90% of particles which are smaller than 5 μm. Results of these granulometric examinations by functions < 2 μm, 2-60 μm and > 60 μm are shown in figure 4.

Determination of distribution of particles in fraction 0-5 μm was done by morphologic method. Technique of membrane filtration was used with usage of disc filter membranes, diameter 47 mm and retention rate 0,45 μm (*PALL Versapor, PALL, USA*). Particles extracted on the membrane are digitalized under electron microscope. Particle sizes and number of particles in considered water are measured by digital image analysis technique which is incorporated in the program ImageJ (*National Institutes of Health (NIH), Bethesda, Maryland, USA*).

Results of distribution of particles in technical water before and after filter, obtained on this manner are shown on images 5 and 6.

Distributions of particles before and after filter of 30 μm are showing significant resemblance in the 30 μm distribution. This is result of the fact that nominal filter of 30 μm was not able to play a role of significant barrier for particles whose sizes are in range of 0-5 μm. It is also noticed unexpected increase in quantity of particles sizes 0,6-0,8 μm after the filter.

Observed system with one step constant pressure nominal filtration process represent characteristic incomplete pilot equipment. Technical water in system with heath pump must have certain characteristics which enable reliable function of system. Achieving these characteristics means insertion of one additional filtration step behind existing filter. In case when that is one filtration step, that would be filter whose filter elements have retention rate which covers class of particles concentrated around the value of 1,5 μm. Choice of this additional filtration step most satisfy conditions recommended for filtration practice which enable robust liquid filter process.

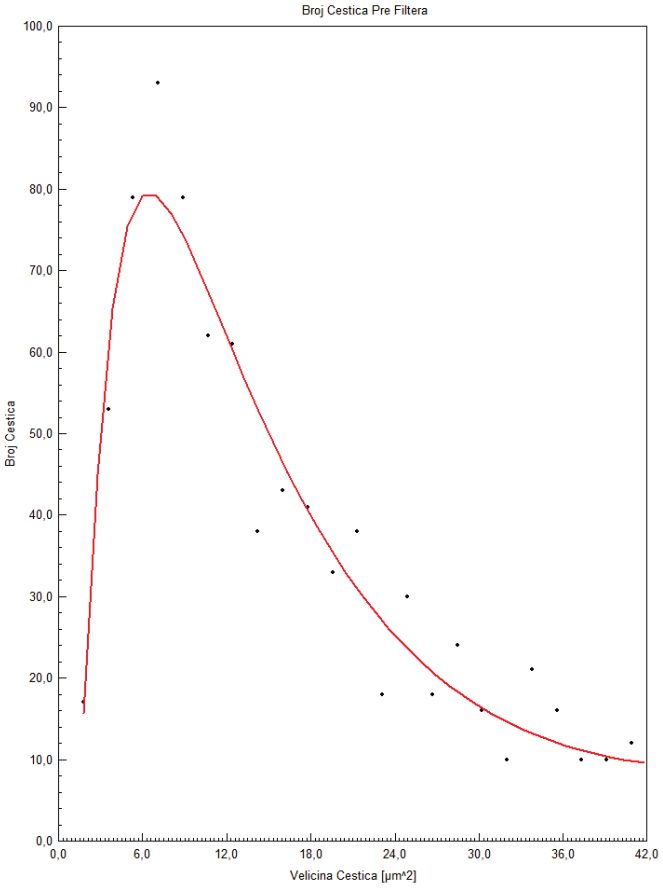

Figure 5. Number of particles before filter - fitted curve.

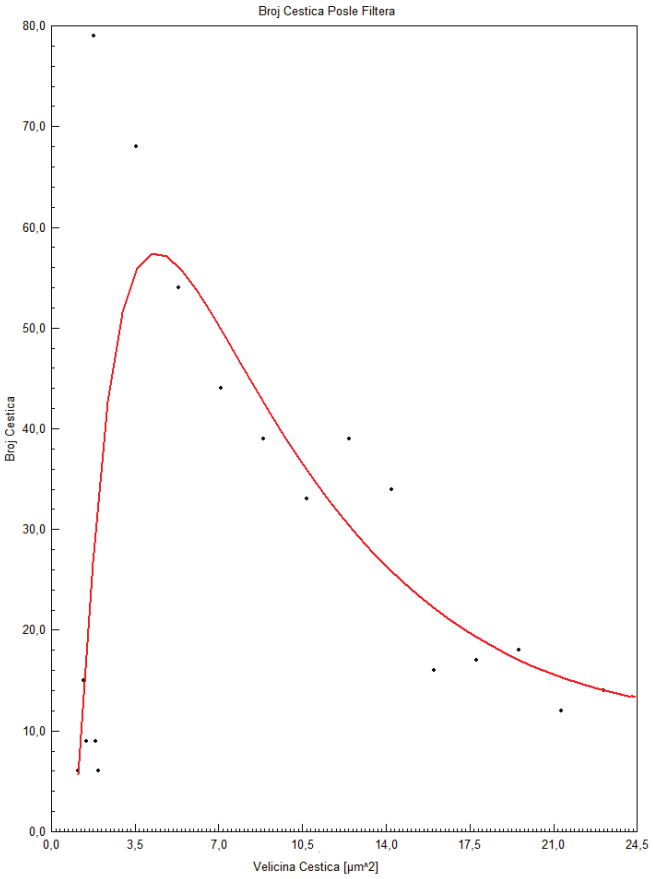

Figure 6. Number of particles after filter - fitted curve.

4. Conclusion

Particle size distribution has a significant influence on constitutive properties of the filter material and filter performances. Because of that, the main reason for measuring the sizes of particles is to predict behavior of filter material in a separation process and to specify the performance of a filter medium in terms of its ability to retain particles of different sizes.

Anyhow, raw experimental data on the size distribution are not suitable enough for a sophisticated analysis and design of contemporary highly efficient filtration systems and their components.

5. References

[1] Jaisinghani J. „Merus Oil & Gas Ltd – Water Treatment“ - Project Report, International MBA in Specialization in „Project Management“, Jero Education, Mumbai, 2014.

[2] Golubovic ZDj, Petrovic D, Golubovic ZZ, Tasic S, Milosavljevic M. The Size Distribution of Solid Particles in a Technical Water, 28th Danubia-Adria Symposium on Advances in Experimental Mechanics, Siofok, Hungary, 28 September-01 October 2011, p. 131-132. ISBN: 978-963-9058-32-3.

[3] http://www.merusonline.com/in-general/watertreatment

[4] Sun-Kyung Sung, Sang-Ho Suh, Dong-Woo Kim. Characteristics of cooling water fouling in a heat exchange system. ournal of Mechanical Science and Technology 22 (2008) p.1568-1575.

[5] Richard Wakeman. The influence of particle properties on filtration. Separation and Purification Technology 58 (2007) 234–241

[6] Paul A. Webb. Interpretation of Particle Size Reported by Different Analytical Techniques, Micromeritics Instrument Corp.

[7] http://www.thefreedictionary.com/