Wind turbines and public health
A summary of knowledge
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Final introductory section

This report was produced in order to provide regional public health authorities with the most complete information. The subjects addressed herein were identified in accordance with the health concerns indicated by the public during public hearings or in requests for information received by public health authorities, or based on potential problems perceived by committee members. These subjects include the social and community effects related to implementation of wind farms (chapter 1), sound (chapter 3), infrasound and low-frequency sound (chapter 4), the shadow flicker effect or moving shadows (chapter 5), annoyance during the construction phase and safety (chapter 6) and electromagnetic fields (chapter 7). Chapters 1 and 3 to 7 are presented following this general structure: description of the situation, health concerns and summary. To help workers understand general sound concepts, a quick reference guide was prepared and can be found in chapter 2. The committee also suggests support materials from public health authorities for public hearings, such as sample public information sheets (Appendix 1). It also prepared a list of the typical questions asked by the public (Appendix 2). Finally, the committee also selected the most relevant reading materials for understanding the various subjects addressed (Appendix 3).

The informational research was conducted from January to December 2008 using databases such as *PubMed* and *EBSCO* and Internet search tools. The resource people consulted also suggested documents. Thus, the information gathered by the committee was collected from scientific journals, conference presentations, documents from Quebec, Canadian and international government agencies, from experts in certain specific fields and from various Internet sites. This document is not a systematic, exhaustive, critical review of the literature.

Sound

3.3 Summary

According to current scientific knowledge:

• The levels of sound levels generated by wind turbines do not have any direct impact on the auditory health of individuals living nearby, such as hearing loss or auditory fatigue.

• The sound levels generated by wind turbines do not seem to have negative health effects other than on sleep and as an annoyance. However, the absence of sufficient evidence for some effects implies that we should remain attentive to future research and literature reviews.

• Accounts from residents imply that wind turbine sound could disturb the sleep of people living nearby. Scientific evidence has yet to be established.

• The annoyance caused by wind turbine sound has been linked to sound levels and other factors, specifically wind turbine visibility and the attitude of individuals exposed to them.

• Under certain conditions, exposure to wind turbine sound can be an annoyance for neighbours, but scientific knowledge must be acquired regarding levels and factors affecting them as well as criteria to apply to evaluate and reduce them.

Infrasound low-frequency sound

4.5 Summary

According to current scientific knowledge:

• Infrasound produced by wind turbines does not seem to constitute an annoyance or threat to the health of residents.

• Low-frequency sounds can be masked by wind sound when there is turbulence.[12, 24]
• The low-frequency sound produced by modern wind turbines is of moderate intensity and, at normal separation distances, would be near the detection limit.[11]
• There is no evidence to conclude that low-frequency sound has any health effects when it is below the human detection limit.[3]
• It is not possible to conclude that the low-frequency sound produced by wind turbines constitutes an annoyance to residents. Nevertheless, it is important to consider that complaints may be attributed to it, keeping in mind that the intensity modulation of mid-frequency sound could be perceived by the human ear as low-frequency sound, although it is not.

Shadow flicker effect and moving shadows
5.2 Summary
According to current scientific knowledge:
• Moving shadows produced by wind turbines do not cause convulsive seizures;
• These moving shadows may constitute an annoyance under certain conditions. However, knowledge still must be acquired with respect to exposure limits and criteria to be applied to reduce the possibility of annoyances.
• Modeling makes it possible to anticipate this phenomenon.
• Mitigation measures exist.

Construction-phase annoyances and safety
6.3 Summary
According to current scientific knowledge:
• The installation, operation and dismantling of a wind farm may lead to safety risks.
• Injuries and deaths are infrequent and mainly affect workers during construction and maintenance phases.
• On the other hand, there is no consensus on the separation distance to minimize or avoid this risk.

Electromagnetic fields
7.5 Summary
According to current scientific knowledge and the available information:
• Wind turbines themselves do not cause health problems related to electromagnetic fields.
• Transmission lines incur a slight degree of uncertainty since they may cause significant electromagnetic fields for nearby populations. There may be a greater-than-normal risk for children developing leukaemia after prolonged exposure to the magnetic fields in the immediate proximity of electrical transmission lines.
• For individuals wearing pacemakers, the American Conference of Governmental Industrial Hygienists (ACGIH) recommendations regarding exposure to electromagnetic fields may be exceeded.

CONCLUSION
From an examination of the literature conducted by the *Table Nationale de concertation en santé environnementale* (TNCSE) [national environmental health panel] wind turbine committee, it seems that the main health concern arising from the implementation of wind farms is annoyance. This is defined as “a feeling of displeasure associated with any agent or as a determined condition known or believed to adversely affect” an individual or group.[1]

Discomfort, inconvenience, displeasure and feelings of powerlessness may occur to varying degrees during the set-up and operation of a wind farm. These are related to the integration of new elements (such as sound, structures that change the landscape, moving shadows and, for some individuals, a loss of tranquillity and the imposition of a new development that they do not endorse) into the physical and social environment.

This document gathers information on health concerns. These observations, based on the scientific information assembled, are intended to encourage a better analysis of wind turbine projects by regional public health authorities.

Social impact
The social impact constitutes an aspect of public health interventions to which it is appropriate to grant significant importance. In light of the information available on the social impact of implementing a wind farm project, it is clear that there are multiple interactions among the factors that influence acceptability and social impact.

Social acceptability is affected by four groups of factors suggested by the *Université du Québec à Rimouski* (UQAR) group: factors related to wind turbines, to the specific project, to the decision-making process and to the social environment. Although wind turbine projects have a positive social impact, conflicts arising mainly from differences of opinion and feelings of injustice among community members may have a negative effect on the social capital.

Sound annoyance
In some situations, wind turbines can be responsible for sound disturbances in an environment that is generally calm and has been chosen by several residents for this quality. Furthermore, under certain conditions, wind turbines emit a characteristic sound, mainly due to changes in intensity, which is difficult for some individuals to ignore.

Wind turbine sound intensity is insufficient to negatively affect the hearing of nearby residents. Accounts from some individuals lead to suspicions that wind turbine sound can disturb the sleep of those living nearby. However, scientific evidence of this has yet to be established. On the other hand, under certain conditions, exposure to wind turbine sound outside of homes can be an annoyance, but scientific knowledge still needs to be acquired regarding the sound levels causing the annoyance and the criteria to apply in reducing them. Furthermore, while wind turbine annoyance effects vary with sound levels, these effects have been associated with other factors, specifically wind turbine visibility and individual attitudes toward wind turbines.

Infrasound and low-frequency sound
Wind turbine-generated infrasound does not seem to be of sufficient intensity to cause health problems or annoyance.

Low-frequency sound emitted by wind turbines could be heard under certain conditions and complaints would be attributed to it. However, at the usual separation distances acceptable for higher-frequency sounds, levels would be close to the detection limit. In addition, modulation in the intensity of mid-frequency sound could be perceived by the human ear as low-frequency sound, although it is not. Considering the limited current scientific knowledge, it is not possible to conclude that the low-frequency sound produced by wind turbines constitutes an annoyance.

Moving shadows or the shadow flicker effect
The increased and moving shadows caused by wind generators may stimulate additional

discomfort for residents. This phenomenon is experienced particularly on summer evenings when residents are outside their homes and the sun is on the horizon. In particular, residents located to the east of wind turbines could be most affected. Precise modelling would give an exact idea of the phenomenon so that an appropriate separation distance would allow these shadows to be reduced to acceptable levels. It is thus possible to reduce the annoyance.

Construction-phase safety and annoyance
According to current knowledge, the installation, operation and dismantling of a wind farm can lead to safety risks. However, injuries or deaths are infrequent and mainly affect workers during construction or maintenance phases. On the other hand, wind turbines have several systems that decrease the risk of improper operation. Finally, there is no consensus on the separation distance that would decrease or prevent this risk.

Electromagnetic fields and stray voltage
Given the low production density, according to the information obtained, electromagnetic fields created by wind turbines do not present a health risk for nearby residents. However, there may be a greater-than-normal risk for children developing leukaemia after prolonged exposure to the magnetic fields in the immediate proximity of electrical transmission lines. If this risk is proven to be real, it would be low. On the other hand, animal studies conclude, almost unanimously, that there are no negative effects associated with electromagnetic fields produced by electrical installations. Given the uncertainty with respect to serious effects on children, caution is recommended.

Annoyance synergy
It is important to mention that, for certain individuals, each type of annoyance resulting from wind turbines can reinforce the others. Annoyance due to sound may be accentuated by the visual intrusion of the wind generators. In fact, there is a direct relationship between the height of a wind turbine in front of a residence (vertical visual angle) and sound-related discomfort.[2] The moving shadows projected onto residences can also reinforce this annoyance.

In addition, according to the survey conducted by Multi Reso in 2007, 20% of individuals surveyed who live within 10 km or less of a wind farm disagreed or slightly disagreed with the statement “the developer listened to citizen concerns,” and 19% did not think that the developer presented and explained his project well.[3] This is not an insignificant proportion, and among these individuals, the impression of a lack of transparency in the projected data, the absence of consultation, the injustice and powerlessness could encourage a negative perception of the wind industry or of the project. This perception could increase discomfort due to the annoyances mentioned above.

Recommendations
Considering that scientific knowledge on several aspects is often limited, it would be appropriate to set up scientific intelligence addressing the main concerns addressed in this document.

Several concerns should be supported by additional knowledge. This is the case specifically for the following:
• A method for evaluating the sound effects of wind turbines in an environment, the levels and conditions causing an annoyance as well as criteria for reducing it
• Uncertainties regarding low-frequency sound produced by wind turbines
• Scientific demonstration of the relevance of a specific separation distance to the effective attenuation of the shadow-flicker effect
• The safe separation distance that would decrease the risk of accident due to projected objects,

fires, electrical discharge and wind turbine collapse.
Given the increasing number of citizens living near wind turbines, it would also be appropriate to document the complaints and describe the exposure of the affected individuals. Finally, from a sustainable development perspective, the TNCSE wind turbine committee believes that it is important to reduce each annoyance to levels deemed acceptable for protecting community health, well-being and quality-of-life. Involving the public as early as possible in wind project planning and implementing processes will make it possible to take these annoyances into consideration and reduce them as effectively as possible. Transparency of communication appears to be essential to the social acceptability of projects and to decreasing the social impact.