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NOISE ANALYSIS AND REDUCTION METHODS IN SANITATION FACILITIES AND EQUIPMENT

The article presents an analysis of noise in sanitary devices, and the described methods of reducing noise in places where noise occurs. The given results of noise tests of sanitary facilities and workplaces concerns one of the municipal company. Described sources of noise in water supply, sewage as well as ventilation and air conditioning systems. It has been shown that the noises occurring in residential buildings may be caused by excessively high pressure inside the installation, where, for example, when closing the valve, a water hammer phenomenon arises, causing audible noises, especially when the installation is made of metal materials. The article analyzes noise in sanitary facilities, describes the methods of reducing noise in places where noise occurs. The given results of noise tests of sanitary facilities and workplaces in one of the municipal companies of the city of the Subcarpathian province. Described sources of noise in water supply, sewage as well as ventilation and air conditioning systems. It has been shown that the noises occurring in residential buildings may be caused by excessively high pressure inside the installation, where, for example, when closing the valve, a water hammer phenomenon arises, causing audible noises, especially when the installation is made of metal materials. It has been shown that the main causes of noise in plumbing systems can be rigid pipe fittings. Noises in the sewage system are related to the outflow of used water in vertical and horizontal sections. The phenomenon most often occurs in places connecting vertical pipes with horizontal pipes, as well as the use of too small diameters of pipes. Material noise reduction in sewage systems can be ensured thanks to a properly designed system of fastening pipes to fixed elements. An important step is to use appropriate sound insulation to stop unwanted sounds. The reason for noise in the air-conditioning and ventilation system are changes in the velocity of the flowing air mass and the occurrence of turbulences during the change of the air flow direction. This causes the ducts to resonate and the air flow noise through the diffusers. The most common noise problem in the central heating installation is the use of a solid fuel

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boiler, the maintenance work of the device is a problem, as it requires cleaning the furnace, which is related to the noise that is transmitted through the installation pipes to the rooms. Based on the analysis of workstations at the municipal company plant, it has been shown that the highest conformity deviation level is in the drying room in the position of a machine and device operator

Keywords: noise, sanitation facilities, sanitation equipment, noise reduction methods

1. Introduction

In the last few decades, it has become an obvious necessity to protect the environment as a response to threats to human living conditions caused by the development of industry, means of transport, communication, and mechanization [1-4]. The enormous development of technology and industry brought not only great inventions, new machines and devices, huge buildings, but also many kind of hazards [5, 6].

The basis of environmental hazards includes acoustic hazards, i.e. noise and vibrations. Man is daily exposed to many noise sources. Machines and devices are sources of noise not only at workplaces, but also in public spaces. Recent studies show that exposure to noise is on an increasing trend and poses a serious threat to public health. The hazards related to excessive noise exposure, especially at night, are sleep disturbances, excessive fatigue, stress, irritability, weak concentration capacity or cardiovascular diseases [7, 8].

This article presents the results of noise tests in sanitary facilities (/plants) and workplaces in one of the municipalities in the Subcarpathian province.

2. Noise protection in sanitary installations

2.1. Noise in water systems

The best solution to avoid noise in the water system is to identify its source. Noises in the water pipes arise during water intake, due to cross-sectional narrowing. Even a properly designed plumbing system in terms of the hydraulics of the selection of pipes materials does not definitively reduce noise. The vibrations of the pipes' walls are stimulated by the fluid-structure dynamic interactions [9]. Then, pipes' wall vibrations are propagated through the surrounding air and the walls in which the pipes are installed. If this mechanical vibrations are at the right frequency and intensity, the human's ear will detect an acoustics effect. This is noise.

Noises in residential buildings can be caused by too high pressure inside the installation, where, for example, when closing the valve, a water hammer phenomenon occurs, causing audible noises, especially if the installation is made of metallic materials.

Static pressure in a properly designed installation should not exceed 0.5 MPa (5 bars). In situations where the pressure is too high, a pressure reducer can be used at the main water intake of the installation. Rigid pipe fittings can also be a major cause of noise. Installation brackets are designed to ensure flexibility through the use of rubber pads. Other sources of noise may be the result of design errors or constructors lack of experience.

2.2. Noise in sewage installations

According to the 2018-01 standard PN-B-02151-2: the permissible noise level in residential premises should not exceed 35 dB during the day and 25 dB at night [10]. First of all an important issue is the fact that we cannot completely eliminate the noise of the sewage system. Nevertheless, we must make every effort to ensure that their noise level does not exceed the prescribed standards. Noise reduction is possible. However, it requires multi-specialized knowledge in many fields, skillful pipe-circuit design, appropriate selection of materials and the most important requirement is a skillful assembly work.

Noises in the sewage system are related to the outflow of used water in the vertical and the horizontal sections. The phenomenon most often occurs in connecting crosses of vertical pipes with horizontal pipes, as well as the use of too small diameters of pipes. An equally important issue is the optimal location of sanitary facilities. The arrangement of the rooms takes place at the architectural design stage, and this is the most important issue of the appropriate design. The best way is to locate them next to each other, preferably in one riser. That would reduce the risk of excessive noise. It is a mistake to install the facilities next to a rest zone, such as the bedroom. A significant issue is the routing of the evacuation pipes and the properly designed pipes slope. The easiest way to do this is in the case of a sink or washbasin, which is always located at a certain height above the floor.

Regarding soundproof systems, an important role is played by the clamps used to fasten the pipes, they should have acoustic inserts made of flexible material. However, in traditional installations it is necessary to fill the space with mineral wool [9-11].

There are two types of noise in sewage installations:

- material noise - these are vibrations of pipes, transferred by means of assembly elements (e.g. clamps) to walls and ceilings, and as a result to adjacent rooms,
- air noise - the noise is caused by air in the downpipe, especially in connecting crosses of horizontal and vertical sections.

One way to reduce air noise is to increase the mass of the installation as increasing just the thickness of the duct walls does not give significant results. In

the case of using modern types of non-metallic materials with higher density, this allows for higher noise absorption parameters.

Material noise reduction can be ensured thanks to a properly designed system of fastening pipes to fixed elements, the task of which will be to damp unwanted vibrations [9-11].

There are three basic types of noise sources in sewage pipes:

- noises of water falling vertically,
- horizontal water flow noises,
- kickback noises due to bents.

Regardless of the pipe routing technique, it is recommended to use insulated pipes horizontally, vertically and at the floors. If we have spare space, it is recommended to isolate the approaches. It is burdensome to install in the wall grooves of rooms that require special protection. Running vertical installations in tight grooves causes more and more problems in damping the vibrations of the material. On the other hand, the use of lighter pipes has a negative effect on the noise reduction phenomenon. As a result of the conducted research and experiments on the noise phenomenon in sewage systems, low-noise installation solutions are used, made of polypropylene (PP) and polyvinyl chloride (PVC) materials by increasing the specific weight of the materials compared to the use of traditional pipes. At present, there are many low-noise sewage systems available on the market, which include complete sets of pipes, fittings, and fixings. A characteristic feature of such systems are tapes, securing bands and noise dampening mats [11].

From the point of view of acoustic properties, sewage systems should be installed with properly designed clamps (this recommendation has been repeated at least 4 times. It is better to remove). Regarding clamps, it is recommended to:

- fix the clamps in the permanent structure of the building,
- mind the distance between two handles in a horizontal installation as it should be equal to 10 times the outer diameter of the designed conduit,
- in sewage risers, where the storey is higher than 2.5 m, to use fixed and sliding clamps,
- for vertical installation, the distance should be 1-2 m,
- keep the appropriate distances between the clamps and other cables.

The proper passage of the installation should be tightly secured and the use of a material enabling tight acoustic and anti-moisture insulation.

2.3. Noise in air conditioning and ventilation systems

The main sources of noise in air conditioning and ventilation systems are:

- air conditioners,
- fans,

- air launchers and air intakes,
- exhaust air diffusers and diffusers,
- air-conditioning and ventilation unit,
- channels.

The main source of noise in the air conditioning and ventilation system is the fan. To minimize excessive noise, a key step is to select the fan at the design stage. The reasons for noise in the installation are also changes in the velocity of the flowing air mass and the occurrence of turbulences when changing the flow direction. This causes the ducts to resonate and amplify the noise through the diffusers. The recommended air flow velocity in the main canals is a value of up to 5 m/s and up to 3 m/s in the branches. The air flow velocity in the supply air grilles should be in the range of 1-2 m/s, while in the exhaust grilles the velocity range is of 2-3 m/s.

The device responsible for damping noise is a duct silencer. When designing the silencer for the installation, the possibility of maintenance and repair works should be taken into account (disassembly, assembly, cleaning or testing).

When selecting the installation, you should take into account the need to meet specific requirements. In areas where this is impossible, we use measures for insulation and noise suppression to reduce the noise. When designing ventilation systems, remember that the noise inside the installation easily propagates, reflects and interferes over long distances. The control panel, which will be located on the lowest floor, can be heard in the attic. Therefore, acoustic silencers should be used. Mineral wool is a very good acoustic insulator and absorber of noise.

Permissible noise level of air conditioner for a single-family unit is: 50 dB in daytime and 40 dB at night. While for multi-family units it is 55 dB during daytime and 45 dB at night.

The best materials to provide protection against excessive noise are made of raw materials with a density above 700 kg/m^3, such as rubber. It is made of 20 mm high boards. Highly flexible and resilient materials are used to damp unwanted vibrations throughout their service life. In the past, mineral wools were used to insulate buildings. Unfortunately, they do not meet modern legal requirements. Nowadays, polyester wool is used, they are easy to install at lower cost. An additional counteracting against excessive noise is the use of vibration-absorbing pads and materials outside or inside the housing of the device.

2.4. Noise in central heating installations

The main sources of noise in central heating systems are pipes and fittings, pumps, valves, and radiators.

The most common noise problem in the central heating installation is the use of a solid fuel boiler. To reduce the noise level, pipe insulation and proper

routing are used. In the case of using gas fueled boilers, noise is unusual. They are distinguished by their quiet operation, unlike solid fuel boilers. If the boiler room is properly situated, the problem with the burner operation is not bothersome. Radiator valves with a regulation function can be other types of noise sources in the central heating systems. To avoid, two variants are used: the reduction of the efficiency of the water circulation pump and the replacement of the flow control valve with a larger diameter one.

The central heating installation should be designed in such a way as to minimize noise to the greatest possible extent. Loud noise is related to the hot fluid flow in the pipelines and the pipes fastening system. Excessive noise in hot water installations is produced by the turbulent fluid-wall interactions, change of flow direction at separations, elbows, valves and hammer phenomena. The solution to reduce excessive noise in the installation is to reduce the water flow velocity. It will significantly affect the turbulence effect of the medium. The hotter the medium is, the lower flow should be the water flow velocity. If additional room is available, it is worth using supply lines with larger diameters.

3. Noise analysis at the municipal water and sewerage plant

The main task of the Municipal Water and Sewerage Plant is the supply of drinking water and the disposal of sewage. The water supply for the city and the neighbouring communes is based on a shore intake located on the river, with a daily average production capacity of 40,000 m³/d, and a peak production capacity of approximately 84,000 m³/d.

Within the Occupational Health & Safety preventive actions frame, the noise exposure hazard and noise risk management in the water supply plant were controlled and monitored [12].The audit concluded the full conformity of the practices with the Occupational Health & Safety regulations regarding the average level of daily noise exposure, the maximum sound level, and the use of hearing protection of the employees in workplace. The audit included two independent noise measurements at two different locations in the building of the clean and raw water pumping station. The two measurements were different by 2.9 dB. The difference of 2.9 dB is significant as it is about 5 times of the standard uncertainty level of 0.6 dB of the conventional measuring equipment. However, it has no significant impact of the Occupational Health & Safety level of the plant given that the measured noise level was low.

The Municipal Sewerage Plant was also audited within the Occupational Health & Safety preventive actions frame. Noise measurements in the sediment management building - press room, were carried out by BQJ Research Laboratory for 2020 in accordance with PN-N-01307:1994 and PN-EN ISO 9612:2011 [13-15].

The characteristics of the site are: work in 3 shifts, in changing weather conditions, in the field, at heights and in hollows, there is a possibility of contact

with chemical substances, in crisis situations it is necessary to wear a gas mask, breathing apparatus and gas-tight suit.

The results of measurements of exposure to noise and the maximum A-sound level at the Municipal Water and Sewerage Company in 2017, 2018 and 2020 at the Water Treatment Apparatus stand (based on [3]) are as follows:

- noise exposure level related to an 8-hour working day 86.40 dB, maximum A sound level 90.30 dB. The permissible noise values were found to be exceeded at the tested workplace in terms of $L_{ex,8h}$. Place of measurement: building of sediment management (14.06.2017 y.),
- two noise measurements were made. Noise 1 related to an 8-hour working day 95.90 dB, maximum A sound level 96.50 dB. Noise 2 related to an 8-hour working day - 95.20 dB, maximum sound level A - 95.20 dB. In both cases, the permissible noise values at the tested workplace were exceeded in terms of $L_{ex,8h}$. Place of measurement: building of sediment management (04.09.2018 y.),
- noise exposure level related to an 8-hour working day 77.50 dB, maximum sound level A 89.10 dB. The permissible noise values were not exceeded in terms of $L_{ex,8h}$ and L_{Amax}. Place of measurement: sludge concentration station (22.10.2018 y.),
- two noise measurements were made. The first noise related to an 8-hour working day 79.50 dB, maximum A sound level 91.70 dB. The second noise related to an 8-hour working day 83.50 dB, maximum A-sound level 94.60 dB. The permissible noise values were not exceeded in terms of $L_{ex,8h}$ and L_{Amax}. Place of measurement: sludge press room (30.10.2020 y.).

Noise limits were exceeded in the sludge management building and in the sludge management building. The highest noise values were measured in the sludge management room, in this respect it is necessary to use individual protection equipment in the room. However, in the other buildings, the values are appropriate, there is no obligation to use hearing protectors.

Summing up the water production department at the municipal water and sewerage company plant, according to the conducted research on the harmful factor of noise, the highest conformity deviation in terms of daily exposure to noise (8-hour working day) is in the Sediment Management Building. The measurements were carried out on September 4, 2017 by the Labor Hygiene Laboratory of the Provincial Sanitary and Epidemiological Station. The results of noise exposure measurements for this building oscillated between 95.20-95.90 dB, which significantly exceeded the permissible values, while the maximum A-sound level for the same building was within 96.50-95.20 dB. On the other hand, the lowest noise measurement values were the sludge thickening station. The measurement was carried out on October 22, 2018 by the Labor Hygiene Laboratory of the Provincial Sanitary and Epidemiological Station. The measurement result in relation to an 8-hour working day was 77.50 dB, which

was the lowest value among the studies conducted on the harmful factor, which is noise [13].

Noise measurements were carried out directly in the sewage treatment plant and in individual rooms, i.e. the room of blowers, grates, pumps, compactor and dryer. All measurements were made in accordance with the applicable PN-N-01307: 1994 and PN-EN ISO 9612: 2011 standards. Factors were measured in 2018 and 2020. No noise limits were exceeded in any of the presented rooms due to the protection of hearing of employees employed at the examined workplace.

The next room in the sewage treatment plant is the pump room, the measurement was carried out in 2020 at the workplace of the machine and device operator, foreman. The noise measurements are as follows: the noise exposure level related to the 8-hour working day was 69 dB, and the maximum sound level was 82.20 dB.

In the compactor room at the wastewater treatment plant, the measurement was carried out in 2020 at the position of a machine and device operator, foreman. The measurement results are as follows: the noise exposure level related to the 8-hour working day was 74.60 dB, and the maximum sound level was 81.90 dB.

The last room is a drying room, the measurement was carried out in 2020 at the position of a machine and equipment operator, foreman. The measurement results are as follows: the noise exposure level related to the 8-hour working day was 84.50 dB, and the maximum sound level was 90.70 dB.

The results of the measurements of noise exposure at the machine operator's station refer to the following station: 4-team system, duration of the work shift 480 minutes, personal protective equipment - sound-absorbing ear muffs, duration of occupational exposure - 50 minutes (10 minutes supervision and operation of the compactor, 15 min pump operation supervision, 10 minutes supervision of magnetic blowers ABS TURBOCOMPRESSOR HST 40, 15 minutes supervision of grilles), during the rest of the work in the control room, visiting the individual facilities of the sewage treatment plant.

The results of the measurements of noise exposure and the maximum sound level A w municipal water and sewerage company in 2018 and 2020 as a machine operator (based on [13]) are as follows:

- noise exposure level related to an 8-hour working day 67.90 dB, maximum A sound level - 83.90 dB. The permissible noise values were not exceeded in terms of $L_{ex,8h}$ and L_{Amax}. Place of measurement: sewage treatment plant building, work position: machine operator (22.10.2018 y.),
- noise exposure level related to an 8-hour working day 57.20 dB, maximum A sound level – 69.50 dB. The permissible noise values were not exceeded in terms of $L_{ex,8h}$ and L_{Amax}. Place of measurement: blowers room, work position: machine and device operator, foreman (30.10.2020 y.),

- noise exposure level related to an 8-hour working day 68.10 dB, maximum A sound level – 80.40 dB. The permissible noise values were not exceeded in terms of $L_{ex,8h}$ and L_{Amax}. Place of measurement: grids room, work position: machine and device operator, foreman (30.10.2020 y.).

4. Conclusions

According to the measurements carried out for noise health & safety hazards in work, the highest conformity deviation is in the drying room in the position of the machine and equipment operator, foreman. The measurement result was 84.50 dB. The blower room turned out to be in the best conformity level, the measurement oscillated around 57.20 dB, which is perfectly within the standard and compliant with the permissible values at workplaces.

When analyzing buildings and rooms in municipal water and sewage company, highest conformity deviation were recorded in water treatment buildings, the values in two buildings exceeded the permissible standard threshold values (85dB) in the sludge management building. In a situation where the sound level is too high and exceeds the permissible values, it is necessary to use personal protective equipment, such as noise protection (inserts, ear muffs, a set of helmets with ear muffs) and 10-minute breaks are recommended. In the sewage treatment plant, at the positions of the machine and equipment operator, the foreman, significantly lower values of the noise levels of the equipment operation were registered, and the permissible standard, i.e. 85 dB, was not exceeded in any of the cases. In such a situation, personal protective equipment is not recommended, but personal protective equipment may be used voluntarily during the work.

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