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Effect of mist nozzle supply pressure on the ammonia absorption process

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Abstract: The article shows the effect of the supply pressure of mist nozzles on the process of ammonia sorption. In the tests, the nozzles flow characteristics Q=f(p) and the dependence of NH_3 concentration as a function of the water stream feeding in time at different supply pressures were determined. For the TF 6 NN, TF 6 V, NF 15, CW 50 nozzles, measurements were carried out at the following supply pressures: 0.1 MPa; 0.2 MPa; 0.3 MPa; 0.4 MPa; 0.5 MPa. It was observed that the greatest effect of nozzle feed pressure on ammonia sorption efficiency may be expected at lower pressure values. At higher values, the sorption rate becomes stabilized and even starts to decrease. The decreases in the sorption rate constant observed for higher pressures may be due to a reduction contact time of the droplet and the achievement of the critical mixing rate of ammonia vapors in the air intensively saturated with water streams. This is due to diffusion rate limitations. The measurements show that the use of supply pressures for mist nozzles above 0.4 MPa is not justified. It should be noted that varying the feed pressure of nozzles of various designs can affect their ammonia sorption efficiency differently. The type of nozzle and supply pressure affects the distribution of droplets in space. The angle of dispersion and the shape of the generated jet have a critical influence on the efficiency of the sorption process. Complete filling of the space and a large spray angle assure relatively high sorption efficiency.

Introduction

Ammonia is an inorganic compound with a wide range of applications. Despite its toxic, corrosive and flammable properties (Chung et al. 2022) it is used, *inter alia*, in the pharmaceutical industry (Salamonowicz et al. 2022), artificial fertilizers (Rosa et al. 2021) and industrial freezing (Ubowska 2018). In recent years, the world has seen an increasing production of ammonia, which in 2020 exceeded the value of 185·109 kg (Intern. Fertilizer Association 2022). This substance may be found in a number of process installations, often in quantities that exceed several tones, hence its uncontrolled release is potentially a source of serious danger to humans and the environment (Fedoruk et al. 2005, Tan et al. 2017). In addition, accidents involving ammonia pose a major challenge for the emergency services because, due to the reactivity of ammonia with water, they require operations to be carried out in appropriate personal protective equipment, often in chemically resistant isolation clothing (Sukumar et al. 2022). In Poland, more than 40 incidents with this substance have been recorded on average every year over the past decade (Banaczkowski 2022).

Agriculture and industry is the main source of ammonia emissions. In 2019, NH_3 emissions from agriculture accounted for approximately 95% of the total emissions of this gas in Poland (Mielcarek-Bocheńska and Rzeźnik 2022). Ammonia is released to the environment in either a gaseous or a 2-phase form. Only during the initial stage of a liquid phase leak does the ammonia vapor tend to accumulate in depressions in the ground and in the ground-floor spaces. Once they have absorbed heat from the environment, they are easily dispersed, increasing the risk of occurrence of adverse effects in confined spaces. In open areas, NH_3 vapors tend to disperse easily under the influence of air currents and heating from the ground surface, forming a cloud with a maximum range in line with the wind direction (Danasa et al. 2019).

The basic action undertaken by emergency services to minimize the risk generated by the release of a hazardous substance is the installation of water curtains (Bara and Dusserre 1997). Water sprays are commonly used to adsorb hazardous substances (Schoten et al. 2000, Węsierski and Majder-Łopatka 2018, Liu et al. 2022). In many cases, fixed installations with spray nozzles actuated automatically by a detection system are employed to protect technological processes in which hazardous substances are used (Węsierski 2015).

Research studies conducted by (Węsierski 2015, Majder-Łopatka et al. 2016, Buchlin 2017, Hua et al. 2018, Shen et al. 2017, Wąsik et al. 2022) demonstrate that NH_3 is extremely effectively sorbed by water sprays owing to its good solubility in water. At 0°C, 900 g of NH_3 becomes soluble in 1 dm^3 of water. This solubility, similarly to other gases, decreases with temperature. However, at a temperature of 25°C, it is still possible to achieve a very high concentration of ammonia in solution, up to 31% by weight, which is the basis for the use of H_2O in rescue operations (Cheng et al. 2015). Ammonia becomes adsorbed on the surface of the droplets, penetrates them and falls with them. This significantly reduces the concentration of this substance in the air. Some of ammonia reacts with water, alkalizing the environment. However, an aqueous solution of ammonia does not pose a long-term threat to the environment owing to its high bioavailability (Li et al. 2016).

Given its properties and widespread occurrence, water is an effective and inexpensive means of decontamination in the event of an uncontrolled release of many hazardous substances (Węsierski and Majder-Łopatka 2018). However, the efficiency of vapor elimination is dependent on a number of factors, not only the solubility and reactivity of the substance. Sorption also depends on the rate of vapor diffusion to the droplet surface, the kinetics of sorption at the air-water interface and the rate at which the compound becomes diffused into the interior of the droplet (Węsierski 2015).

Results of scientific research, confirmed in practice in rescue operations, suggest that changing the supply pressure of the spray device has a major impact on the micro- and macro--structural parameters of the sprayed water jet (Majder-Łopatka et al. 2017, Wąsik et al. 2021, Ochowiak et al. 2020). Among these, the average diameter of the droplets produced, the spray spectrum, the water flow rate, the spray angle, and the intensity of the spray are particularly important for the efficiency of the sorption process (Majder-Łopatka et al. 2016, Buchlin 2017, Wąsik et al. 2022, Warych 1998).

No data are available in the literature that would describe the precise correlation between the change in supply pressure of mist nozzles and the ammonia sorption efficiency of the water jets they produce. The published information on this topic only relates to a narrow pressure range of 0.05–0.2 MPa (Hua et al. 2018). The aim of the study was, therefore, to assess the influence of the supply pressure of mist nozzles on the efficiency of the ammonia absorption process with the streams generated by them. The structure of the dispersed stream depends mainly on the type of nozzle (Majder-Łopatka et al. 2016, Hua et al. 2018, Orzechowski and Prywer 2018, Orzechowski and Prywer 2008, Wąsik et al. 2018), and for this reason, different types of mist nozzles were used in the tests, characterized by different parameters of the produced water streams. For each nozzle type, flow characteristics were established to determine the effect of pressure on nozzle efficiency Q=f(p) and curves of change in ammonia concentration as a function of time C=f(t), at different nozzle supply pressures.

Materials and Methods

In the research the following four types of nozzles were applied:

- spiral nozzle with full sprinkler cone and 60° dispersion angle (TF 6 NN), (Bete Europe GmbH 2022a)
- spiral nozzle with full sprinkler cone and 60° dispersion angle (TF 6 V) (Bete Europe GmbH 2022a)
- flat jet nozzle with 65° spray angle (NF 15) (Bete Europe GmbH 2022b)
- axial nozzle with full spray cone and 80° spray angle (CW 50) (Bete Europe GmbH 2022c)

The appearance of the nozzles used in the study is shown in Figure 1.

Fig. 1. Mist nozzle (viewed from left: TF6 NN, TF6 V, NF 15, CW 50)

The nozzles were selected due to their purpose and various spraying parameters. They were the subject of studies published by the authors (Wąsik et al. 2022, Majder-Łopatka et al. 2016, Majder-Łopatka et al. 2017, Wąsik et al. 2021). The important parameters affecting the efficiency of gas sorption include, among others, the size of the droplets fed through the nozzle, the shape of the water stream and the droplet fall time.

The tests were carried out in two stages. In the first one, the effect of supply pressure on nozzle performance was measured. For each of the nozzles tested, measurements were carried out at the following supply pressures: 0.1 MPa, 0.2 MPa, 0.3 MPa, 0.4 MPa, and 0.5 MPa. The duration of a single measurement always exceeded 60 seconds and the deviation of the actual value from the set point was no greater than 0.005 MPa. For each measurement series, the mean value and standard deviation of the pressure and flow rate were calculated. It is the value of the arithmetic average of the measurements of the supply pressure and water flow rate for a given nozzle in individual measurement series. On the basis of the averages obtained, the flow characteristics Q=f(p) and the average value of the K-factor were established for the 4 nozzles. The coefficient of the individual measurement series was determined from the formula (Wąsik et al. 2018):

$$K = \frac{Q}{\sqrt{p}} \tag{1}$$

where:
K – factor [$dm^3/(min \cdot bar^{0,5})$]
Q – average value flow [dm^3/min]
p – average value supply pressure [bar]

The K coefficient is a constant that relates the parameter of supply pressure and flow rate of water nozzles. It allows for the comparison of flow parameters among nozzles of the same type and the evaluation of changes in flow rate at different supply pressures. On the basis of K-factors, an evaluation was made of the influence of supply pressure and nozzle capacity on the ammonia sorption process.

In the second stage of the testing, the concentration of ammonia in the test chamber was measured while water was being fed through the mist nozzles. The tests were carried out on a test rig, a diagram of which is shown in Figure 2.

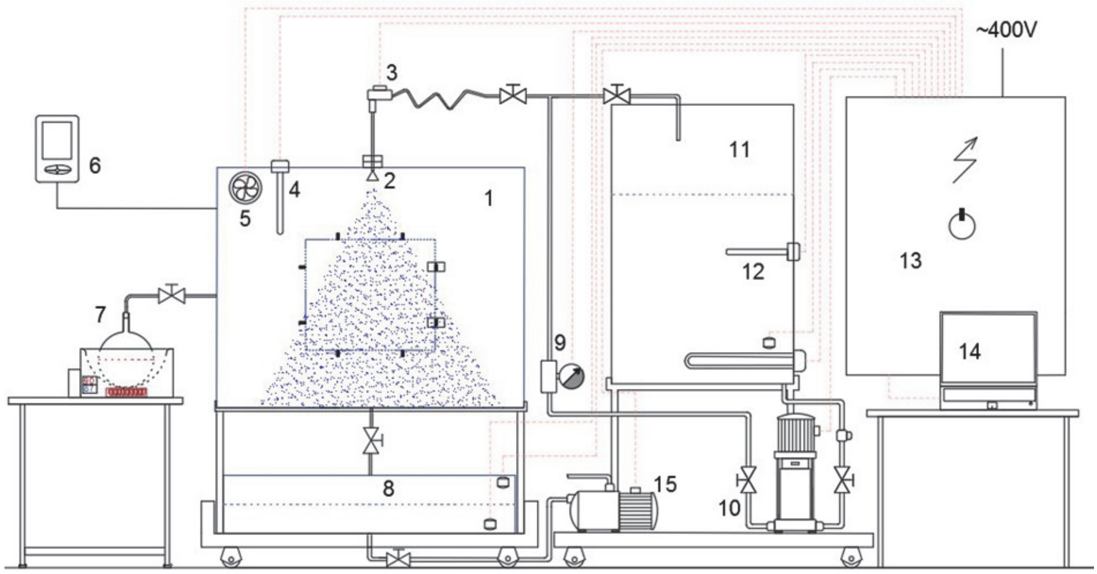

Fig. 2. Test bench diagram: 1 – test chamber in the shape of a cube with a side length of 1.2 m, 2 – spray nozzle, 3 – pressure sensor, 4 – temperature sensor, 5 – mixer, 6 – photoionization detector MX6 iBrid, 7 – ammonia generation system, 8 – water discharge tank, 9 – electromagnetic flow meter, 10 – main feed pump with piping and valves, 11 – water tank, 12 – water temperature sensor, 13 – signal and power supply cabinet, 14 – computer of the workstation with special software heater, 15 – discharge pump

The initial concentration of ammonia in the chamber was 1000 ± 50 ppm. In order to eliminate the influence of water and ambient temperature on the sorption process, all measurements were carried out under identical conditions, i.e., water and ambient temperature 20 ±1°C. During the tests at the supply pressure 0.1 MPa; 0.2 MPa; 0.3 MPa; 0.4 MPa and 0.5 MPa, water flow rate and ammonia concentration in the test chamber were registered:. The sampling frequency for all measurements was 1 Hz and the uncertainty was estimated to be less than 1% of the measured value. Pressure measurements were taken with a WIKA model A-10 pressure sensor (WIKA, Poland) and flow measurements were made with a UniEMP-05 electromagnetic flow meter (Uniprod-Components, Poland). An MX6 iBrid multigas meter (Industrial Scientific, USA) was used to measure ammonia concentration inside the test chamber.

To assess the efficiency of ammonia sorption use was made of the parameter apparent rate constant of the sorption process kp and the half-life of the concentration t½.

The ammonia sorption from the kinetic viewpoint can be described according to the pseudo-first order kinetic reaction described by equation 2 (Węsierski and Majder-Łopatka 2018):

$$-\frac{d[C]}{d[t]} = k_p[C] \qquad (2)$$

where:
C – concentration of ammonia in the chamber [ppm],
k_p – apparent constant for the absorption process rate [s^{-1}],
t – time [s].

An another important parameter characterizing this process is the half-time concentration, described by equation 3:

$$t_{½} = \frac{ln2}{k_p} \qquad (3)$$

where:
$t_{½}$ – the concentration half-time [s],
k_p – apparent constant for the absorption process rate [s^{-1}].

In ammonia sorption the value of k_p and $t_{½}$ is influenced by many factors related to the water feed and its parameters. Among these factors, the following are particularly important: the type of spray nozzle and its supply pressure, as they determine the extent to which the space is sprinkled and how long the drops remain in the air (Wąsik et al. 2022).

Results and discussion

The test results including flow characteristics of the tested nozzles and the established K-factor are shown in Table 1–4. According to equation 1, the dependence of the water output of a nozzle is a function of the square root of the supply pressure as shown in the Figure 3. The stability of the nozzle's performance in the tested measuring range is confirmed by the high correlation coefficients.

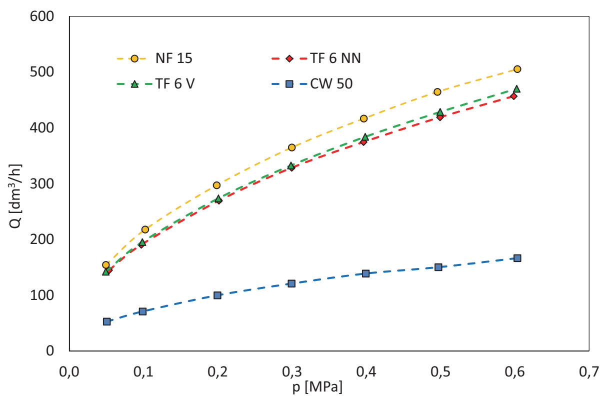

Fig. 3. The water output of the tested nozzles as a function of the supply pressure

Table 1. Flow characteristics of the NF 15 nozzle

Pressure average (p)		Flow average (Q)	Standard deviation for pressure (Δp)	Standard deviation for flow (ΔQ)	K-factor
MPa	bar	dm^3/h	MPa	dm^3/h	$(dm^3/min)\cdot bar^{-0,5}$
0.0493	0.493	154.35	0.0003	0.31	3.664
0.1022	1.022	217.81	0.0004	0.34	3.590
0.1985	1.985	297.15	0.0005	0.40	3.515
0.2997	2.997	364.93	0.0004	0.56	3.513
0.3966	3.966	416.80	0.0011	0.52	3.488
0.4958	4.958	464.64	0.0007	0.36	3.478
0.6034	6.034	505.51	0.0010	0.65	3.430
K-factor average					3.525

Table 2. Flow characteristics of the TF6 NN nozzle

Pressure average (p)		Flow average (Q)	Standard deviation for pressure (Δp)	Standard deviation for flow (ΔQ)	K-factor
MPa	bar	dm^3/h	MPa	dm^3/h	$(dm^3/min)\cdot bar^{-0,5}$
0.0535	0.535	144.83	0.0003	0.21	3.299
0.0970	0.970	190.47	0.0004	0.41	3.223
0.2015	2.015	269.53	0.0004	0.29	3.164
0.2995	2.995	328.53	0.0005	0.88	3.164
0.3963	3.963	374.71	0.0007	0.31	3.137
0.4992	4.992	419.09	0.0008	0.20	3.126
0.5985	5.985	456.89	0.0007	0.10	3.113
K-factor average					3.175

Table 3. Flow characteristics of the TF6 V nozzle

Pressure average (p)		Flow average (Q)	Standard deviation for pressure (Δp)	Standard deviation for flow (ΔQ)	K-factor
MPa	bar	dm^3/h	MPa	dm^3/h	$(dm^3/min)\cdot bar^{-0,5}$
0.0491	0.491	142.12	0.0004	0.97	3.379
0.0984	0.984	195.30	0.0003	0.56	3.281
0.2008	2.008	273.70	0.0005	0.44	3.219
0.2985	2.985	332.68	0.0004	0.26	3.209
0.3985	3.985	384.01	0.0005	0.33	3.206
0.4994	4.994	428.68	0.0009	0.32	3.197
0.6025	6.025	470.23	0.0007	0.37	3.193
K-factor average					3.241

Table 4. Flow characteristics of the CW 50 nozzle

Pressure average (p)		Flow average (Q)	Standard deviation for pressure (Δp)	Standard deviation for flow (ΔQ)	K-factor
MPa	bar	dm^3/h	MPa	dm^3/h	$(dm^3/min)\cdot bar^{-0,5}$
0.0506	0.506	52.63	0.0017	0.18	1.233
0.0989	0.989	70.81	0.0003	0.18	1.187
0.1995	1.995	99.79	0.0004	0.25	1.178
0.2993	2.993	120.86	0.0007	0.53	1.164
0.3993	3.993	138.83	0.0012	0.24	1.158
0.4970	4.970	150.24	0.0017	0.31	1.123
0.6034	6.034	166.48	0.0032	0.57	1.130
K-factor average					1.168

The characteristics of the CW50 nozzle differ significantly from those of other ones due to its significantly lower K-value and the shape and angle of dispersion of the water stream, which affects the longer time the drops remain in space. When pressurized to more than 0.2 MPa, the nozzle produces a homogeneous cone-shaped jet with a high atomization angle of 80° (Majder-Łopatka et al. 2016).

As regards TF 6 NN and TF 6 V, the relationship Q=f(p) shows similar flow parameters for these nozzles. This is due to the equal size of the outlet opening of both nozzles and their similar design. The NF 15 nozzle has a slightly higher K-factor value as compared to the TF 6. However, the jet produced by it, over the entire pressure range, is characterized by a high droplet density and low dispersion level (Wąsik et al. 2022). The tests carried out on the flow characteristics of all the nozzles suggest that the smallest changes in flow rate occur at high pressures. This is proof of the presence of high hydraulic resistance when the liquid flows through the nozzle and its limiting flow values are approaching. This is particularly evident in the case of the nozzle with the smallest K-factor value, i.e. nozzle CW 50.

The conducted tests (Wąsik et al. 2022, Majder-Łopatka et al. 2016, Wąsik et al. 2021) show that the increase in the supply pressure above 0.2MPa did not significantly affect the change in the size of the droplets and the spray angle. Between the supply pressure of 0.2 and 0.6 MPa for all nozzles, the average surface diameter Ds. changed by less than 5 µm and was approximately 230 µm for the CW 50 nozzle, 290 µm for the FT 6NN nozzle and 536 µm for the NF15 nozzle (Wąsik et al. 2022, Majder-Łopatka et al. 2016, Wąsik et al. 2021).

The results of the tests on the process of ammonia sorption by water streams are presented as the dependence of NH_3 concentration as a function of time C=f(t) and are shown in Figures 4, 6, 8 and 10. The kinetic range of the curves, reflecting the maximum rate of the sorption process, is presented as the dependence lnC=f(t) in Figures 5, 7, 9 and 11. The tests were performed in the supply pressure range from 0.1 to 0.5 MPa..

The results of the apparent sorption rates of ammonia and the half-life of the concentration are shown in the Table 5. The obtained values for the parameters k_p and $t_{1/2}$ indicate that the ammonia removal efficiency generally increases with increasing nozzle supply pressure, which has also been confirmed by the experimental results of the team led by Hua. The researchers discovered that as the supply pressure increased from 0.05 MPa to 0.2 MPa, the efficiency of ammonia removal by the dispersed stream increased by 5% (Hua et al. 2018).

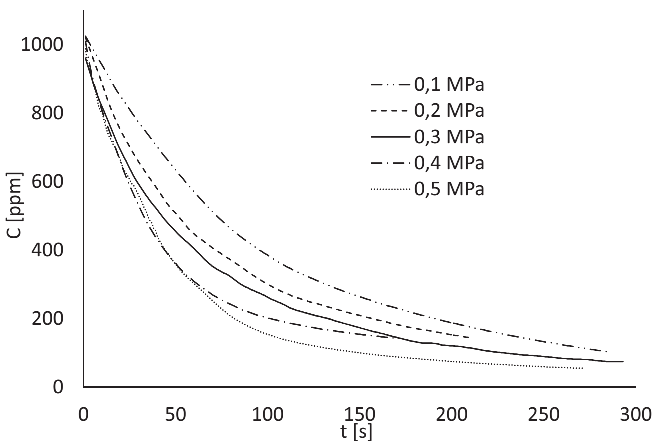

Fig. 4. Ammonia concentration as a function of time during water feed via nozzle NF 15 for different feed pressures

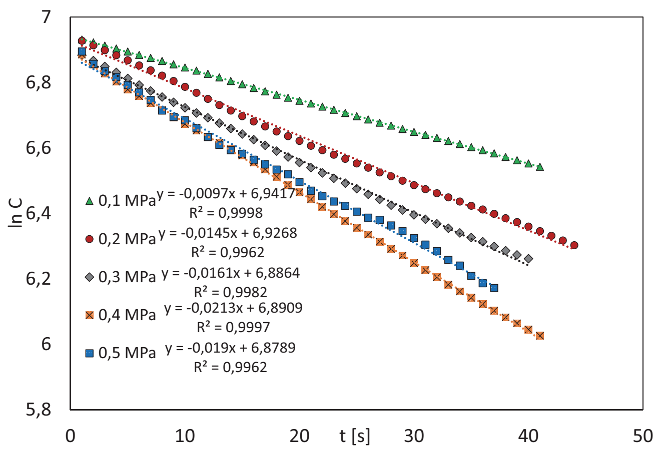

Fig. 5. Ammonia sorption curves in the kinetic range for the NF 15 nozzle for different feed pressures

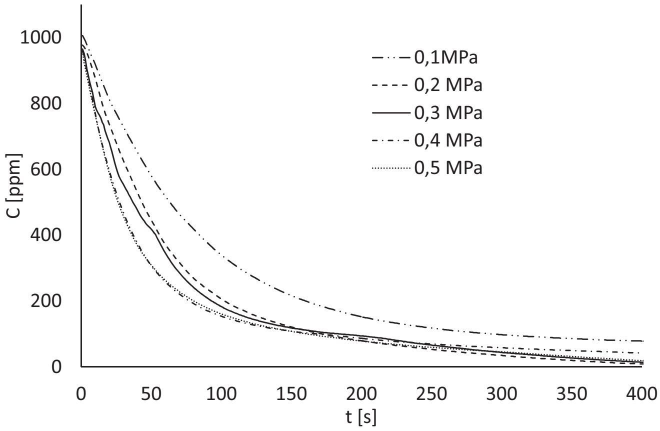

Fig. 6. Ammonia concentration as a function of time during water supply via nozzle TF 6 NN for different supply pressures

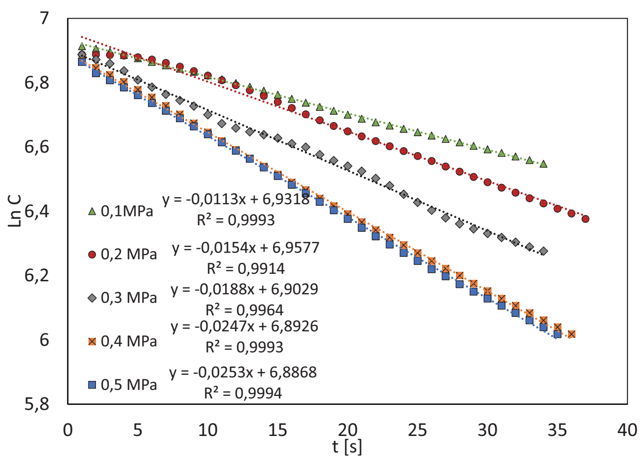

Fig. 7. Ammonia sorption curves in the kinetic range for TF 6 NN nozzle for different supply pressures

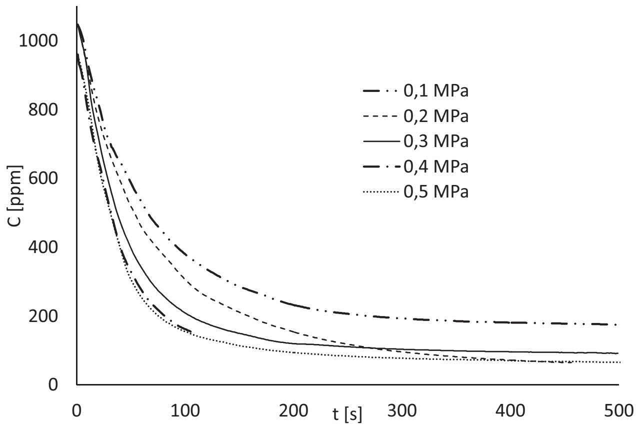

Fig. 8. Ammonia concentration as a function of time during water feed via TF 6 V nozzle for different supply pressures

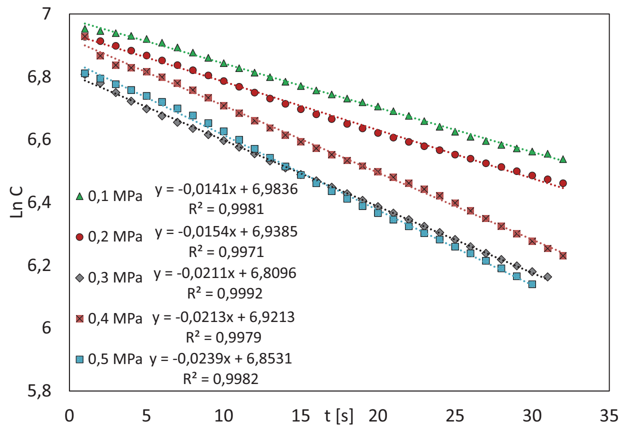

Fig. 9. Ammonia sorption curves in the kinetic range for a TF 6 V nozzle for different supply pressures

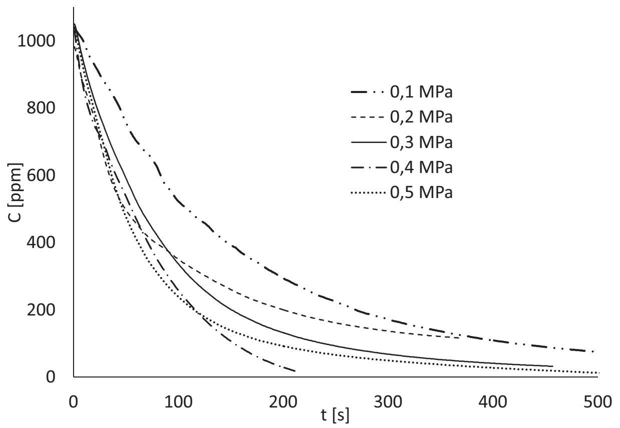

Fig. 10. Ammonia concentration as a function of time during water feed through nozzle CW 50 for different supply pressures

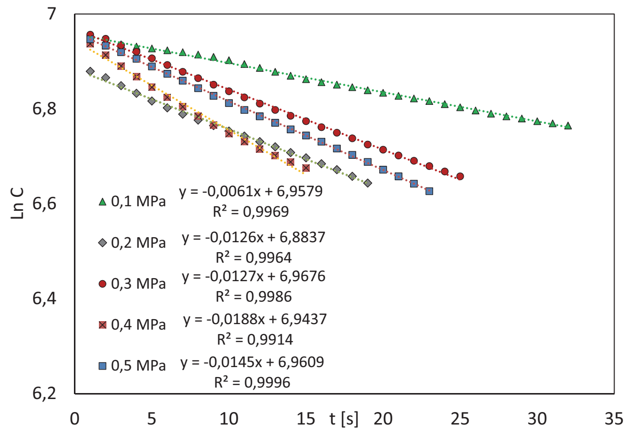

Fig. 11. Ammonia sorption curves in the kinetic range for a CW 50 nozzle for different supply pressures

Table 5. Kinetic parameters for ammonia sorption for the tested nozzles

Supply pressure	Nozzle type							
	NF 15		TF 6 NN		TF6 V		CW 50	
p	kp	$t_{1/2}$	kp	$t_{1/2}$	kp	$t_{1/2}$	kp	$t_{1/2}$
MPa	s-1	s	s-1	s	s-1	s	s-1	s
0.1	0.0097	71.46	0.0113	61.34	0.0141	49.16	0.0061	113.63
0.2	0.0145	47.80	0.0154	45.01	0.0154	45.01	0.0126	55.01
0.3	0.0161	43.05	0.0188	36.87	0.0211	32.85	0.0127	54.58
0.4	0.0213	32.54	0.0247	28.06	0.0213	32.54	0.0188	36.87
0.5	0.019	36.48	0.0253	27.40	0.0239	29.00	0.0145	47.80

The results of the tests have shown that the greatest effect of nozzle supply pressure on ammonia sorption efficiency may be observed at lower values of p (Table 5, Figure 12). At higher pressures (above 0.4 MPa), the sorption rate becomes stable and even commences to decrease. This is particularly noticeable for the CW50 and NF15 nozzle. On the one hand, this may be due to the limitations of the diffusion rate, but on the other hand, at a certain intensity of space saturation with water streams, a critical rate of mixing of ammonia vapors is reached above which it is no longer possible to deliver its vapors to the droplet surface more rapidly. A similar situation may be observed for electrochemical systems with a rotating disk electrode. Once a certain rotational speed is exceeded, no higher process stream values are observed. The limiting stream value is reached (Bard and Faulkner 2001).

Achievement of the limiting parameters of the system will depend not only on the intensity of the water jet application. The spray characteristics will also have a very important influence. The NF15 nozzle is a flat jet nozzle that produces a relatively narrow spray pattern (Wąsik et al. 2022). An increase in pressure above 0.4 MPa in the narrow water supply zone will no longer increase the rate of ammonia delivery from deep inside the chamber. The impact of the liquid stream is of a local nature and hence the rate of NH_3 delivery will be limited by the rate of diffusion. What is more, the increase in pressure will result in an intensified rate of droplet fall. This contributes to reducing the contact time of the droplet with ammonia vapor. Ultimately, above a certain pressure, a decrease in curtain efficiency can be observed, as may be seen by comparing the constant kp for the NF15 nozzle at 0.4 and 0.5 MPa.

Different observations than those for the NF15 nozzle have been made for the CW50 nozzle, an axial nozzle with a full spray cone and a spray angle of 80°. This angle is significantly larger than in the case of the remaining tested nozzles. In addition, the jet is characterized by a much greater uniformity of spraying. Saturation of space with water droplets and the effectiveness of the mixing effect can therefore be achieved much quicker than with other nozzles. This becomes apparent for the $t_{1/2}$ value, which tends to fluctuate relatively insignificantly already at pressures over 0.2 MPa.

The dispersion angle and the shape of the generated jet have a significant effect on the efficiency of the sorption process. As the supply pressure increases, the spray area tends to increase as well (Majder-Łopatka et al. 2017). The CW50 nozzle's better space-filling and large spray angle provides it with relatively high sorption efficiency at similar supply pressures, but at much lower water capacities. This may be clearly seen in Figures 13 and 14, that illustrate the dependence of the apparent sorption constant of ammonia as a function of water capacity and supply pressure. The CW50 nozzle has similar k_p values at a flow rate of 100–150 $dm^3 \cdot h^{-1}$ as the other nozzles at a value that is two or even three times higher. A particularly large difference is observed in comparison with the NF15 nozzle.

This conclusion is of particular importance from the point of view of rescue techniques that involve uncontrolled releases of hazardous substances. This clearly shows that the water curtains currently in use, which produce a narrow jet of water characterized by high intensity, serve primarily as a mechanical barrier to prevent the spread of hazardous substance vapors. Better use of water streams to absorb substance vapors would be possible by changing the nozzle design to allow it to better fill the space by optionally providing the curtain with a wider throw angle.

For the efficiency of vapors sorption of hazardous substances by the curtains, the residence time of the drops in the air is important. The flight trajectory of small drops can be described to a good approximation by Newton's second law (Sheppard 2002). Drops thrown at a greater angle have a longer residence time in the air. According to the fourth-order Runge-Kutta equation (equation 4), the terminal velocity (Vt) of water drops decreases as their diameter decreases, with the velocity reaching its minimum when the drops reach a size where du/dt=0 (Fig. 15).

$$\frac{du}{dt} = g - \frac{3q_a}{8rq}\left[\frac{12\nu}{ru} + \frac{6}{1+\sqrt{2ru/\nu}} + 0{,}4\right]u^2 \qquad (4)$$

where:
u – drop velocity [ms^{-1}]
q_a – air density [$kg\ m^{-3}$]
q – liquid density, [$kg\ m^{-3}$]
ν – kinematic viscosity [m^2s^{-1}]
r – drop radius [m]

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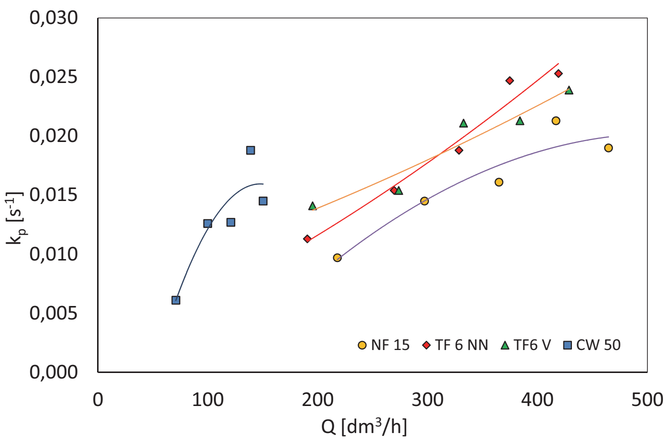

Fig. 13. Apparent sorption rate as a function of nozzle efficiency

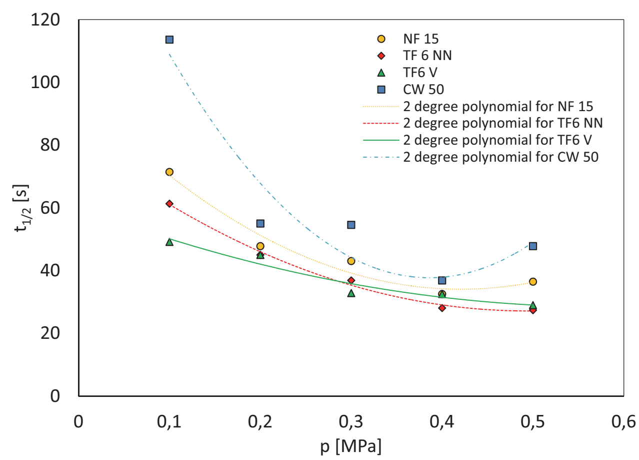

Fig. 12. Half-life of NH_3 concentration as a function of nozzles feed pressure

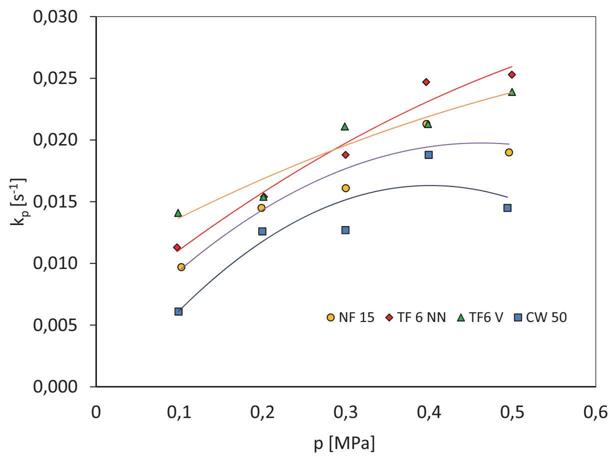

Fig. 14. Apparent absorption rate as a function of nozzles feed pressure

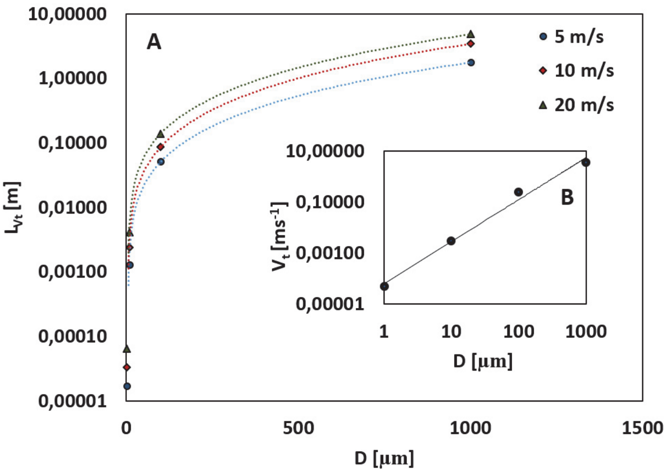

Fig. 15. A-dependence of the distance travelled by the drop (L_{Vt}) to reach the limiting velocity (V_t) for the initial velocity of the droplet V_o=5, 10 and 20 ms^{-1}. B- the limiting velocity of the droplet as a function of the droplet diameter (r). The results obtained after the numerical solution of the fourth degree Runge-Kutta differential equation (Sheppard 2002).

This condition is met for the nozzle CW50 which has drops with the smallest average surface diameter among the tested nozzles. The distance travelled by the drops (L_{Vt}) to reach the terminal velocity (V_t) increases with the initial drop velocity (V_o) what is shown in Fig 15. It has been observed that drops with a high initial velocity decelerate to reach their terminal velocity in the air. On the other hand, drops that have a low initial speed, under the influence of gravity, accelerate until they reach V_t.(Chan 1994). Therefore, with the achievement of a certain limiting pressure, the sorption efficiency does not increase, not only due to the achievement of the limiting parameters of the diffusion and nozzle capacity, but also due to the shortening of the droplet's residence time in the air.

Conclusions

On the basis of the conducted tests it was observed that the greatest effect of nozzle supply pressure on ammonia sorption efficiency may be expected at lower pressure values. At higher values, the sorption rate becomes stabilized and even starts to decrease. This is particularly evident for nozzle CW50 and NF15. On the one hand, this may be due to diffusion rate limitations. On the other hand, at a certain intensity of air saturation with water streams, a critical mixing rate of ammonia vapors is reached above which it is no longer possible to deliver ammonia faster to the droplet surface. In such a way the process limit is reached.

The decreases in the sorption rate constant observed for higher pressures may be due to a reduction in the residence time of the droplet. The longer this time, the more ammonia molecules diffuse to the surface of the falling droplet. As the supply pressure increases, especially for droplets dispersed at low angles, the contact time becomes significantly reduced, which impairs the potential for utilizing the water stream. Consequently, the executed tests indicate that the use of supply pressures for mist nozzles above 0.4 MPa is not justified.

The type of nozzle and supply pressure affects the distribution of droplets in space. The angle of dispersion and the shape of the generated jet have a significant effect on the efficiency of the sorption process. Complete filling of the space and a large spray angle assure relatively high sorption efficiency. The CW50 nozzle in the 0.2–0.4 MPa supply pressure range, with significantly lower water capacities than the other nozzles, has similar apparent sorption rate values.

It has been clearly demonstrated that flat jet nozzles generating a water stream in a narrow range tend to have a less intense ammonia sorption than full cone spray nozzles. It results from the fact that the space is filled much more narrowly and less evenly by the injected water current. However, this is very important from the point of view of rescue operations during the uncontrolled release of hazardous substances. This shows that the water curtains currently used by rescue units are of limited use. By producing a narrow jet of water of high intensity, they serve primarily as a mechanical barrier intended to prevent the spread of vapors of hazardous substances. Their absorption potential is therefore left largely unexploited, indicating the need for design changes to increase their scope of use in the elimination of clouds of hazardous substances.

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Wpływ ciśnienia zasilania dyszy mgły na proces absorpcji amoniaku

Streszczenie: W artykule przedstawiono wpływ ciśnienia zasilania dysz mgłowych na proces sorpcji amoniaku. W badaniach wyznaczono charakterystyki przepływowe dysz Q=f(p) oraz zależność stężenia NH_3 w funkcji czasu podawania strumienia wody różnych ciśnieniach zasilania dysz. Dla dysz TF 6 NN, TF 6 V, NF 15, CW 50 pomiary wykonano przy następujących ciśnieniach zasilania: 0.1 MPa; 0.2 MPa; 0.3 MPa; 0.4 MPa; 0.5 MPa. Zaobserwowano, że ciśnienie zasilania dyszy w największym stopniu wpływa na efektywność sorpcji amoniaku przy jego niskich wartościach. Przy wyższych wartościach ciśnienia szybkość sorpcji stabilizuje się, a nawet zaczyna spadać. Obserwowane spadki stałej szybkości sorpcji dla wyższych ciśnień mogą wynikać ze skrócenia czasu kontaktu kropli z amoniakiem i osiągnięcia krytycznej szybkości mieszania się par amoniaku w powietrzu intensywnie nasyconym strumieniami wody. Wynika to z ograniczeń szybkości dyfuzji. Z przeprowadzonych pomiarów wynika, że stosowanie ciśnień zasilania dysz mgłowych powyżej 0.4 MPa nie ma uzasadnienia. Należy zauważyć, że zmiana ciśnienia zasilania dysz o odmiennej konstrukcji może w różny sposób wpływać na ich efektywność sorpcji amoniaku. Rodzaj dyszy i ciśnienie zasilania wpływa na rozkład kropel w przestrzeni generowanej strugi. Kąt rozpylenia i kształt tworzonego strumienia mają decydujący wpływ na efektywność procesu sorpcji. Całkowite wypełnienie przestrzeni oraz duży kąt rozpylania zapewniają stosunkowo wysoką skuteczność sorpcji.