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STUDY OF THE IMPACT OF NOISE POLLUTION IN THE WIND FARM: CASE OF AL KOUDIA AL BAIDA WIND FARM - TETOUAN

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Since 2000 several wind energy parks has been installed in Morocco. The Al Koudia Al Baida park is the first implemented in the North non-far from Tangier and Tetouan. The main objective of this study is the noise mapping of this park, which consists of 84 Vestas 600KW wind turbines. To achieve this study, we used a set of tools and applications such as the CadnaA software, the international standard ISO 9613-2 (1996) and the World Coordinate Converter. A total of 72 receivers around the park near at the dwellings close to the park in order to create the Noise map using
Keywords: noise mapping, wind farms, CadnaA, Morocco, Tangier.

1. Introduction

Currently Morocco imports more than 96% of its energy needs. Without fossil resources but endowed with significant potential in solar and wind energy, it adopted since many years ago an ambitious strategy based on renewable energies to reduce its energy bill.

To this end, several large-scale wind farm projects, photovoltaic systems and high-temperature solar thermal projects have been implemented or are in progress.

The oldest wind farm in Morocco (carried out on two slices) is AL KOUDIA AL BAIDA located in the region of Tangier in the north. Spreading over approximately 10 km and comprising 91 wind turbines with an installed capacity of 53,900 Kw. [1]

Table 1:Information about the park AL KOUDIA AL BAIDA

	Number of turbines	Power	Date
Tranche 1	84	50 400 Kw	august 2000
Tranche 2	07	3 500 Kw	march 2001

Since the installation of this park, no acoustic studies have been carried out to evaluate the impact of acoustic nuisances in its vicinity.

The purpose of this preliminary work is to determine the level of acoustic noise impeded by wind turbines and its impact on citizens.

2. Technical and acoustic characteristics of wind turbines

The park comprises 84 turbines Vestas V44/600 with a height of the mast 45m, and 7 turbines Enercon E40/500 implanted with a height of the mast 43.5 m. The other technical characteristics are summarized in the table below.

2.1 Technical characteristics of wind turbines

Table 2: Technical characteristics of wind turbines Vestas V44/600 [2] and Enercon E40/500 [3]

	Vestas V44/600	Enercon E40/500
General data		
• Manufacturer	Vestas (Denmark)	Enercon (Germany)
• Model	V44/600	E40/500
• Rated power	600 kW	500 kW
• Rotor diameter	44 m	40 m
• Offshore model	No	No
• Swept area	1,521 m²	1,257 m²
• Power density	2.54 m²/ kW	2.52 m²/ kW
• Number of blades	3	3
• Power control	Pitch	Pitch
• Commissioning	1995	1993
Weights		
• Nacelle	19.8 tons	26.5 tons
• Tower	58 tons	
• Rotor + hub	9.2 tons	120 tons
• Total	87 tons	
Rotor		
• Minimum rotor speed		18 rd/min
• Maximum rotor speed	28 rd/min	34 rd/min
• Cut-in wind speed	5 m/s	2.5 m/s
• Rated wind speed	16 m/s	13.5 m/s
• Cut-off wind speed	20 m/s	25 m/s
• Manufacturer	Vestas	Enercon
Gear box		
• Gear box	Yes	No
• Stages	2	
• Gear ratio	1:51	
• Manufacturer	Hansen	
Generator		
• Type	ASYNC	SYNC Wounded
• Number	1	1
• Maximum speed	1650 rd/min	38 rd/min
• Voltage	690 V	440 V
• Manufacturer	Weier	Enercon

2.2 Acoustic characteristics of wind turbines

Table 3: Sound Power Spectrum: EnerconE40/500: Mast height 43.5m [5]

Mast height 43.5 m	Wind speed (m/s)	
	8	10
Lw global (dB)	98.3	101.0

Table 4: Sound Power Spectrum: Vestas V44/600: Mast height 45m [4]

Mast height 45 m		Wind speed (m/s)	
		6	8
Octave band (Hz)	63	76.2	76.6
	125	84.8	85.2
	250	89.9	90.3
	500	93.9	94.3
	1,000	94.3	94.7
	2,000	91.3	91.7
	4,000	85.0	85.4
	8,000	70.9	71.3
Lw global (dB)		99.1	99.5

2.3 Materials and methods of noise mapping of the wind farm

2.3.1 Materials

The realization of the predictable noise map of AL KOUDIA AL BAIDA Park after construction of the wind farm was carried out using the specialized software CadnaA. This software suite includes a set of modules for calculating, among other things, the variation of the sound pressure level as a function of the distance between the source of the noise and the receiver, taking into account the topography, the nature of the ground, the Meteorology (wind speed and orientation, temperature), buildings, etc.

2.3.2 Method of calculation

There are several methods for calculating the sound pressure level as a function of the distance between the noise source and the receiver (ISO 9613-2, DIN 18,005, ÖAL -28, BS5228, TNM Industry, Harmonoise, etc.)

In this study, we adopted the international standard ISO 9613-2 (1996): Sound attenuation during its propagation in the open air. This method takes into account geometric divergence, atmospheric absorption, soil effect, reflection from the surfaces of the screen effect, the effect of vegetation, dwellings and sites industrial sectors.

2.4 Noise Indicators

In its European Directive 2002/49/EC, the European Commission retained the L_{den} (Leq Day-Evening-Night) for the 24-hour period and, more specifically, for the night period, the LAeq (8 hours). L_{den} is defined as the average energy level over the 24-hour period, divided into 3 phases for which "penalties" are applied (5 dB [A] for the evening, 10 dB [A] for the night). It is given by Eq(1).

$$\mathbf{L_{den} = 10 \cdot \log\left(\frac{12*10^{\frac{L_{day}}{10}}+4*10^{\frac{L_{evening}+5}{10}}+8*10^{\frac{L_{night}+10}{10}}}{24}\right)} \quad (1)$$

with:

- L_{day} Is the A-weighted mean long-term sound level as defined in [6] determined over all day periods in a year,
- $L_{evening}$ Is the A-weighted mean long-term sound level as defined in [6] determined over all evening periods in a year,
- L_{night} Is the A-weighted mean long-term sound level as defined in [6] determined over all night periods in a year.

The coefficients 12, 4 and 8 are respectively the duration in hours of the day, evening and night. A year corresponds to the year taken into consideration for sound emission and to an average year for meteorological conditions, the height of the L_{den} assessment point depends on the application for which noise mapping (in the case of impact studies, European regulations impose 4m +/- 0,2m).

3. Application to the AL KOUDIA AL BAIDA wind farm: Preliminary calculations

To develop the L_{den}, L_{day}, $L_{evening}$ and L_{night} noise map of the AL KOUDIA AL BAIDA wind field, we produced a geographic database comprising:

- The map of land use: digitized on recent Google Earth images of the region (November 2016) including dwellings;
- Geographical location of wind turbines;
- The location of the receivers in the vicinity (4 to 7 m) of the houses most exposed to wind turbine noise;
- The different altitudes (wind, dwellings, relief, receivers…) using the World Coordinate Converter [7].

In addition, preliminary calculations have been carried out to specify the topography of the wind farm location area (contour lines…) with the delimitation of the calculation area. The locations are shown in Fig. 1.

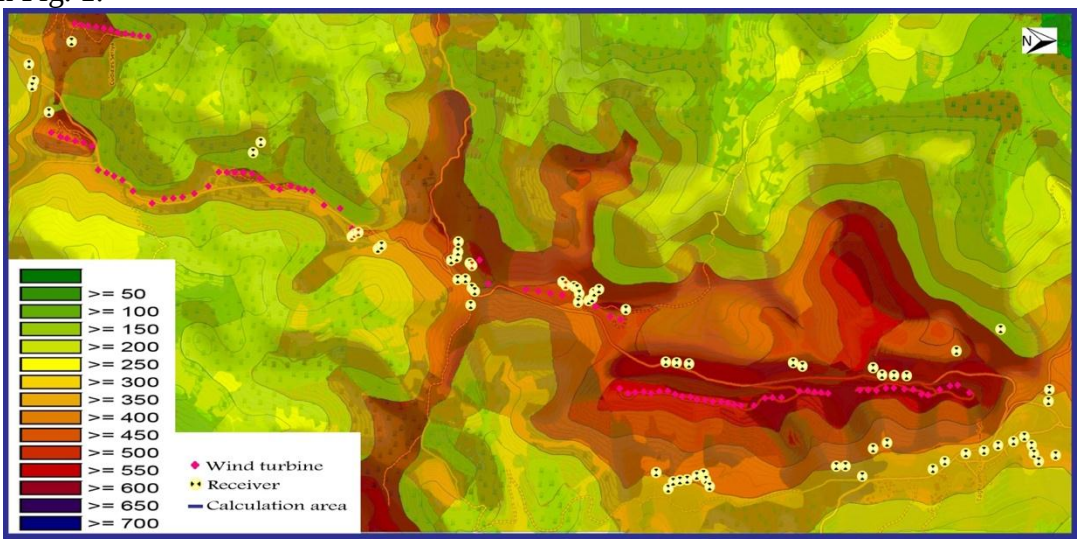

Figure 1:Topography: contours in (m) and delimitation of the AL KOUDIA AL BAIDA wind farm

4. Calculation assumptions

4.1 Environment

4.1.1 The wind

Table 5: The wind rose for the Tangier region [8]

	Average wind speed		Average wind speed
345-15	6.99	**165-195**	6.91
15-45	7.18	**195-225**	6.15
45-75	5.74	**225-255**	3.75
75-105	3.36	**255-285**	3.28
105-135	3.53	**285-315**	3.04
135-165	4.60	**315-345**	4.82

4.1.2 Humidity, mean temperature and atmospheric pressure [9]

- Humidity = 75%
- Temperature = 19 °C
- Atmospheric pressure = 1021 hPa

4.2 Some calculation parameters

The table below shows some calculation parameters.

Table 6: Calculation parameters

Number of Receivers	72 receivers located near the dwellings (1 to 7 m) at a height of 4m above the ground
Radius of the calculation circle	2000 m
Mesh factor	0.5
Soil Absorption	G=0.8
Reference periods	6-18h: day; 18–22: evening; 22h-6h: night
Radius of the receiving action	2000 m
Wind speed	8 m/s
Mast Height	43.5 and 45 m

It should be noted that until now Morocco has no specific regulations for noise from wind turbines. But industrial noise in general is regulated by the decree of the Minister of Labor n ° 93-08 under the Labor Code, In particular Articles 15 to 20 which regulate the exposure of workers to noise in the workplace.

For this purpose, the German regulations (TA-Lärm) are applied. This regulation applies to all types of noise that have an effect on the environment. It is based on the notion of maximum permissible global levels (with the functioning of the facility in question), the values of which are defined as a function of the area concerned, outside or inside.

In our study, it will be used that the external part, or the critical levels of the ambient noise for a Villages or mixed areas zone must not exceed 50 dBA on the day and 45 dBA at night.

The simulations concerned the speed of 8 m/s and were not made for this speed only because the sound power spectrum is not available for the two types of wind turbines used.

The results are presented in the form of maps of sound pressure levels, thresholds and tables of these values at the selected receivers.

5. Results and Mapping Analysis

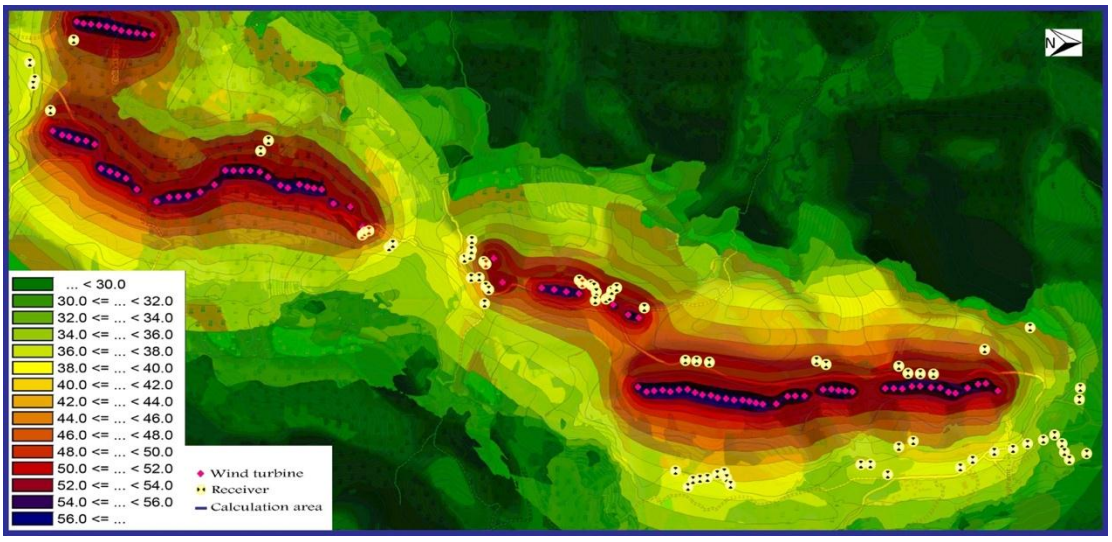

Figure 2: The overall sound pressure levels dBA of the day L_{day}: Wind speed 8 m/s

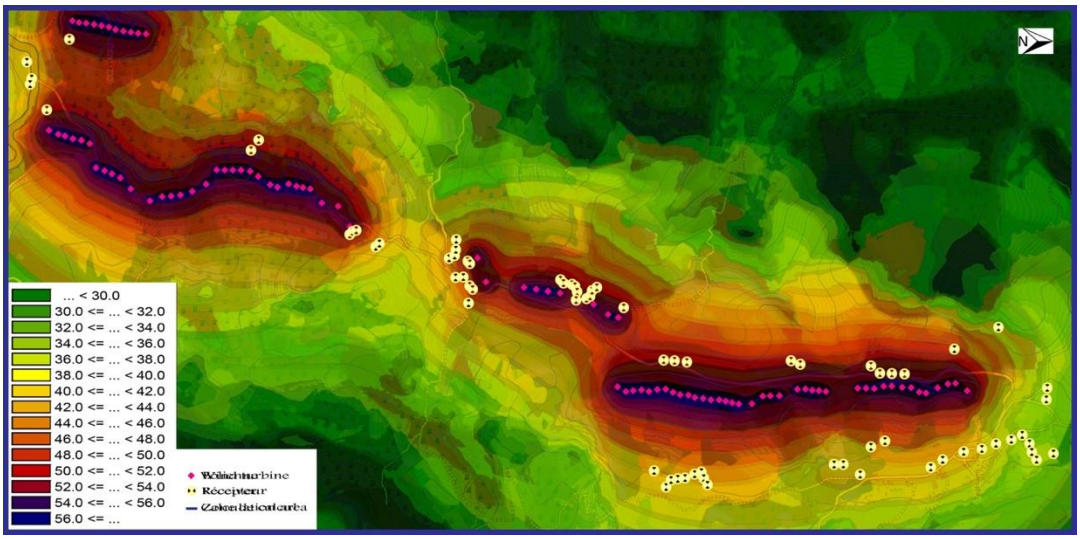

Figure 3: The overall sound pressure levels dBA at night L_{night}: Wind speed 8 m/s

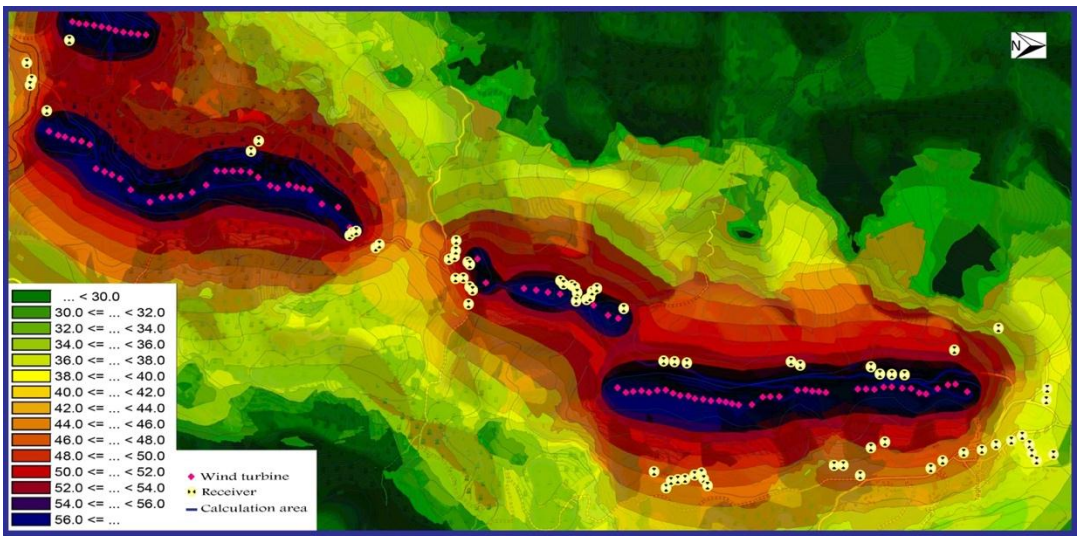

Figure 4: The overall sound pressure levels dBA of the L_{den}: Wind speed 8 m/s

According to the previous figures, a few receivers with a red color appear, which means that the receivers have exceeded their threshold, this change in color concerns only the figures of the level L_{day} and L_{night} because there is only one limitation Compared to L_{day} and L_{night}.

Table 7: Summary of the L_{day}, L_{night} and L_{den} at the receivers: wind speed 8 m/s

Receptor	Level Lr (dBA)			Receptor	Level Lr (dBA)		
	L_{day}	L_{night}	L_{den}		L_{day}	L_{night}	L_{den}
R01	38.2	38.2	44.7	R37	47.3	47.3	53.9
R02	39.4	39.4	45.9	R38	39.9	39.9	46.5
R03	39.4	39.4	46.0	R39	38.7	38.7	45.2
R04	46.4	46.4	52.9	R40	39.5	39.5	46.0
R05	49.4	49.4	55.9	R41	39.8	39.8	46.4
R06	48.6	48.6	55.1	R42	40.1	40.1	46.6
R07	45.7	45.7	52.2	R43	40.7	40.7	47.3
R08	50.7	50.7	57.2	R44	41.0	41.0	47.5
R09	52.6	52.6	59.1	R45	40.3	40.3	46.8
R10	51.5	51.5	58.0	R46	39.6	39.6	46.1
R11	39.6	39.6	46.2	R47	46.8	46.8	53.3

Receptor	Level Lr (dBA)			Receptor	Level Lr (dBA)		
	L_{day}	L_{night}	L_{den}		L_{day}	L_{night}	L_{den}
R12	40.4	40.4	46.9	R48	47.8	47.8	54.3
R13	41.7	41.7	48.2	R49	39.6	39.6	46.2
R14	43.3	43.3	49.8	R50	39.2	39.2	45.8
R15	43.1	43.1	49.6	R51	38.3	38.3	44.8
R16	41.4	41.4	47.9	R52	41.6	41.6	48.1
R17	42.3	42.3	48.8	R53	42.5	42.5	49.1
R18	44.8	44.8	51.3	R54	49.2	49.2	55.7
R19	49.4	49.4	55.9	R55	51.6	51.6	58.1
R20	50.2	50.2	56.7	R56	51.8	51.8	58.3
R21	42.5	42.5	49.0	R57	51.6	51.6	58.1
R22	46.0	46.0	52.5	R58	44.6	44.6	51.1
R23	46.4	46.4	52.9	R59	39.1	39.1	45.6
R24	49.4	49.4	56.0	R60	39.7	39.7	46.2
R25	50.4	50.4	57.0	R61	39.3	39.3	45.8
R26	48.2	48.2	54.8	R62	37.7	37.7	44.3
R27	47.9	47.9	54.5	R63	35.7	35.7	42.2
R28	48.2	48.2	54.8	R64	33.6	33.6	40.1
R29	48.6	48.6	55.2	R65	32.8	32.8	39.3
R30	50.5	50.5	57.0	R66	32.2	32.2	38.7
R31	50.5	50.5	57.1	R67	32.8	32.8	39.4
R32	48.0	48.0	54.5	R68	33.1	33.1	39.6
R33	46.5	46.5	53.0	R69	35.0	35.0	41.5
R34	49.6	49.6	56.2	R70	32.5	32.5	39.1
R35	47.5	47.5	54.0	R71	32.7	32.7	39.3
R36	47.6	47.6	54.1	R72	31.9	31.9	38.5

The values mentioned on the receivers relate only to the noise emitted by wind turbines only, and it should be recalled that the receivers are placed at 4 m from the ground at a distance of between 1m and 7m of the dwellings around the wind turbines.

The results shows that about 13.9% of the receivers have a daytime threshold overrun against 43% of the receivers that have a threshold violation the night.

6. Conclusion

This study provides an overview of the noise impact of wind turbines (AL KOUDIA AL BAIDA Park). It is also an important source of information for noise policy in Morocco. The acoustic level near the inhabitants beside the wind farms, a long exposure can cause serious problems to the citizen of the region. More detailed results are being prepared, notably the various socio-economic factors in the community and the effect of the proximity of wind turbines.

The combination of this study with on-site noise measurements is more than desirable in order to estimate the impact of wind noise on the health of citizens.

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