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IMPACT OF THE DIFFERENT ACTIVE FILLING HEIGHT OF THE FILTER ON THE SORPTIVE CHARACTERISTICS OF FILTERING

MARINA ILIĆ
Military Technical Institute, Belgrade, marinailic1970@gmail.com

TATJANA MARKOVIĆ
Military Technical Institute, Belgrade, tanjin.mejl.@gmail.com

BILJANA MIHAJLOVIĆ
TRAYAL Corporation, Kruševac, aktivni.ugljevi@gmail.com

VUKICA GRKOVIĆ
TRAYAL CorporaTion, Kruševac, vukica.g30@gmail.com

SONJA BAUK
Military Technical Institute, Belgrade, bauk.sonja@gmail.com

Abstract: *This paper presents, in accordance with the defined requirements of the SRPS 8748 and SRPS EN14387 standards, the impact of the filter different active filling height, with activated carbon impregnated with the salts of* Cu^{2+}*,* Ag^{+} *and* Zn^{2+} *instead of* Cr^{6+} *salt, on the filter sorptive characteristics. This work also investigates the sorptive characteristics of filters with the different active filling height, upon phosgene, chloropicrin, hydrogen cyanide, ammonia, sulphur dioxide, cyclohexane and carbon monoxide challenge at different testing conditions of concentrations and flow rates of the inlet gas mixture.*

Keywords: *active filling height, filters, sorptive characteristics of the filters and the efficiency of filtering.*

1. INTRODUCTION

The Combined filter is a filtering device for respiratory protection which, together with the protective mask, makes up a complex device for the protection of eyes, face and respiratory organs against CBRN contamination in the form of gases, vapours, solid and liquid particles of aerosols.

The Combined filter can be used for the protection against the following contaminants:

- for dust, areosols and smoke (anti aerosol filter),
- for vapours and gases (anti vapour filter),

in the way that the removal of the harmful substances is performed by mechanism of filtration or sorption.

The latest world trends, more frequent terrorist attacks or other potential forms of diversions, as well as accidents at the industrial plants, impose new requirements for the human protection.

Many toxic industrial chemicals used for the industrial purposes, due to their availability and low cost on the world market, can be used nowadays as chemical agents for causing the general threat to the people, with short-term effects or longterm effects.[1]

Consequently, besides providing the CBRN protection against clearly defined chemical warfare, the Combined filter also serves to protect from toxic chemicals and industrial gases, especially from ammonia, sulphur dioxide, cyclohexane, carbon monoxide and hydrogen cyanide.

On the other hand, the requirements for the environmental protection bring restrictions regarding the use of chemicals being used for the impregnation of activated carbon in the filter. For this reason, the salts of six valent atom chrome are not used in many countries of Europe and worldwide due to their toxicity for humans and for the environment.[3]

For this reason, this work emphasizes the change of the texture (activate carbon impregnated with the salts of Cu^{2+}, Ag^{+} and Zn^{2+} instead of Cr^{6+}salt), as well as impact of the anti vapour active filling height, for the purpose of testing the sorptive properties of the filters against:

- Contaminants from the group of CBRN contaminants,
- Toxic industrial chemicals that can be used as contaminants.

Since the Filter M3 is official CBRN protection equipment of Serbian Armed Forces, experimental results for sorptive properties of the Filter M4 (changed impregnation and active filling height of 27 mm, 32 mm and 39 mm) are compared with the Filter M3 sorptive properties (standard impregnation and filling height of 27 mm).

The process of impregnation of the activated carbon is conducted in accordance with precisely defined parameters and conditions of application of impregnation compounds, and it is strictly monitored in each stage of the production, according to the prescribed monitoring procedures. After the thermal processing, the impregnated carbon is sifted to be dust-free and brought to quality in accordance with prescribed technical characteristics.[2]

The two batches of the impregnated activated carbon have been produced. The batch of the activated carbon impregnated with the salts of Cu^{2+}, $Ag^{+}$and Cr^{6+}, according to the standard recipe for making of Filter M3, and the batch of the activated carbon impregnated with the salts of Cu^{2+}, $Ag^{+}$and Zn^{2+}, instead of Cr^{6+}salt according to the altered recipe for the Filter M4. All the filters used for the purpose of testing the sorptive properties, are filled with batches of the impregnated activated carbon of both standard and altered impregnation.

2. EXPERIMENTAL PART

Testing the sorptive properties of the Filter M3 and Filter M4 are in accordance to two standards: SORS 8748 and SRPS EN 14387

2.1. Testing methods for the time of sorption properties for the Filter M3 and the FilterM4 with different active filling height, upon phosgene, chloropicrin and hydrogen cyanide challenge, according to the SORS 8748

2.1.1. Principle

The principle of the method consists of the monitoring and comparative analysis of the time of sorption properties of the Filter M3 (with standard impregnation and active filling height of 27mm) and the Filter M4 (with altered impregnation and filling height of 27 mm, 32 mm and 39 mm) upon phosgene, chloropicrin and hydrogen cyanide challenge at testing conditions of different concentrations, relative humidity and flow rates of the inlet gas mixture.

2.1.2. The activities sequence of methods for testing the time of sorption properties of the Filter M3 and the Filter M4 with different active filling height upon phosgene challenge.

The flow of the mixture of air and phosgene gas is to be set until the preset inlet concentration and relative humidity of gas mixture has been reached. The time is to be measured from the moment of introduction of the air and phosgene mixture into the filter till the change in colour of the indicator paper. The measured time indicates the protection time of the filter against phosgene.[4]

2.1.3. The activities sequence of methods for testing the time of sorption properties of the Filter M3 and the Filter M4 with different active filling height upon chloropicrin challenge.

The flow of the mixture of air and chloropicrin gas to be set until the preset inlet concentration and relative humidity of gas mixture has been reached. The time is to be measured from the moment of introduction of the air and chloropicrin mixture into the filter, till the change in colour of the indicator paper.

The measured time indicates the protection time of the filter against chloropicrin.[4]

2.1.4. The activities sequence of methods for testing of the sorption properties time of the Filter M3 and the Filter M4 with different active filling height upon hydrogen cyanide challenge

The flow of the mixture of air and hydrogen cyanide gas to be set until the preset inlet concentration and relative humidity of gas mixture has been reached. In this case the the sample of Filters M3 is not wetted to a constant mass.

The time is to be measured from the moment of introduction of the air and hydrogen cyanide mixture into the filter till the change in colour of the indicator paper.

The measured time indicates the protection time of the filter against hydrogen cyanide.[4]

2.2. Testing methods for the time of sorption properties of the Filter M3 and the Filter M4 with different active filling height upon ammonia, sulphur dioxide, cyclohexane and carbon monoxide gas challenge, according to the SRPS EN 14387

2.2.1. Principle

The principle of the method consists of the monitoring and comparative analysis for the time of sorption properties of the Filter M3 (with standard impregnation and active filling height of 27mm) and of the Filter M4 (with altered impregnation and filling height of 27 mm, 32 mm and 39 mm) upon three test gases from the group toxic chemical, ammonia, sulphur dioxide, cyclohexane and carbon monoxide gas challenge, at testing conditions of different flows, constant concentrations and relative humidity of the inlet gas mixture.

2.2.2. The activities sequence of methods for testing of the time of sorption properties of the Filter M3 and the Filter M4, different active filling height upon ammonia challenge.

The flow of the mixture of air and ammonia gas to be set until the preset inlet concentration and relative humidity of gas mixture has been reached. The time is to be measured from the moment of introduction of the air and ammonia mixture into the filter till the change in colour of the indicator paper.

The time that has been measured indicates the protection time of the filter against ammonia.[5]

2.2.3. The activities sequence of methods for testing the sorption properties time of the Filter M3 and the Filter M4 with different active filling height, upon sulphur dioxide challenge

The flow ofthe mixture of air and sulphur dioxide gas to be set until the preset inlet concentration and relative humidity of gas mixture has been reached. The time is to be measured from the moment of introduction of the air and sulphur dioxide mixture into the filter till the change in colour of the indicator solution.The time that has been measured indicates the protection time of the filter against sulphur dioxide.[5]

2.2.4. The activities sequence of methods for the time of sorption properties testing of the Filter M3 and the Filter M4 with different active filling height upon cyclohexane challenge

The flow of the mixture of air and cyclohexane gas to be set until required inlet concentration, relative humidity of gas mixture in system of detection has been reached. The time is to be measured from the moment of introduction of the air and cyclohexane gas mixture into the testing filter until the output concentration of cyclohexane of 10 ppm is detected.[5]

2.2.5. The activities sequence of methods for the time of sorption properties testing of the Filter M3 and the Filter M4 with different active filling height upon carbon monoxide challenge

The gas analyzer and the artificial lungs are activated. The flow of the mixture of air and carbon monoxide gas is to be set until required inlet concentration, relative humidity and temperature of gas mixture in system of detection, has been reached. The time is to be measured from the moment of introduction of the air and carbon monoxide gas mixture into the testing filter until the output concentration of carbon monoxide of 100 ppm is detected on gas analyzer.[5]

3. RESULTS AND DISCUSSION

In the aim of quality control of active filling for Filters M3 and Filter M4, two different produced batches of carbon were sampled for testing. The first batch used in Filter M3 is carbon impregnated according to standard recipe (activated with Cu^{2+}, Cr^{6+} and Ag^{+} salts). The second one used in Filter M4 is impregnated to altered recipe (activated with Zn^{2+}salt which serve as a substitute for Cr^{6+} salt).

Filter M3 is official CBRN protection equipment of Serbian Armed Forces, so experimental results for the Filter M4 sorptive properties are compared with the Filter M3 sorptive properties. Filters M4 are filled with active carbon, different filling heights of 27 mm, 32 mm and 39 mm and activated with Cu^{2+}, Zn^{2+} and Ag^{+} salts.

The samples from two above mentioned batches (with different impregnation of active carbon) were tested on the following quality parameters:

– - moisture content (according to SORS 8830/05),

– - apparent density (according to SORS 8830/05),

– - mechanical strength (according to SORS 8830/05),

– - grain size distribution (according to SORS 8830/05),

The results of testing are given in Table 1.

Table 1. Physical-mechanical properties of impregnated activated carbons for filters

Activated carbon type	Standard Impregnation for Filter M3	Changed Impregnation for Filter M4
Moisture content[%]	1.0	2.4
Apparent density [g/l]	536	570
Mechanical strength[%]	71	72
Grain size distribution		
> 1.6 mm	0.10 %	0.53 %
>1.4 mm	2.61 %	7.12 %
0.7-1.4 mm	95.01 %	91.82 %
0.5-0.7 mm	1.89 %	0.44 %
<0.5 mm	0.18 %	0.09 %

Before testing filters on CBRN gases, the Filters M3 and Filter M4 with different active filling height, were controlled according to the quality demands for following parameters:

- filter weight (according to SORS 8829),
- inhalation resistance (according to SORS 8829),
- filtration efficiency on paraffin aerosol mist (according to SORS 8829)

and the mean of obtained results are shown in Table 2.

Table 2. The values of mean weight, inhalation resistance and filtration efficiency for filters

Filter type	Weight [g]	Inhalation resistance [Pa]	Filtration efficiency [%]
Filter M3 (27 mm)	297.8	127	$1x10^{-3}$
Filter M4, (27 mm)	298	129	$1x10^{-3}$
Filter M4, (32 mm)	327	138	$1x10^{-3}$
Filter M4, (39 mm)	369	151.5	$1x10^{-3}$

The samples of impregnated activated carbons and Filters M3 and Filter M4 with different active filling height, were satisfied all the tested required parameters, that are shown in Tables 1 and 2. [6],[7].

Mentioned testing parameters were main requirement for gas testing to be continued. Comparative testing for both type of filters on above mentioned test gases, were done with the aim to justify the idea to change the recipe of impregnation and active filling height, in order to expand the existing requirement for the protection provided by the official Filter M3.

3.1. The sorption properties of Filter M3 and Filter M4 with different active filling height upon pho-sgene, chloropicrin and hydrogen cyanide challenge

All the Filters M3 and Filters M4 that successfully passed the quality control on previous testing phase, were tested with CBRN gases. Wide range of conditions (inlet concentrations, flow rates and relative humidity of gas mixture), upon which the Filter M3 (with standard impregnation recipe and active filling height of 27 mm and the Filter M4 (with altered impregnation recipe and filling height of 27 mm, 32 mm and 39 mm) are tested, gives assurance that results obtained can be taken as representative for diverse exploitation conditions of filters.

The results of comparative testing of Filters M3 and Filter M4 with different active filling height, upon phosgene, chloropicrin and hydrogen cyanide challenge are shown in Tables 3, 4, 5 6, 7 and 8.

3.1.1. Sorption properties of Filters M3 and Filter M4 with different active filling height upon phosgene challenge.

Filter M3 (with active filling height of 27 mm) and Filter M4 (with filling height of 27 mm, 32 mm and 39 mm) were tested upon phosgene challenge, under the following conditions:

– inlet concentration of gas mixtures: 1000 ppm and 5000 ppm
– flow rate of gas mixtures: 30 l/min and 64 l/min
– relative humidity: 25 % and 80 %.

The results of protection time for Filter M3 and Filter M4 upon phosgene challenge, under different concentrations, flow rates and relative humidity of gas mixture are shown in Table 3 and 4.

Table 3. The protection time of filters against phosgene at flow rate of 30 l/min for different inlet concentration and relative humidity gas mixture

Inlet concentration [ppm]	Relative humidity [%]	Protection time [min] Filter M3 27 mm	Protection time [min] FilterM4 27 mm 32 mm 39 mm
1000	**25**	111	107
			127
			143
1000	**25**	110	108
			126
			142
1000	**80**	105	102
			119
			137
1000	**80**	106	104
			121
			136
5000	**25**	35	28
			35
			40
5000	**25**	34	29
			36
			42
5000	**80**	34	25
			33
			37
5000	**80**	33	25
			34
			38

Table 4. The protection time of filters against phosgene at flow rate of 64 l/min for different inlet concentration and humiditiy gas mixture

Inlet concentration [ppm]	Relative humidity [%]	Protection time [min] Filter M3 27 mm	Protection time [min] FilterM4 27 mm 32 mm 39 mm
1000	**25**	75	69
			73
			80
1000	**25**	77	67
			72
			82
1000	**80**	72	62
			69
			79
1000	**80**	74	60
			68
			78
5000	**25**	15	15
			17
			19
5000	**25**	16	15
			17
			21
5000	**80**	14	18
			19
			24
5000	**80**	13	19
			20
			22

The results show that the influence of active filling height on the protection time for Filter M4 (changed impregnation with Zn^{2+}salt) is significant. There is a noticeable increase in protection time with an increase in active filling height of Filter M4.

The influence of phosgene flow rates on protection time for the Filter M4 considerably high, because the filter time of protect directly proportional to contact time between filter adsorbens and test gas. At testing condition of lower flow rates gas mixture, the values of results in relation to high flow rates, for the Filters M4 times protection, are significantly higher, Figure 1.

For the same active filling height of 27 mm, the protection times upon phosgen challenge for Filters M3, has some advantages comparing to Filter M4. Since salt of chrome (VI)-chloride [2] are formed on active carbon, phosgene decomposition rate with Cr^{6+} ions (Filter M3) are considerably higher than rate with Zn^{2+}ions (Filter M4), Figure 1.

The differences between results in Filter M4, caused by relative humidity change (25% and 80%), are not as high as in case of flow rate, inlet concetration of gas mixture as well as recipe and height of active filling filters, Figure 2.

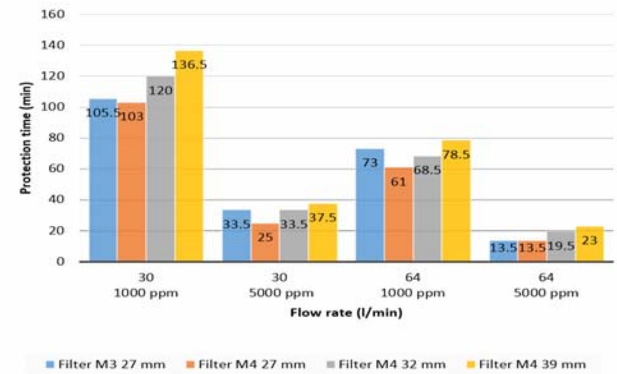

Figure 1. Influence of flow rates and inlet concentrations on protection time against phosgene for different filling heights filters at constant relative humidity of 80 %.

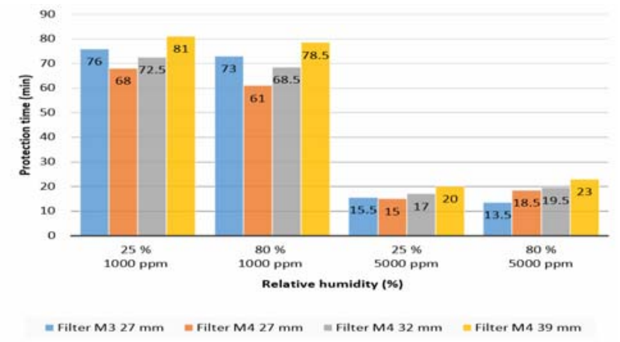

Figure 2. Influence of relative humidity and inlet concentrations on protection time against phosgene for different filling heights filters at constant flow rate of 64 l/min

3.1.2. Sorption properties of Filters M3 and Filter M4 with different filling height upon chloropicrin challenge

Filter M3 with active filling height of 27 mm and Filter M4 with height of 27 mm, 32 mm and 39 mm were tested upon chloropicrin challenge, under the following conditions:

– inlet concentration of gas mixture: 2200 ppm and 5000 ppm;

– flow rate of gas mixture: 30 l/min and 64 l/min and

– relative humidity: 25 % and 80 %.

The results of protection time for Filter M3 and Filter M4 upon chloropicrin challenge, under different concentrations, flow rate and relative humidity of gas mixture, are shown in Table 5 and 6.

Table 5. The protection time in filters against chloropicrin at flow rate of 30 l/min for different inlet concentration and relative humidity gas mixture

Inlet concentration [ppm]	Relative humidity [%]	Protection time [min] Filter M3 27 mm	Protection time [min] FilterM4 27 mm 32 mm 39 mm
2200	**25**	26	32
			38
			117
2200	**25**	25	32
			40
			115
2200	**80**	21	22
			36
			103
2200	**80**	18	20
			33
			102
5000	**25**	14	32
			34
			48
5000	**25**	14	32
			36
			50
5000	**80**	11	22
			26
			43
5000	**80**	10	20
			28
			45

Table 6 The protection time in filters against chloropicrin at flow rate of 64 l/min for different inlet concentrationand relative humidity gas mixture

Inlet concentration [ppm]	Relative humidity [%]	Protection time [min] Filter M3 27 mm	Protection time [min] FilterM4 27 mm 32 mm 39 mm
2200	**25**	10	12
			15
			20
2200	**25**	11	11
			17
			19
2200	**80**	7	10
			13
			17
2200	**80**	7	11
			14
			16
5000	**25**	breakthrough	5
			7
			10
5000	**25**	breakthrough	5
			8
			10
5000	**80**	breakthrough	4
			7
			8
5000	80	breakthrough	4
			6
			9

The influence of relative humidity on adsorption of chloropicrin is greater than in the case upon phosgene challenge, Figure 4.

At condition of lower flow rates of gas mixture, the values of results for the Filters M4 times protection (filling height of 32 mm and 39 mm) are significantly higher. Under the extreme conditions at flow rate of 64 l/min and inlet concentration of 5000 ppm gas mixture, the value of the results for Filters M4 times protection (filling height of 32 mm and 39 mm) are some lower. However, the Filter M3 does not protect against chloropicrin Figure 3.

Decomposition and adsorption of chloropicrin on activated carbon is based on mechanism of physical adsorption (on the interfacial area) and partly by chemical decomposition of chloropicrin on impregnated carbon.

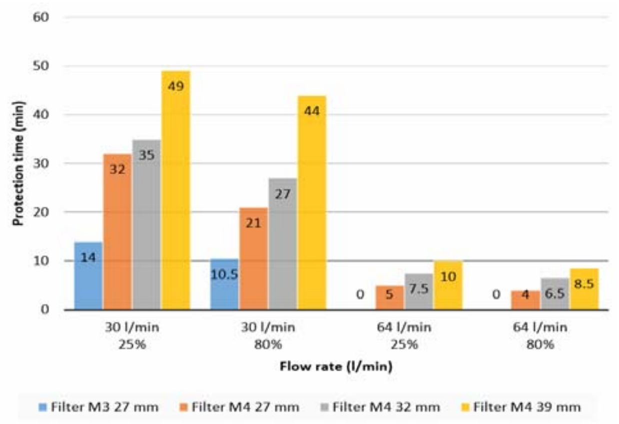

Figure 3. Influence of relative humidity and flow rate on protection time against chloropicrin for different filling heights filtersat constant inlet concentration of 5000 ppm.

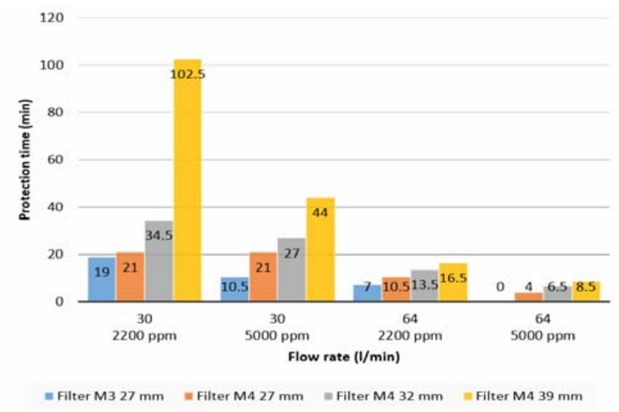

Figure 4. Influence of relative flow rate and inlet concentration on protection time against chloropicrin for different filling heights filters at relative humidity of 80 %.

3.1.3. Sorption properties of Filters M3 and Filter M4 with different filling height upon hydrogen cyanide challenge

Filter M3 with active filling height of 27 mm and Filter M4 with height of 27 mm, 32 mm and 39 mm were tested upon hydrogen cyanide challenge, under the following conditions:

– inlet concentration of gas mixture: 1000 ppm and 5000 ppm;

– flow rate of gas mixture: 30 l/min and 64 l/min and

– relative humidity: 25 % and 80 %.

The results of protection time for Filter M3 and Filter M4 upon hydrogen cyanide challenge, under different concentrations, flow rates and humidity of gas mixture, are shown in Table 7 and 8.

Table 7. The protection time in filters against hydrogen cyanide of flow rate of 30 l/min for different inlet concentration and relative humidity gas mixture

Inlet concentration [ppm]	Relative humidity [%]	Protection time [min] Filter M3 27 mm	Protection time [min] FilterM4 27 mm 32 mm 39 mm
1000	**25**	68	66
			70
			77
1000	**25**	69	68
			72
			76
1000	**80**	69	70
			78
			85
1000	**80**	72	73
			77
			83
5000	**25**	53	52
			55
			63
5000	**25**	55	55
			54
			64
5000	**80**	58	55
			60
			67
5000	**80**	53	53
			58
			66

Table 8. The protection time in filters against hydrogen cyanide flow rate of 64 l/min for different inlet concentration and relative humidity gas mixture

Inlet concentration [ppm]	Relative humidity [%]	Protection time [min] Filter M3 27 mm	Protection time [min] FilterM4 27 mm 32 mm 39 mm
1000	**25**	34	33
			38
			45
1000	**25**	36	31
			37
			51
1000	**80**	35	36
			45
			53
1000	**80**	37	38
			43
			54
5000	**25**	24	23
			27
			29
5000	**25**	26	27
			27
			28
5000	**80**	29	**29**
			31
			32
5000	**80**	40	28
			28
			29

Decomposition and adsorption of hydrogen cyanide on activated carbon is based on mechanism of chemical decomposition on impregnated active carbon (salts of cuprum (II)-cyanide are formed) and partly by physical adsorption.There is a noticeable increase in protection time with an increase in active filling height of Filter M4, Figure 5.

The differences between results in Filter M4, caused by relative humidity change (25% and 80%), are significant. At testing condition of higher relative humidity of gas mixture (80 %) the values of the Filter M4 time protection are some higher, Figure 6.

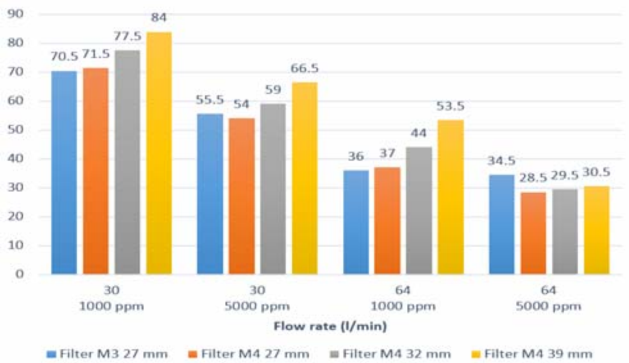

Figure 5. Influence of flow rate and inlet concentration on protection time against hydrogen cyanide for different filling height of filters at constant relative humidity of 80 %

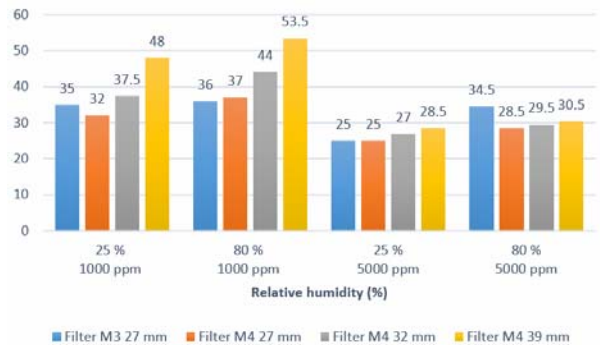

Figure 6. Influence of relative humidity and inlet concertation on protection time against hydrogen cyanide for different filling heights filters at constant flow rate of 64 l/min

3.2. The sorption properties of Filter M3 and Filter M4 upon ammonia, sulphur dioxide cyclohexane and carbon monoxide challenge

Testing methods for the time of sorption properties of the Filter M3 and the Filter M4 with different active filling height upon ammonia, sulphur dioxide, cyclohexane and carbon monoxide challenge, according to the SRPS EN 14387.

All the filters and activated carbons were satisfied required parameters of weight, inhalation resistance and filtration efficiency on paraffin aerosol mist.

The samples were tested to all above mentioned gases from SRPS EN14387 under the following test conditions.[5].

– inlet concentration of gas mixtures: 5000 ppm

– flow rate of gas mixtures: 30 l/min and 64 l/min

– relative humidity: 70%

The obtained results are shown in Table 9. The expected the values of results for protection time for filters of two different types of impregnation, are achieved.

The results confirmed that both filter types protect against following toxic gases.

The Filter M3 did not protect against ammonia, while the Filter M4, with different active filling height, protects against ammonia. Therefore, Filter M4 with active filling heights of 32 mm and 39 mm, has slightly better protective properties then Filter M3 and Filter M4 with the same active filling heights.

Table 9. Protection time for filters against toxic compounds at flow rates 30 l/min and 64 l/min.

Inlet concentration [ppm]	Relative humidity [%]	Flow rate [l/min]	Test gas	Protection time [min] Filter M3	Protection time [min] Filter M4
5000	**70**	**30**	NH_3	1	23 35 42
5000	**70**	**30**	NH_3	1	22 35 43
5000	**70**	**64**	NH_3	breakthrough	7 17 23
5000	**70**	**64**	NH_3	breakthrough	8 15 22
5000	**70**	**30**	SO_2	22	10 20 23
5000	**70**	**30**	SO_2	22	10 19 25
5000	**70**	**64**	SO_2	10	5 11 13
5000	**70**	**64**	SO_2	8	4 12 14
5000	**70**	**30**	C_6H_{12}	42,4	30 48,6 62
5000	**70**	**30**	C_6H_{12}	43,6	26 44,9 59
5000	**70**	**64**	C_6H_{12}	17,6	17 21 33
5000	**70**	**64**	C_6H_{12}	16,3	18 21 31
5000	**70**	**30**	CO	0	0 0 0
5000	**70**	**30**	CO	0	0 0 0

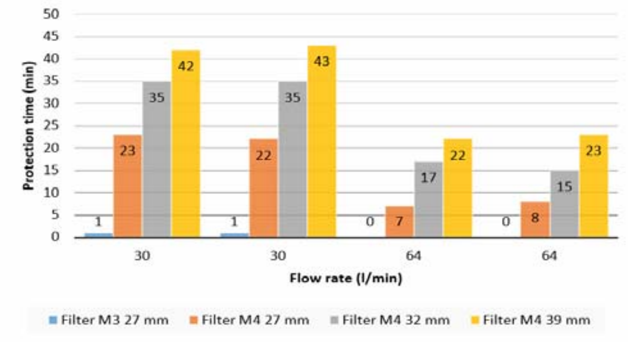

Figure 7. Influence of flow rate on protection time against ammonia for different filling heights of filters at relative humidity of 80 % and inlet concentration of 5000 ppm

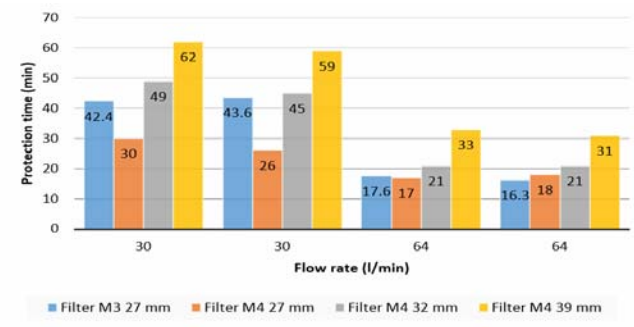

Figure 8. Influence of flow rate on protection time against cyclohexane for different filling heights filters at relative humidity of 80 % and inlet concentration of 5000 ppm

4. CONCLUSION

The aim of this work was to analyze the protection time of Filters M4 (loaded with Zn^{2+} impregnated activated carbon) with different filling height of 27 mm, 32 mm and 39 mm and official Filter M3 (loaded with Cr^{6+} impregnated activated carbon) against several different CBRN gases as well as industrial toxic chemical. Filters were tested upon gasses challenge, under the different conditions of inlet concentrations, flow rates and relative humidity of gas mixtures, in order to examine the validity of the idea replacing the active filling height of the official Filter M3 with the most optimal one (impregnated with Zn^{2+} salt instead Cr^{6+}) with the aim to expand the existing requirement for the protection provided by the Filter M3.

The obtained results have shown that there are differences in the protection time of Filter M4 with different filling height (of 27 mm, 32 mm and 39 mm) and official Filter M3. The influence of active filling height on the protection time upon all CBRN gasses challenge in Filter M4 is significant. There is a noticeable increase in protection time with an increase in active filling height of Filter M4, which is specifically expreessed under conditions of lower values inlet concentrations and flowe rates gas mixtures. This can be explained by the mechanism of physical adsorption (on the interfacial area of active carbon) and partly by chemical decomposition.

Both filters were also examined against the toxic industrial chemicals according to SRPS EN 14387 standard, and proved that satisfactory protection was achieved upon sulphur dioxide and cyclohexane challenge, except upon carbon monoxide challenge.
It is especially important that protection against ammonia is provided by Filter M4, which is not the case by Filter M3. Ammonia is gas which is easily accesible, which makes it eligible for system paralyzing or provoking general danger against people.

Based on the tested and satisfied all required physical mechanical parameters for Filter M4 of filling height of 32 mm (mean weight and inhalation resistance) and taking into account the Filter M4 with mentioned filling height, provide protection against CBRN contaminants as well as industrial toxic chemicals, including the ammonia, we can reliably claim that Filter M4 (with filling height of 32 mm, impregnated with Zn^{2+} salt) has advantages compared to official Filter M3 (with filling height of 27 mm, impregnated with Cr^{6+} salt).

Based on the obtained results for protection time of the Filter M4 and Filter M3 against carbon monoxide gas (breakthrough), in the following period, work will be done on changing the composition of the active filling in the mentioned filters (based on hopcalite) with the aim to expand the existing requirement for the protection provided by the tested filters.

References

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