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ON NOISE ASSESSMENT AND NOISE CONTROL ENGINEERING PROBLEMS CAUSED BY SEASONAL VARIATIONS OF NOISE EMISSION AND EXCESS ATTENUATION

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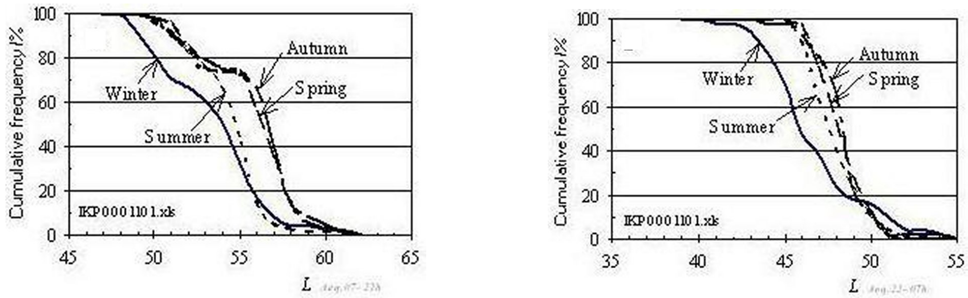
ABSTRACT
Big seasonal variations in noise emissions, excess attenuation, and living styles are typical in cold northern climates. The paper describes these variations and noise control engineering problems caused.

1 - INTRODUCTION
I limit the subject to North-European climate and conditions, although we can meet similar cold climates, for example, in North America, in North and Middle Russia, and in high mountain areas. A North-European type climate does not mean only low temperatures and snow in wintertime, but big seasonal climatic variations, too. In northern latitudes climatic variations are closely connected with the annual rotation of the length of daylight, or better to say, with the rotation of daily sun radiation budget.
Many noises exposing people have season dependent statistical characteristics. We can divide these characteristic features into a) activity or noise emission dependent and b) excess attenuation related ones. When we consider noise effects, we have to add variations that depend on receiver's behaviour or living habits. For example, a skiing centre usually produce noise only in winter time, as well as are the main part of the affected people there only during the season. The rest of the year the place with it's roads may be very silent and without audience. Another example: snowmobiles are used only in wintertime, but motorboats in inland water routes in summer time, when the waters are open.
Many countries have certain vacation times. In Nordic cold climates main vacations are held usually in July and (shorter) winter vacations in February, March, or April. Vacations and weekends increase noises and the number of exposed people in vacationing, recreational, and free time areas outside big cities, but may, or may not, decrease noises in urban areas. A special feature in Finland is the big number of free time houses. Nearly every fourth family has a free time house or cabin that is used mainly in summer time, during the vacation month and in weekends.
In winter time the short − or nil − daylight time limits all outdoor activities, and snow limits easy access to off-road areas by foots. For example, residential outdoor gardens and backyards are not actively used when temperatures are, say, bellow + 5...+10 °C, or when those are snow covered. People spend their free time mainly in indoor activities.
Cumulative statistical distributions in Fig. 1 give an example about typical annual and seasonal variations of daily $L_{Aeq,\ 07\ -\ 22h}$ - and $L_{Aeq,\ 22\ -\ 07h}$ -levels of urban ambient noise in a medium size (population: 86 000) Northern city centre [1]. In this case most winter days and nights are 2...3 dB(A) more silent than those in the other seasons.

2 - PROBLEMS AND BENEFITS CAUSED BY LOW TEMPERATURES
Most sound and vibration measuring instruments have the lower guaranteed operating temperature somewhere near −10 °C. Long time measurements in winter time expect special arrangements like heated microphones and closed, heated instrument cabins. A special problem to be considered is condensing humidity when cold instruments are moved (temporarily) indoors or in a warm car. Modern electronics, especially microphone preamplifiers, may be very sensitive for internal moisture.



(a): $L_{Aeq,07-22h}$. **(b):** $L_{Aeq,22-07h}$.

Figure 1: Cumulative seasonal distribution of daily levels over one year in a down town residential area in Kuopio/Finland [1].

Low temperatures, snow, and icing must be considered also in noise control design. For example, in industrial plants outdoor gearboxes and ventilation grilles, even outdoor silencers, must often be equipped with heating or deicing device. Materials used outdoors must tolerate $-30...-45$ °C. Machine designs and plant layouts must be such that snow and ice doesn't cause problems and can be cleaned easily off, when needed.

Low wintertime temperatures expect good thermal insulation in buildings. A benefit is that most thermally acceptable facade and window constructions have also rather high sound reduction, typically R'_w = 35...60 dB. A typical modern window construction is: 4 mm glass/ 10...12 mm air space/4 mm glass/100...150 mm air space/4...5 mm glass.

3 - SEASONAL VARIATIONS IN NOISE EMISSIONS, INDUSTRIAL NOISES

There are some industries that work only in certain season. Quality and/or quantity of raw materials used or plant capacity may be season depended. For example, a sugar plant using turnip as the raw material may operate only 2...3 months a year, and many smaller harbours are closed when thick ice cover the water routes. Power and district heating plants have higher capacity and fuel consumption (and fuel traffic, too?) in winter than in summer. Peak power stations may operate only during the coldest winter days. Another example: In wood handling plants and machinery frozen wood usually emits more impact noise, typically 3...10 dB(A) higher levels, than non-frozen wood.

Heating and cooling demands usually depend on external temperature. Most heating device emit more noise in winter time than in summer time, but cooling and ventilation device have the opposite behaviour. For example, a paper mill may have 2...4 dB(A) higher noise emission in summer than in winter due to increased ventilation capacity.

4 - SEASONAL VARIATIONS IN NOISE EMISSION, ROAD TRAFFIC NOISE

There are several reasons resulting in traffic noise emission variation. Most frequently we meet seasonal variation in traffic densities, speeds and/or tire/road noise. In Finland all light vehicles must be equipped with winter tires in wintertime. The season of winter tires starts on 1st November and ends on 31st March. The period of mandatory use is from 1st December to end of April. In Finland about 90 % of drivers use studded tires and ca. 10 % use either winter tires without studs or friction tires [4].

On bare asphalt pavements studded winter tires have 3...7 dB(A) higher noise emission than summer tires. Higher noise emission occurs at 0,1...2 kHz and at frequencies over 4...5 kHz [2, 3]. Studs wear asphalt pavements. A worn, rough surface has 1...4 dB(A) higher tire noise emission in late winter and early spring than the same surface in summer and autumn time [2]. Porous asphalt qualities that works on warm and moderate climates can not be used in cold climates. Freezing water in voids easily destroys the pavement and very often a porous asphalt wears too fast when studded tires are used.

Snow cover on road (Fig. 2) lowers significantly, up to 5...15 dB(A), traffic noise. On main roads snow cover wear off in some hours or days, but countryside and urban roads with low traffic densities usually has permanent winter time snow cover. In wintertime and annual noise predictions and in normalisation of measured results the problem is, that we don't have adequate local (pointwise) pavement snow/ice-cover statistical data available.

In Finland most motor- and highways outside urban areas have lowered speed limits in winter time. Typically highest motorway speeds are 120 km/h in summertime, but 100 km/h in wintertime. Maximum signed highway speeds use to be 100 km/h in summer time and 80 km/h in winter time. In addition

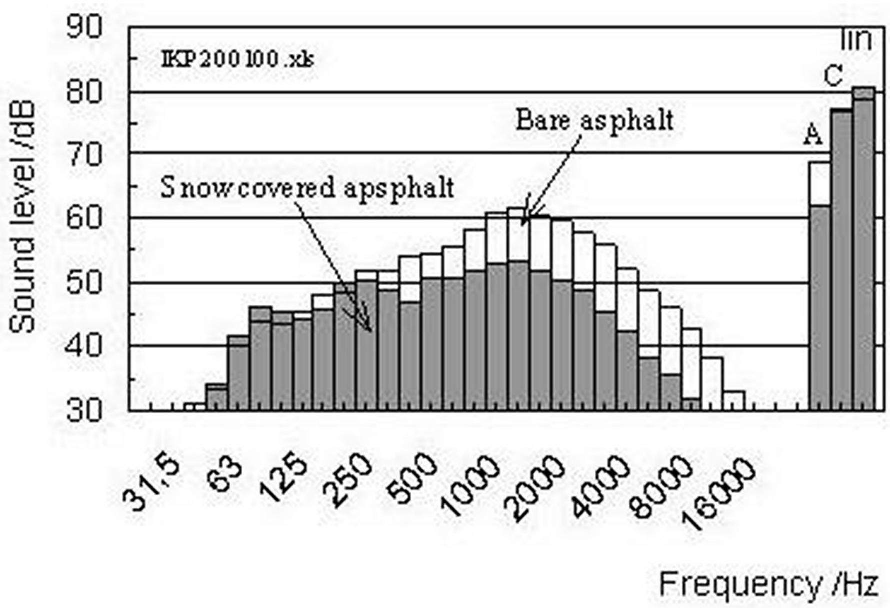


Figure 2: Traffic noise spectrum at a bare and snow covered main city street in winter; four lanes, 50 km/h; same traffic density and measurement position; A-weighted.

to signed lower speed limits, ice and/or new, densely falling snow often decrease traffic speeds and wintertime traffic noise.
Road traffic noise emission depends on pavement and air temperature, as well as on tire type and load. Typical change is −0,2...+0,1 dB(A)/°C, the average being ca. −0,1 dB(A)/°C [5,6,7]. The main rule is that noise emission increase with decreased temperature. In Nordic latitudes pavement temperatures vary −40...+50 °C. Theoretically this should mean about 9 dB(A) annual variation in tire/road noise emission. Noise spectra will vary, too.

5 - AIR TRAFFIC, AIRPORTS

Snow or ice on a runway decreases surface friction. Landing jets must use higher and longer lasting reverse powers that may significantly increase noise emission. The lower the temperature, the higher density the air has. Higher density air usually gives higher engine powers than warm air. External temperature (air density) has minor effects on take-off powers and profiles, as well as on noise foot prints. Fig. 3 gives examples about a) daily L_{DEN}-variation over two years at Stockholm-Arlanda airport [8] and b) annual variation of operations and air craft noise related complaints at Helsinki-Vantaa airport.

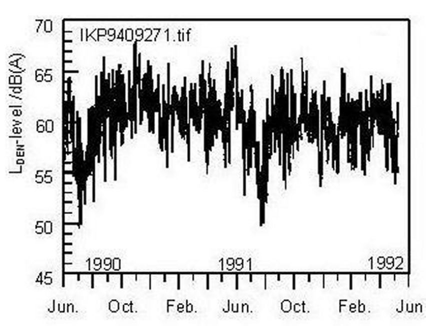


Figure 3(a): Two year L_{DEN}-levels at ca. 6 km from Stockholm-Arlanda airport [8].

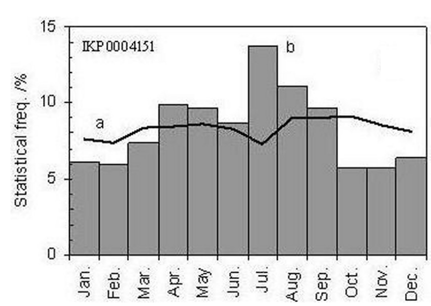


Figure 3(b): Distribution of noise related complaints (bars) and flight operations (line) in Helsinki-Vantaa airport; average monthly figures for years 1997 and 1998.

Fig. 3b tells that the number of complaints is higher in warmer seasons than in colder ones and monthly figures do not correlate well with the number of operations. The high peak in July most probable indicates

that in residential areas the number of people exposed in day time is increased due to vacations, people spend more time outdoors and have windows open. A Japan study [9] shows similar results: at same L_{Aeq}-levels people seem to show higher annoyance and bigger difficulties to fall asleep in warmer climatic conditions than in colder ones. In Fig. 3a lower L_{DEN}-levels in July are due to lower traffic density in vacation time.
In Nordic countries non-commercial aviation is practised more in warm than in cold seasons. For example, pilot training, towing of gliders and parachute jumping flights arouse most noise and complaints in spring and summer time.

6 - FREE AND LEISURE TIME ACTIVITIES

Outdoor civilian shooting ranges are not usually used in winter time due to short day light time, uncomfortable, low temperatures, and excessive snow work (costs). The same concerns also motor sports venues and circuits, but special ice races on circuits made on lake ice. Outdoor concerts, open air exhibitions and festivals are held only in summer time.

7 - SEASONAL VARIATIONS IN EXCESS ATTENUATION

In cold climates we have several typical reasons that cause season related variations in excess attenuation. The main ones are: 1) meteorology, 2) ground impedance, and 3) vegetation related.
The main reasons decreasing excess attenuation are down wind and/or thermal inversion near the ground surface. In cold climates winter time near-ground inversions are more frequent and deeper than summer time ones. It is well know that many remote sounds are well audible in calm summer evenings and in clear, calm winter nights. A special phenomenon to be considered in noise control engineering is sound channelling above a bigger lake or sea in calm summer mornings and evenings see data, e.g., in [10, 11]. In (2D) sound channels excess attenuation is negative compared with ordinary 3D-propagation. It is very usual that noise complainers want to use these low excess attenuation periods as the reference conditions in noise nuisance assessment.
In summer days the atmosphere use to be unstable. Sound rays bent upwards that increase excess attenuation and unstability increase short time fluctuations. Fig. 3a shows higher levels in May and October-November. The reasons is that morning inversions coincide with the high flight density at $07 - 09$. Otherwise summer time L_{DEN}-levels use to be lower than those in cold seasons are.
A snow layer is a good thermal insulator that decreases thermal energy conduction between air and ground. In a clear, calm winter night the cold air that settles down will not be warmed by thermal energy conduction from the ground, but the air will cool and cool down. Within the near-ground inversion layer very steep gradients can develop. Temperature changes can be as much as 30 °C per 100 m, although 10...15 °C per 100 m winter time inversion gradients are more common. Frequent wintertime inversions decrease excess attenuation and increase background noise levels from remote sources. For example, even in New Zealand 10 dB(A) higher background levels from remote sources have been observed in wintertime than in summer time [12].
In cold climates many water containing soils, like clay and silt, as well as peat, can freeze rather deeply in winter time, and lakes and seas freeze, too. Depending on soil quality, climate conditions and time of the year frost-depth varies typically 0...2 m. Frost does change ground impedance and attenuation. It is impossible to classify frozen soils to different acoustical impedance classes by visual observations, especially if the soil is snow or ice covered. We have to make measurements. We need rather extensive sets of measurements to get statistically reliable data describing **local** (pointwise) long term variation inside a bigger noise zone. When considering long term variations in simple words, soils classified in summer time as soft ones, can turn to a hard one for a part of a year and vice versa.
Snow does change ground impedance and it can form natural or artificial drifts that act as noise barriers (e.g., road side drifts). Rocks and lakes are extreme examples. Both are considered as acoustically hard surfaces, but when covered by thick snow layer they act as soft surfaces. There are tens of studies concerning sound propagation over (even layers of) snow [e.g. 13, 14, 15]. The longer the distance the more snow increase excess attenuation.

8 - CONCLUSIONS

In cold climates a typical feature is big seasonal variations in noise emissions, excess attenuation, and living styles. We have to ask: what are the reference conditions we should use in noise assessment? Most Nordic countries use summer time and down wind as the reference for noise sources operating all the year round. It has been suggested [16] that long term (annual) average L_{DEN}- and L_{night}-levels should be used as the indicator in noise assessment. In climates were seasonal and local variations are big and sparsely (arealt) or otherwise roughly documented, or unavailable, this results at least in big practical problems. For example, a modern computer based noise zone prediction program use typically 5 m × 5 m...20 m × 20 m grid and expect sound speed profile and ground impedance as input at each grid point. Long term average estimations expect prediction of several type cases before averaging. The more accurately we model real sound propagation the more input variables and type cases we need, but the more results will vary (randomly), if users don't have access to reliable statistical local data (at each grid point).

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