

## Synopsis of WHO noise guidelines with reference to wind turbines:

All extracts from WHO Environmental Noise Guidelines for the European Region 2018 in italics (**Bold and underlined** is my emphasis)

### **References of huge significance (Headlines):**

#### **Page 85:**

**Wind turbines can generate infrasound or lower frequencies of sound than traffic sources. However, few studies relating exposure to such noise from wind turbines to health effects are available.** *It is also unknown whether lower frequencies of sound generated outdoors are audible indoors, particularly when windows are closed.*

*The noise emitted from wind turbines has other characteristics, including the repetitive nature of the sound of the rotating blades and atmospheric influence leading to a variability of amplitude modulation, which can be a source of above average annoyance (Schäffer et al., 2016). This differentiates it from noise from other sources and has not always been properly characterized. Standard methods of measuring sound, most commonly including A-weighting, may not capture the low-frequency sound and amplitude modulation characteristic of wind turbine noise (Council of Canadian Academies, 2015)*

#### **Page 86:**

**Based on all these factors, it may be concluded that the acoustical description of wind turbine noise by means of Lden or Lnight may be a poor characterization of wind turbine noise and may limit the ability to observe associations between wind turbine noise and health outcomes.**

*Balance of benefits versus harms and burdens*

**Further work is required to assess fully the benefits and harms of exposure to environmental noise from wind turbines and to clarify whether the potential benefits associated with reducing exposure to environmental noise for individuals living in the vicinity of wind turbines outweigh the impact on the development of renewable energy policies in the WHO European Region.**

*Additional considerations or uncertainties*

**There are serious issues with noise exposure assessment related to wind turbines.**

#### **Page 100:**

##### **4.2 Implications for research on health impacts from wind turbine noise**

*Further research into the health impacts from wind turbine noise is needed so that better-quality evidence can inform any future public health recommendations properly. For the assessment of health effects from wind turbines, the evidence was either unavailable or rated low/very low quality.*

**Exposure of interest: Exposure to noise at a wide range of levels and frequencies (including low-frequency noise), with information on noise levels measured outdoors and indoors**

(particularly relevant for effects on sleep) **at the residence is needed**. The noise exposure should be measured objectively and common protocols for exposure to wind turbine noise should be established, considering a variety of noise characteristics specific to wind turbine noise.

**Page 103:**

*The studies should use measures of exposure including noise exposure at a wide range of levels and frequencies (including low-frequency noise), with information on noise levels outdoors and indoors (particularly relevant for effects on sleep).*

**Page 106:**

*The fourth principle is to inform and involve communities that may be affected by a change in noise exposure.*

**Page 110:** 5.6 Route to implementation: policy, collaboration and the role of the health sector

*promoting the guidelines to health practitioners and physicians, especially at the community level (through associations of physicians, cardiologists and so on as part of the stakeholder group);*

*Noise is an important public health issue. It has negative impacts on human health and well-being and is a growing concern. The WHO Regional Office for Europe has developed these guidelines, based on the growing understanding of these health impacts of exposure to environmental noise. The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, **wind turbine noise** and leisure noise. **They provide robust public health advice underpinned by evidence, which is essential to drive policy action that will protect communities from the adverse effects of noise.** The guidelines are published by the WHO Regional Office for Europe. **In terms of their health implications, the recommended exposure levels can be considered applicable in other regions and suitable for a global audience.***

**Significant points with reference to wind turbines (including the above):**

*Recommendations:*

*No recommendation is made for average night noise exposure  $L_{night}$  of wind turbines. **The quality of evidence of night-time exposure to wind turbine noise is too low to allow a recommendation.***

*No evidence is available, however, to facilitate the recommendation of one particular type of intervention over another.*

**Page 1 Introduction:**

*The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, **wind turbine noise** and leisure noise*

### 1.1 The public health burden from environmental noise

Exposure to noise can lead to auditory and nonauditory effects on health. Through direct injury to the auditory system, noise leads to auditory effects such as hearing loss and tinnitus. Noise is also a nonspecific stressor that has been shown to have an adverse effect on human health, especially following long-term exposure. These effects are the result of psychological and physiological distress, as well as a disturbance of the organism's homeostasis and increasing allostatic load (Basner et al., 2014). This is further outlined in the WHO narrative review of the biological mechanisms of nonauditory effects (Eriksson et al., 2018).

Page 5:

### 1.3.2 Trends at the national level

Only limited data are available on the population's perception of newer sources of noise, such as wind turbines.

While perception surveys do not provide information on actual quantitative relationships between noise exposure and health outcomes, it is important to note that the results of such surveys represent people's preferences and values regarding environmental noise. Despite limitations and an incomplete picture, the available data on perception of environmental noise as a public health problem show concern in Europe. **People are not always aware of the health impacts of noise, especially of those related to long-term noise exposure at lower levels.** (my emphasis) Greater awareness of the issue may further increase positive values and preferences.

Page 8:

### 2.2.1 Key questions

The environmental noise guidelines for the WHO European Region seek to address two main questions, which define the issues addressed by the guideline recommendations.

- In the general population exposed to environmental noise, what is the exposure–response relationship between exposure to environmental noise (reported as various indicators) and the proportion of people with a validated measure of health outcome, when adjusted for confounders?
- In the general population exposed to environmental noise, are interventions effective in reducing exposure to and/or health outcomes from environmental noise?

Page 10/11:

The GDG rated the relevance based on the seriousness and prevalence of the outcomes and the anticipated availability of evidence for an association with noise exposure. The following health outcomes were selected as either critical or important for developing recommendations on the health impacts of environmental noise.

#### **Critical health outcome    Important health outcome**

Cardiovascular disease

Adverse birth outcomes

Annoyance<sup>7</sup>

Quality of life, well-being and mental health

Effects on sleep

Metabolic outcomes

Cognitive impairment

### *Hearing impairment and tinnitus*

The GDG noted that research into the relationship between noise exposure and its effects on humans brings into focus several questions concerning the definition of health and the boundary between normal social reaction to noise and noise-induced ill health. As stated in WHO's Constitution: "**Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity**" (WHO, 1946). Accordingly, documenting physical health does not present a complete picture of general health; and being undisturbed by noise in all activities, including sleep, constitutes an asset worthy of protection. Therefore, in accordance with the above definition, the GDG regarded (long-term) annoyance and impaired well-being, as well as self-reported sleep disturbance due to noise, as health outcomes.

Chapter on wind turbine noise:

#### **Page 77:**

*To reduce health effects, the GDG **conditionally** recommends that policy-makers implement suitable measures to reduce noise exposure from wind turbines in the population exposed to levels above the guideline values for average noise exposure. No evidence is available, however, to facilitate the recommendation of one particular type of intervention over another.*

*The GDG stressed that there might be an increased risk for annoyance below this noise exposure level, but it could not state whether there was an increased risk for the other health outcomes below this level owing to a lack of evidence.*

*As the evidence on the adverse effects of wind turbine noise was rated low quality, the GDG made the recommendation conditional.*

#### **Page 78:**

*Based on the low quantity and heterogeneous nature of the evidence, the GDG was not able to formulate a recommendation addressing sleep disturbance due to wind turbine noise at night time.*

*The GDG also looked for evidence about the effectiveness of interventions for wind turbine noise exposure. Owing to a lack of research, however, no studies were available on existing interventions and associated costs to reduce wind turbine noise.*

#### *3.4.2 Detailed overview of the evidence*

*It should be noted that, due to the time stamp of the systematic reviews, some more recent studies were not included in the analysis. This relates in particular to several findings of the Wind Turbine Noise and Health Study conducted by Health Canada (Michaud, 2015).*

*Further, some studies were omitted, as they did not meet the inclusion criteria, including, for instance, studies using distance to the wind turbine instead of noise exposure to investigate health effects.*

**Page 84/85:** This was the general comment with reference to studies on wind turbine noise

*No studies were found, and therefore no evidence was available on the effectiveness of interventions to reduce noise exposure from wind turbines.*

#### **3.4.2.3 Consideration of additional contextual factors**

*As the foregoing overview has shown, very little evidence is available about the adverse health effects of continuous exposure to wind turbine noise. Based on the quality of evidence available, the GDG set the strength of the recommendation on wind turbine noise to conditional*

*Regarding the balance of harms and benefits, the GDG would expect a general health benefit from a marked reduction in any kind of long-term environmental noise exposure. Health effects of individuals living in the vicinity of wind turbines can theoretically be related not only to long-term noise exposure from the wind turbines but also to disruption caused during the construction phase. The GDG pointed out, however, that evidence on health effects from wind turbine noise (apart from annoyance) is either absent or rated low/very low quality (McCunney et al., 2014). Moreover, effects related to attitudes towards wind turbines are hard to discern from those related to noise and may be partly responsible for the associations (Knopper & Ollson, 2011). Furthermore, the number of people exposed is far lower than for many other sources of noise (such as road traffic). Therefore, the GDG estimated the burden on health from exposure to wind turbine noise at the population level to be low, concluding that any benefit from specifically reducing population exposure to wind turbine noise in all situations remains unclear. Nevertheless, proper public involvement, communication and consultation of affected citizens living in the vicinity of wind turbines during the planning stage of future installations is expected to be beneficial as part of health and environmental impact assessments*

*The GDG noticed that the values and preferences of the population towards reducing long-term noise exposure to wind turbine noise vary. Whereas the general population tends to value wind energy as an alternative, environmentally sustainable and low-carbon energy source, people living in the vicinity of wind turbines may evaluate them negatively. Wind turbines are not a recent phenomenon, but their quantity, size and type have increased significantly over recent years. As they are often built in the middle of otherwise quiet and natural areas, they can adversely affect the integrity of a site. Furthermore, residents living in these areas may have greater expectations of the quietness of their surroundings and therefore be more aware of noise disturbance. Negative attitudes especially occur in individuals who can see wind turbines from their houses but do not gain economically from the installations (Kuwano et al., 2014; Pedersen & Persson Waye, 2007; van den Berg et al., 2008). These situational variables and the values and preferences of the population may differ between wind turbines and other noise sources, as well as between wind turbine installations, which makes assessment of the relationship between wind turbine noise exposure and health outcomes particularly challenging.*

*Assessing resource use and implementation considerations, the GDG noted that reduction of noise exposure from environmental sources is generally possible through simple measures like insulating windows or building barriers. With wind turbines, however, noise reduction interventions are more complicated than for other noise sources due to the height of the source and because outdoor disturbance is a particularly large factor. As generally fewer people are affected (compared to transportation noise), the expected costs are lower than for other environmental sources of noise. The GDG was not aware of any existing interventions (and associated costs) to reduce harms from wind turbine noise, or specific consequences of having regulations on wind turbine noise. Therefore, it could not assess feasibility, or discern whether any beneficial effects of noise reduction would outweigh the costs of intervention. In particular,*

*there is no clear evidence on an acceptable and uniform distance between wind turbines and residential areas, as the sound propagation depends on many aspects of the wind turbine construction and installation.*

*In light of the assessment of the contextual factors in addition to the quality of evidence, the recommendation for wind turbine noise exposure remains conditional.*

*In many instances, the distance from a wind farm has been used as a proxy to determine audible noise exposure. However, in addition to the distance, other variables – such as type, size and number of wind turbines, wind direction and speed, location of the residence up- or downwind from wind farms and so on – can contribute to the resulting noise level assessed at a residence. Thus, using distance to a wind farm as a proxy for noise from wind turbines in health studies is associated with high uncertainty.*

**Wind turbines can generate infrasound or lower frequencies of sound than traffic sources. However, few studies relating exposure to such noise from wind turbines to health effects are available.** *It is also unknown whether lower frequencies of sound generated outdoors are audible indoors, particularly when windows are closed.*

*The noise emitted from wind turbines has other characteristics, including the repetitive nature of the sound of the rotating blades and atmospheric influence leading to a variability of amplitude modulation, which can be a source of above average annoyance (Schäffer et al., 2016). This differentiates it from noise from other sources and has not always been properly characterized. Standard methods of measuring sound, most commonly including A-weighting, may not capture the low-frequency sound and amplitude modulation characteristic of wind turbine noise (Council of Canadian Academies, 2015)*

**Page 86:**

**Based on all these factors, it may be concluded that the acoustical description of wind turbine noise by means of  $L_{den}$  or  $L_{night}$  may be a poor characterization of wind turbine noise and may limit the ability to observe associations between wind turbine noise and health outcomes.**

**Balance of benefits versus harms and burdens**

**Further work is required to assess fully the benefits and harms of exposure to environmental noise from wind turbines and to clarify whether the potential benefits associated with reducing exposure to environmental noise for individuals living in the vicinity of wind turbines outweigh the impact on the development of renewable energy policies in the WHO European Region.**

**Additional considerations or uncertainties**

**There are serious issues with noise exposure assessment related to wind turbines.**

**Page 99:**

*Implications for research*

*The development of these environmental noise guidelines for the WHO European Region has made evident some key knowledge gaps and research needs. The main ones specific to the guideline recommendations are presented as implications for research in the sections that follow.*

**Page 100:**

*4.2 Implications for research on health impacts from wind turbine noise*

*Further research into the health impacts from wind turbine noise is needed so that better-quality evidence can inform any future public health recommendations properly. For the assessment of health effects from wind turbines, the evidence was either unavailable or rated low/very low quality. Recommendations for research addressing this priority are proposed in Table 53.*

*Table 53. Implications for research on health impacts from wind turbine noise*

*Current state of the evidence*

*The current evidence on health outcomes related to wind turbine noise is unavailable or of low/very low quality and mainly comes from cross-sectional studies.*

*Methodologically robust longitudinal studies with large samples investigating the quantitative relationship between noise from wind turbines and health effects are needed.*

*Population of interest*

*Research is needed into effects of exposure on children and adults exposed and living near sources of wind turbine noise. Studies should assess subgroup differences in effects for vulnerable groups such as children, elderly people and those with existing poor physical and mental health.*

*Exposure of interest*

*Exposure to noise at a wide range of levels and frequencies (including low-frequency noise), with information on noise levels measured outdoors and indoors (particularly relevant for effects on sleep) at the residence is needed. The noise exposure should be measured objectively and common protocols for exposure to wind turbine noise should be established, considering a variety*

<i>Comparison of interest</i>	<i>of noise characteristics specific to wind turbine noise.</i>
<i>Outcomes of interest</i>	<i>The data should be compared to the effects in similar areas without wind turbines. Pre/post studies of new wind turbine installations are needed, especially if “before measures” unbiased by the stress and knowledge of potential wind turbine farm development need to be developed.</i>
<i>Time stamp</i>	<i>Measures of health outcomes are required, assessed objectively – for example, according to common protocols (ICBEN scale for annoyance and self-reported sleep disturbance). The studies should include the most important situational and personal confounding variables, such as negative attitudes towards wind turbines, visual impact, economic gain and other socioeconomic factors.</i>
<i>Time stamp</i>	<i>The systematic review included studies between October 2014 (review on annoyance) and December 2016 (review on cardiovascular disease).</i>

**Page 103:**

*Future intervention studies should use validated and, where possible, harmonized measures of exposure and outcome, as well as of moderators and confounders.*

***The studies should use measures of exposure including noise exposure at a wide range of levels and frequencies (including low-frequency noise), with information on noise levels outdoors and indoors (particularly relevant for effects on sleep).***

*They should also use measures of health outcomes, including the following outcomes assessed objectively – for example, according to common protocols (ICBEN scale for annoyance) – with consideration that the change in human response for some health outcomes from a step change in exposure may have a different time course to that of the change in exposure:*

- *annoyance*
- *effects on sleep*
- *cardiovascular and metabolic diseases*
- *adverse birth outcomes*
- *cognitive impairment*



- mental health, quality of life and well-being
- hearing impairment and tinnitus
- any other relevant health outcome.

Further, they should use measures of moderators and confounders, including repeated measurements of situational and personal variables such as activity interference, potential confounders such as noise sensitivity, coping strategies and a range of other attitudinal variables.

### **Page 105: 5.2 Guiding principles**

Four guiding principles provide generic advice and support when incorporating the recommendations into a policy framework, and apply to the implementation of all the recommendations.

*The first principle is to reduce exposure to noise, while conserving quiet areas.*

*The second principle is to promote interventions to reduce exposure to noise and improve health. The evidence from epidemiological studies on adverse health effects at certain noise levels, used as a basis to derive the guideline values proposed in the recommendations, supports the promotion of noise interventions.*

*The lack of – or limited direct evidence for – quantifiable health benefits of some specific interventions does not imply that measures to achieve population exposure according to the proposed guidelines should be ignored.*

*The third principle is to coordinate approaches to control noise sources and other environmental health risks.*

**The fourth principle is to inform and involve communities that may be affected by a change in noise exposure.** *In planning new urban and/or rural developments (transport schemes, new infrastructures in less densely populated areas, noise abatement and mitigation strategies), bringing together planners, environmental professionals and public health experts with policy-makers and citizens is key to public acceptability and involvement and to the successful guidance of the decision making process. Potential health effects from environmental noise should be included as part of health impact assessments of future policies, plans and projects, and the communities potentially affected by a positive or negative change in noise exposure should be well informed and engaged from the outset to maximize potential benefits to health. Introducing measures incrementally may help with acceptance.*

### **Page 107: 5.4 Usefulness of guidelines for target audiences**

*For health impact assessment and environmental impact assessment practitioners and researchers, these guidelines provide exposure–response relationships that give insight into the expected health effects at observed or expected noise exposure levels. They offer recommendations on the maximum admissible noise levels for some sources and provide important input to assist in deriving the health burden from noise; in that sense, they can be*

*used when producing studies such as noise maps and action plans to obtain an evaluation of the magnitude of the health problem. The systematic reviews developed in support of these guidelines allow practitioners to raise awareness of the credibility of the issue of noise as a public health problem and to use the recommended exposure–response relationships uniformly. Researchers will also benefit from the guidelines as they clearly identify critical data gaps that need to be filled in the future to better protect the population from the harmful effects of noise.*

*The guideline recommendations provide a useful tool for national and local authorities when deciding about noise reduction measures, as they provide data to estimate the health burden on the population and therefore allow comparison among different policy options. These options can include measures to reduce the noise emitted by the sources, measures aimed at impeding the transmission of noise from the sources to people and measures aimed at better planning the location of houses (urban planning).*

- *The guideline recommendations can also be used by civil society, patients and other advocacy groups to raise awareness and encourage actions to protect the population, including vulnerable groups, from exposure to noise.*

*Regarding noise abatement and mitigation of noise sources, practical exposure–response relationships for various noise sources are useful quantitative input to determine the impact of noise on health. They can be valuable information to use in cost–effectiveness and cost–benefit analyses of various policies for noise abatement. In this respect, the guideline recommendations can be an integral part of the policy process for noise reduction by various institutions; they are of great value for communicating the health risks and potential cost-effective solutions to reduce noise.*

*National and local authorities and nongovernmental organizations responsible for risk communication and general awareness-raising can use these guidelines for promotion campaigns and appropriate risk communication. The guidelines provide scientific evidence on a range of health effects associated with noise and facilitate appropriate risk communication to specific vulnerable groups. They therefore need to be promoted broadly to citizens, national and local authorities and nongovernmental organizations responsible for risk communication.*

### **Page 109:**

*The scientific evidence reviewed and summarized in these guidelines implies that the following health outcomes can be quantified in a health risk assessment, and that their effects are cumulative:*

*from wind turbine noise: annoyance.*

### **Page 110: 5.6 Route to implementation: policy, collaboration and the role of the health sector**

*Preventing noise and related health impacts relies on effective action across different sectors: health, environment, transport, urban planning and so on. **The health sector needs to be engaged effectively in different sectors' policy processes at national, regional and international levels. It needs to provide authoritative advice about the health impacts of noise and policy options that will bring the greatest benefits to health.***

*In most countries in the WHO European Region, the commitment of the health sector to engage in action to address environmental noise issues **needs to be improved and better coordinated**. A more coherent overall response is needed, taking into account relevant linkages with existing health priorities and concerns. Thus, some actions can be seen as aspects of the role of the health sector:*

- engaging in proper communication with relevant sectors about noise exposure from different sectors and sources (environmental, urban development, transport and so on) to ensure that health issues are adequately addressed as part of international, regional, national and/or local efforts to address environmental noise – the implementation approach may differ across sectors, depending on the level of awareness of noise as a public health problem;*
- promoting the guideline recommendations to policy-makers from different sectors and organizing information campaigns and awareness-raising activities in collaboration with national health authorities and WHO country offices to inform citizens and health practitioners about the health risks of environmental noise;*
- using decision support instruments such as health impact and health risk assessments to quantify health risks and potential benefits associated with policies and interventions aimed at addressing environmental noise, including presenting information about the severity of the health effects (for example, with cardiovascular disease) to convey the serious impacts of noise and to try to change attitudes and behaviours of policy-makers and the general public;*
- **promoting the guidelines to health practitioners and physicians, especially at the community level (through associations of physicians, cardiologists and so on as part of the stakeholder group);***
- supporting the establishment of national health institutions capable of initiating and developing health promotion measures, and conducting research, monitoring and reporting on health impacts from environmental noise and its different sources;*

**Page 111:** 5.8 Updating the guidelines

*The progress and pace of noise and health research has intensified over the last 10 years, including new studies published after the completion of the systematic reviews done for these guidelines. This is partly related to the growing car fleet and resulting traffic, the density of urbanization, demographic changes and shifts towards renewable energy, including wind turbines, which have caused an increase in public perception and political awareness of the environmental noise problem*