NOISE DISPERSION MODELING OF THE TERRITORY - OF THE AGRICULTURAL COMPANY AND THE RESIDENTIAL AREA

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Abstract

The mechanization of farm production, increasing traffic flows in towns and villages, and modernization of farm machinery have led to a rapid increase in acoustic discomfort zones. Noise levels in the living environment are a key factor in determining the comfort index. Therefore, there is a growing focus on studying noise processes.

The article presents the company's farm, which includes a newly designed cowshed, a liquid manure lagoon, a calf field camp, and a silage trench. The noise calculations consider the noise sources used in both the existing and project areas. The noise modeling was carried out using the CADNA A 4.0 computer program, and noise dispersion maps for Lday (12h) and Ldvn were modeled using ArcGIS 10.8 software.

The simulations carried out in the article showed that the acoustic situation will change slightly after the implementation of the project compared to the current situation. The noise level at the noisiest location during the daytime will not exceed 35 dB(A), and no noisy activities will occur during the evening and night-time. However, activities conducted outside the territory resulted in a noise level of 57.5 dB(A) during the day, which exceeds the limit set by HN 33:2011.

Keywords: *noise, noise modeling, planned economic activities, background noise sources, maps*

1. INTRODUCTION

The health effects of noise have been known since ancient times. Over the last century, cities have grown rapidly under the influence of society's cultural customs and new technologies. Noise is associated with many types of human activities, but the noise produced by heavy vehicles has the highest impact on humans.

The development of the infrastructure of urbanised areas, industrial districts, roads, and economic companies increasingly expands the zones of acoustic discomfort. Residential and public building areas fall into these zones.

Transport is one of the main sources of noise, which has a particularly large negative impact on the environment (Lezhneva et al., 2019). With the modernisation and expansion of farm companies, the distances between residential quarters are constantly decreasing. The growing traffic of farm machinery, light and heavy vehicles has greatly increased the level of emitted noise in the surrounding area. That is especially relevant when farm machinery rolls onto public roads. In rural areas, loud noise (up to 120 dB(A)) is caused by tractors, harvesters, self-propelled shredders and other agricultural machinery (Jotautienė, Vasiliauskas, 2010).

The main sources of noise in road vehicles are their engines; tires in contact with the road surface; force and motion transmission mechanisms. It was determined that a passenger car emits a noise level of 70-80 dB(A), a bus - 80-85, a truck - 80-90, a motorcycle - 90-95, a tractor - 80-95 dB(A) (Grubesa & Suhanek, 2021). The noise level is also determined by the type of engine and its operating mode, technical condition of the vehicle, volume and intensity of traffic flows, driving speed, which changes from 50 to 30 km/h. can reduce the noise level by 5 dB(A) (Vilniškis et al., 2022). When the speed increases from 40 to 60 km/h, the noise level increases by 2-4 dB(A). When the vehicle is traveling at more than 60 km/h speed, wheel noise due to road surface friction exceeds engine noise (Asensio et al., 2021).

The intensity of the traffic flow is one of the most important factors, that determine the noise level. When the intensity of the traffic flow varies from 100 to 400 cars per hour, the noise level can increase up to 12.5 dB(A), and the most significant influence has the noise caused by heavy vehicles or self-propelled farm equipment. Therefore, the noise caused by transport also depends on the composition of the flow. The noise level of heavy transport at an average speed of 100 km/h is about 87 dB(A). For comparison: the noise of a medium-duty vehicle at the same speed reaches 83 dB(A), and the noice of a light one - 77 dB(A) (Jotautienė, Vasiliauskas, 2010).

Research problem – in rural residential areas, the traffic of the company's farm machinery increases during the day. Although the noise produced by this flow is relatively short term, it is intense (85-90 dB(A) or even more). Therefore, it is important to assess the environmental acoustic pollution caused by such transport in smaller residential areas (rural areas and settlements).

Research aim – to assess the existing situation and the planned expansion of the noise generated by the farm company. As well as, its possible impact on the nearby residential environment. Noise calculations are carried out by evaluating the noise sources used both in the existing area of the farm company and in the planned one.

2. MATERIALS AND METHODS

2.1. Noise sources of planned economic activity (hereinafter referred to as PUV).

Since the company's farm is being expanded to the existing one by connecting the newly designed cow shed, liquid manure lagoon, calf field and silage trench, noise calculations are performed by evaluating the noise sources used in both - the existing area and the planned one.

The main sources of noise in the analysed area are and will be: farm machinery and heavy transport (for transporting milk and livestock) and their flow into the area. Access to the area of the planned facility is provided from the eastern side of the plot, but the the southern side of the area will also be used as the entrance to the newly built cowshed. The loading, unloading, preparation, transportation and distribution of fodder, as well as manure removal, are carried out by the company's tractors. The maximum speed of these vehicles in the area of the company is 20 km/h. Many scientific publications examine the acoustic environment of tractors used in agriculture, where reported noise values range from 79-100 dB(A) (Rottensteiner et al., 2013; Moses et al., 2015; De Vito, 2017; Barač et al., 2016). Older tractors (about 20 years old) produce 100 dB(A), new tractors less. Taking into account, that the company's tractors are up to 7 years old, a worse scenario was adopted during the simulation, when the noise level of the tractors is 96 dB(A), using the document "Noise NavigatorTM Sound Level Database with Over 1700 Measurement Values" (University of Michigan, Department of Environmental Health Science, Ann Arbor, MI June 26, 2015).

Trajectories of transport are accepted in the calculations by evaluating the movement paths of these vehicles in the area, and are calculated as linear sources. Trajectories of movement of farm equipment, light and heavy vehicles are also marked on the area plan. Transport runs on the company's area during the day, when the company's working hours are from 8 a.m. to 5 p.m. The number of employees per shift is up to 8 people (current situation), up to 20 people (planned situation).

Noise modeling was performed with the computer program CADNA A 4.0. Modelled noise dispersion maps of Lday (12h) and Ldvn using ArcGIS 10.8 software.

All existing and planned noise sources are presented in the table below.

Name of the noise source	Type of noise sources	Number of sources, flow per day	Working hours
Heavy vehicles (milk truck)	Line	1 pc.	8 a.m. - 5 p.m.
Heavy vehicles (to transport live animals)	Line	1 time/month	
Light traffic flow	Line	10 cars	
Light vehicles (8 parking spaces)	Polygon	8 cars	
Tractors	Line	3 pc.	
Planned sources			
Heavy vehicles (milk truck)	Line	2 pc.	
Heavy vehicles (to transport live animals)	Line	2 time/month	
Light traffic flow	Line	20 cars	
Light vehicles (15 parking spaces)	Polygon	15 cars	
Tractors	Line	4 pc.	

Table 1. Existing and planned sources of noise in the area

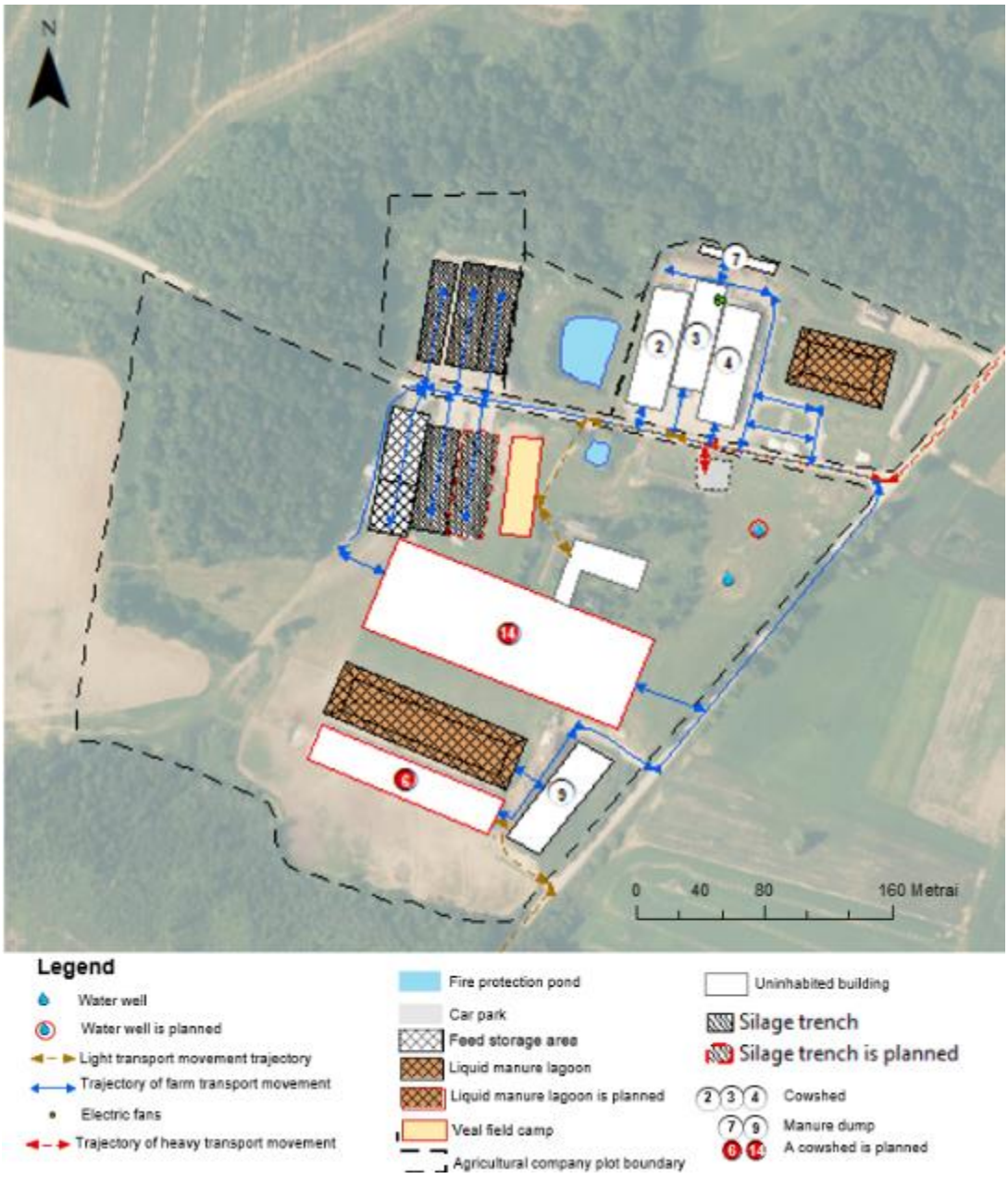


Fig. 1. Analysed area and planned noise sources

2.2. Background noise sources

Environmental noise modelling is carried out in a farm company, that is located in the municipality of Šakiai district. There are residential houses in the vicinity of the planned activity area in the northeast/east direction. The nearest living environment - individual residential house no. 6 environment (i.e. a 40 m zone around the house) is located at a distance of ~39 meters in the northeast direction from the plot boundary of the analysed territory. The next closest protected (residential) environment is 97 m away in the north-east direction (at residential building No. 4; see Figure 2).

Fig. 2. Residential houses and their environment

2.3. Evaluation method

Noise calculations were performed using the computer program CADNA A 4.0., using the methods indicated in the table below. With the help of the program, it is possible to quickly perform noise dispersion calculations influenced by different scenarios of economic activity and infrastructure development (by evaluating various variables: traffic intensity, speed, percentage of heavy and light vehicles in the calculated flow, noise and operating time of linear and area sources), compare the results and choose the best option for area development, structures or noise reduction measures.

The obtained noise level calculation results are displayed on the maps in different color intervals every 5 dB(A). Noise dispersion is calculated at a height of 1.5 m, noise dispersion step size dx(m):5; dy(m):5.

Document	Terms, recommendations
The noise management Act of the Republic of Lithuania was approved on 26 October 2004 order. IX–2499, (Official Gazette, 2004, No. 164–5971), Summary editorial from 2020-09-01 - 2023-01-01	Noise limit value shall mean an average value of L_{day}, $L_{evening}$, or L_{night}, the exceeding of which causes the manager of a noise source to enforce noise prevention and/or reduction measures.

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise	Annex II. Assessment Methods for Noise Indicators. *For industrial noise:* ISO 9613-2: 'Acoustics. Abatement of sound propagation outdoors. Part 2. The general method of calculation. *For road trafic noise*: The French national computation method 'NMPB–Routes–96 (SETRA–CERTU–LCPC–CSTB)', referred to in 'Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Journal Offieciel du 10 mai 1995, Article 6' and French standard 'XPS 31–133'. The above-mentioned methodology is also recommended by the Lithuanian Hygiene Regulation document HN 33:2011.
Lithuanian Hygiene Regulation HN 33:2011: Noise limit values in residential and public buildings and in their environment, approved by the Minister of Health of the Republic of Lithuania on June 13, 2011. by order No. V–604	This Hygiene Regulation determines the limit values of noise emitted by noise sources in residential and public buildings and their surroundings and is applied when assessing the impact of noise on public health.

Table 2. Legal documents related to noise management. Source: Juodkiene, 2023.

The predicted noise level of the planned activity is assessed according to the equivalent sound pressure level LAeq,T and assessed according to the requirements of HN33:2011 "Noise limits in residential and public buildings and their surroundings" (Zin., 2011, No. 75-3638) and the requirements contained therein limit levels of equivalent sound pressure. According to the hygiene norm and the periods provided in the Law on Noise Management of the Republic of Lithuania, the noise level is assessed during the day (7:00 a.m.-7:00 p.m.), evening (7:00 p.m.-10:00 p.m.) and night (10:00 p.m.-7:00 p.m.).3 Table. Maximum permitted noise limits in residential and public buildings and their surroundings (HN 33:2011)

Measurement sites	**Time of day, h**	**Equivalent sound pressure level (L_{AeqT}), dB(A)**	**Maximum sound pressure level (L_{AFmax}), dB(A)**
Dwellings in residential buildings (houses), bedrooms in public buildings, wards in inpatient health care institutions	7–19	45	55
	19–22	40	50
	22–7	35	45
In an environment of residential buildings (houses) and public buildings (except the catering facilities and culture centers), excluding transport noise	7–19	55	60
	19–22	50	55
	22–7	45	50
In an environment of residential buildings (houses) and public buildings (except the catering facilities and culture centres) affected by transport noise	7–19	65	70
	19–22	60	65
	22–7	55	60

Table 3. Maximum permissible noise limit values in residential and public buildings and their surroundings in Lithuania (HN 33:2011)

In the calculations, the height of the buildings, relief, meteorological conditions and noise absorbing properties of the area were evaluated. The area where the noise calculations are carried out is partially built up, so the existing and planned buildings act as noise propagation barriers. Therefore, all existing and planned buildings were evaluated in the noise calculation model.

The article presents only daytime noise dispersion maps, since tractors or other significant noise sources are not operating during the evening and night.

3. RESULTS

3.1. Current acoustic situation

The modelled detailed (Lday and Ldvn) noise dispersion maps of the current situation are presented in Fig. 3.

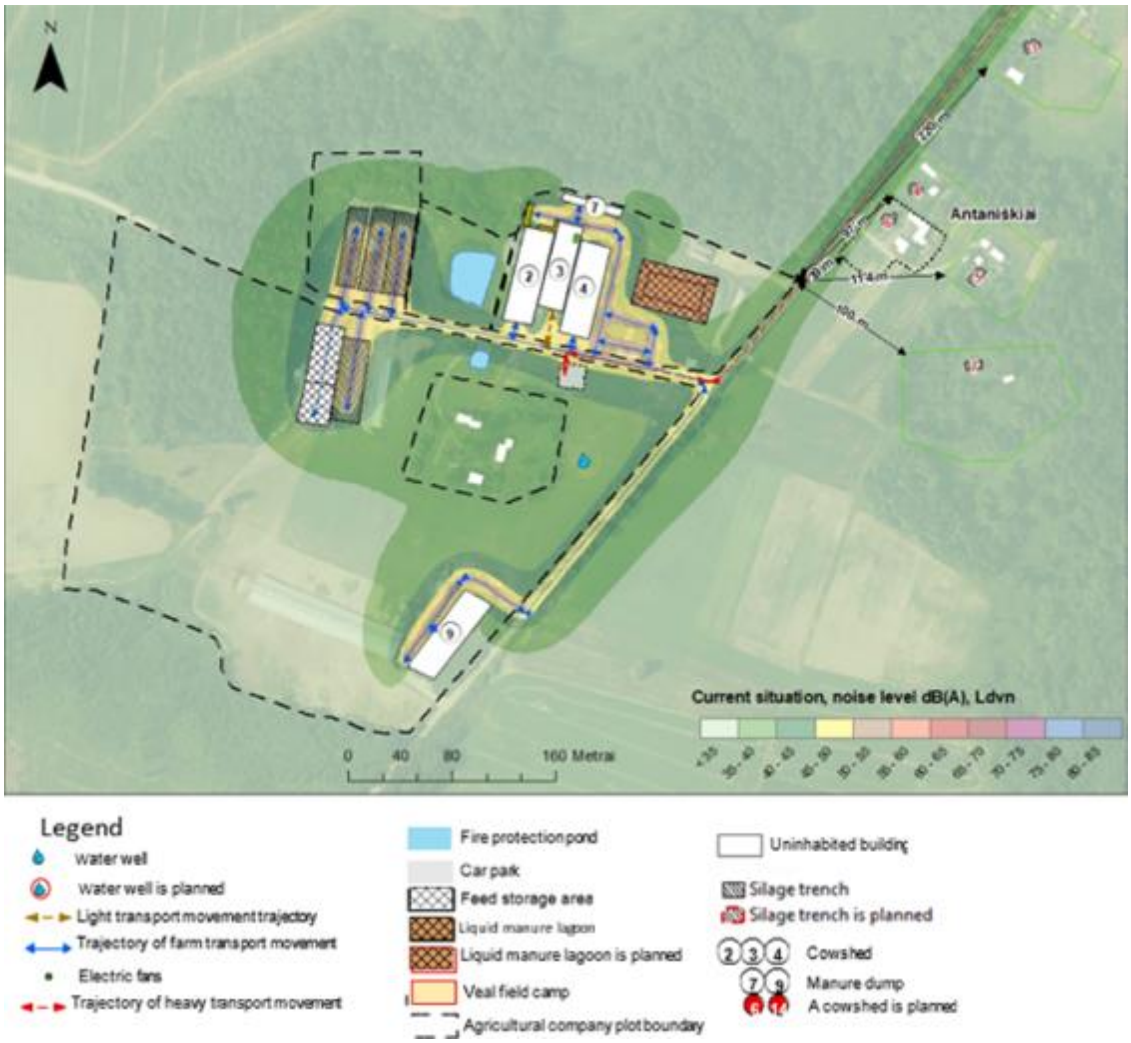


Fig. 3. Current situation Lday and Ldvn noise dispersion

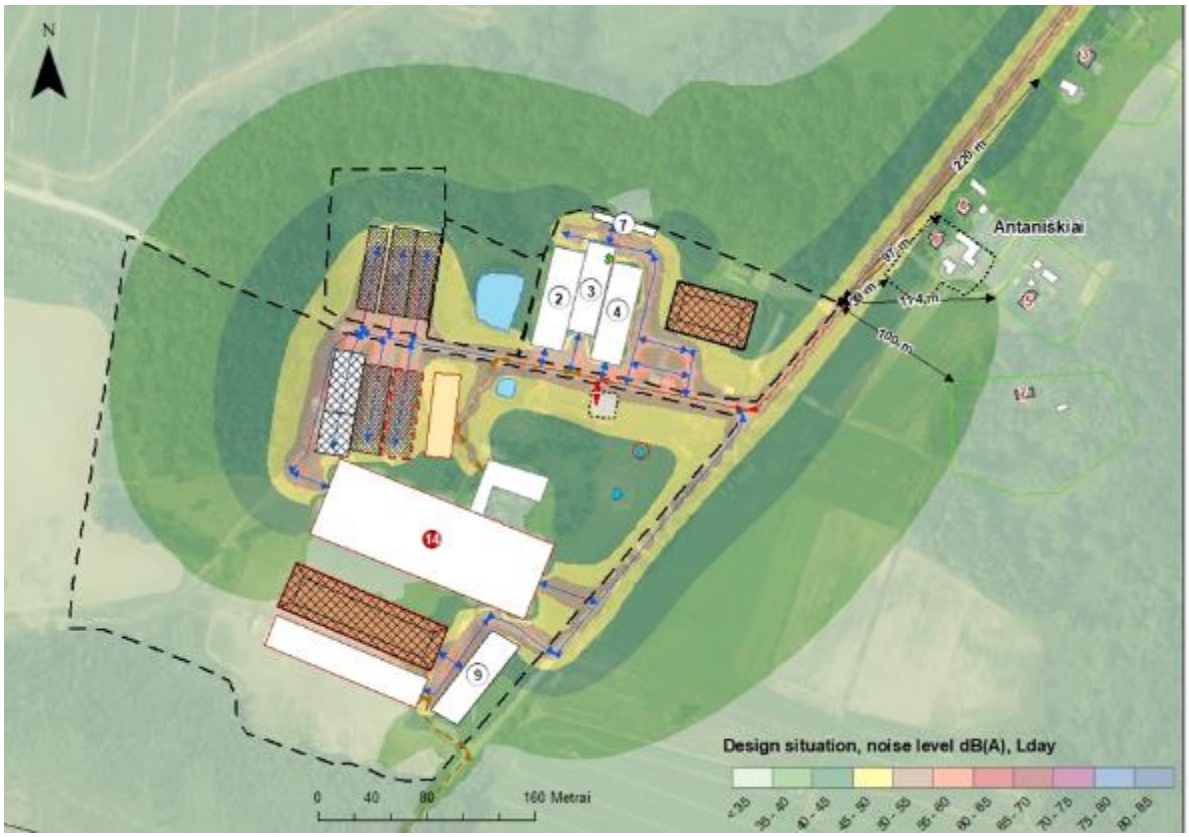
Noise level calculations have been carried out at the residential environments (No. 4; 5; 6 and 7). The calculated noise level caused by economic activity in the vicinity of the nearest residential houses will vary between 35.0-39.2 dB(A) during the day and will not exceed the limit value of HN 33:2011 1.

Address	Calculation location	Calculation height	Lday, dB(A)	Ldvn, dB(A)
No.6 (40 m living surroundings)	Protected environment	1,5 m	39,2	36,2
No. 4	Protected environment	1,5 m	38,3	35,3
No. 5; 7	Protected environment	1,5 m	<35	<35
Regulated equivalent sound pressure level (LAeqT), dB(A) In the environment of residential buildings (houses) and public buildings (except catering and cultural buildings) exposed to traffic noise			65	

Table 4. Background noise in the immediate residential environment

3.2. The predicted acoustic situation is only the of the planned economic activity plot (industrial noise).

The modelled detailed (Lday and Ldvn) noise dispersion maps of the predicted acoustic situation are presented in Fig. 4.



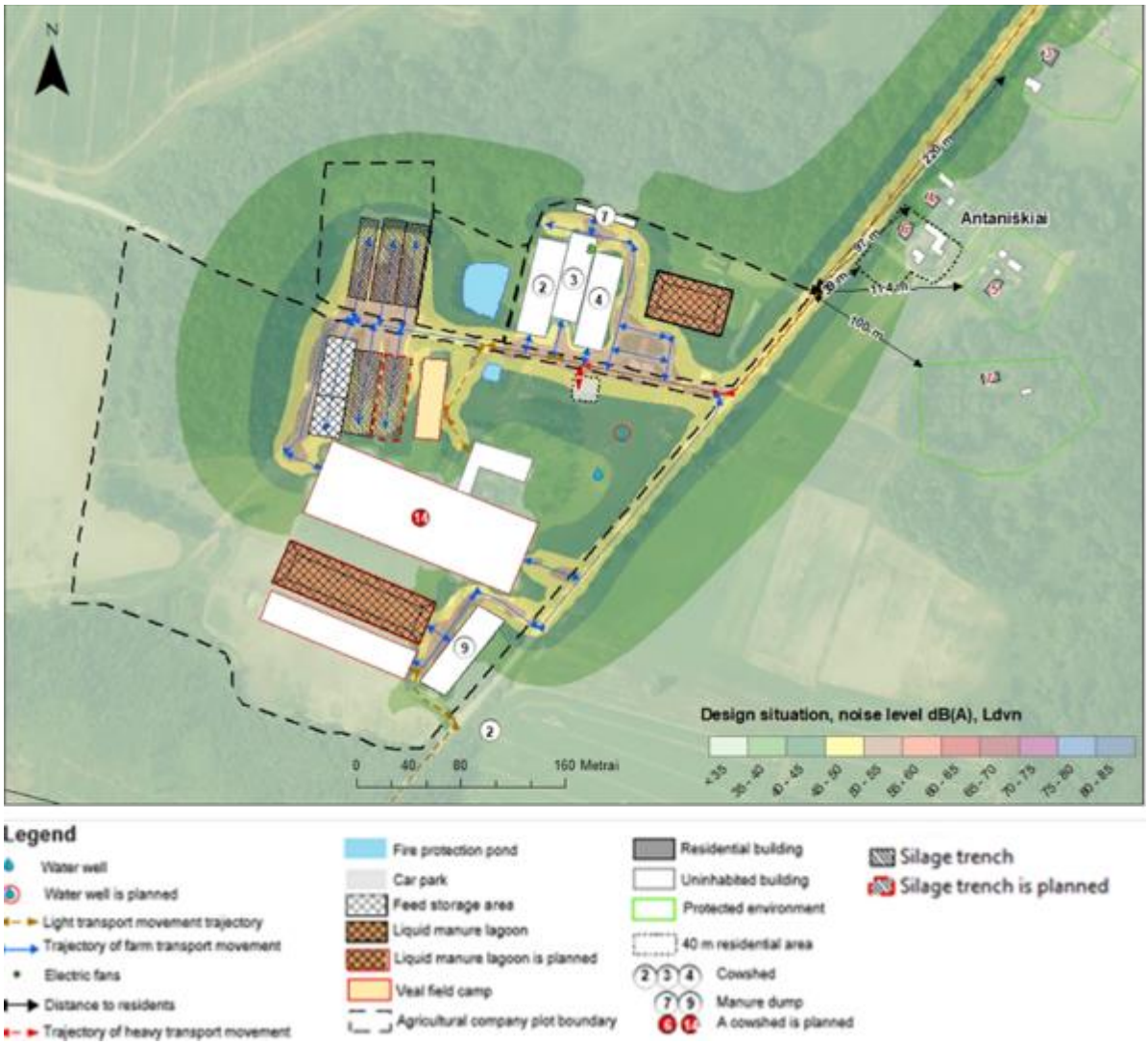


Fig. 4. Projected acoustic situation Lday and Ldvn

The predicted noise levels in the nearest residential areas are calculated and presented in Table 5.

Address	Calculation location	Calculation height	Ldiena, dB(A)	Ldvn, dB(A)
Nr. 6 (40 m living environment)	Protected environment	1,5 m	<35	<35
Nr. 4; 5; 7	Protected environment	1,5 m	<35	<35
Regulated equivalent sound pressure level (LAeqT), dB(A) In the environment of residential buildings (houses) and public buildings (except catering and cultural buildings), except for traffic noise			55	

Table 5. The noise caused by PUV in the immediate residential environment (without background)

Detailed noise modelling has shown that the planned economic activity will not have a negative impact on the nearest living environments in terms of noise. The noise level corresponds to the limit values set by HN 33:2011 "In the environment of residential buildings (houses) and buildings of public purpose

(except catering and cultural buildings), except for traffic noise". All noise indicators near the nearest residential buildings or their surroundings will be less than 35 dB(A).

3.3. The acoustic situation is predicted after evaluating the traffic access roads

Detailed noise modelling has shown that the planned economic activity will not have a significant negative impact on the nearest living environments in terms of noise. The noise level will comply with the limit values set by HN 33:2011 "Noise caused by traffic in the environment of residential buildings (houses) and public buildings (except catering and cultural buildings)". All noise levels near the nearest residential buildings or their surroundings will be less than 46.0 dB(A) during the day.

Home address	**Calculation location**	**Calculation height**	**Lday, dB(A)**	**Ldvn, dB(A)**
Nr. 6 (40 m living environment)	Protected environment	1,5 m	46,0	43,0
Nr. 4	Protected environment	1,5 m	45,3	42,2
Nr. 5; 7	Protected environment	1,5 m	36,4	<35

Table 6. Cumulative PUV and background noise in residential environments

After evaluating the results of the calculation, it can be seen that during the day at the eastern border of the company's plot, the noise level may be exceeded by 2.5 dB(A). This value is determined by the entrance/exit road to the farm running along the eastern border of the plot, which is intended for the manoeuvring of farm transport.

Calculation location, side of plot borders		**Calculation height, m**	**Lday, dB(A)**	**Ldvn, dB(A)**
PUV plot	West	1,5	46,6	43,0
	North	1,5	47,2	48,0
	East	1,5	57,5	54,5
	South	1,5	34,9	31,9
		Boundary values	55	-

Table 7. Noise emitted by PUV at the borders of the PUV plot

Taking into account the noise levels at the borders of the PUV plot, the sanitary protection zone cannot be equated with the borders of the PUV plot.

4. CONCLUSIONS

The performed simulations showed that the acoustic situation after the implementation of the project will change slightly compared to the current situation. After the implementation of the planned activities, it was established that the noise level in the nearest residential environments will comply with HN 33:2011 Residential buildings (houses) and public buildings (excluding catering and cultural buildings).

The noise level will be less than 35 dB(A) at the noisiest place during the day, and no noisy activities will be carried out during the evening and night.

After implementing activities outside the area, the noise level was set at 57.5 dB(A) during the day, i.e. higher than regulated by HN 33:2011 in the environment of residential buildings (houses) and public buildings (excluding catering and cultural buildings), except for traffic noise.

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