INTENSITY OF AEOLIAN PROCESSES IN POLAND (REVIEW OF LITERATURE)

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Present-day aeolian processes can be divided into processes happening under natural conditions (in Poland at seashore, in valleys of large rivers and in mountains above the upper forest boundary) and in cultural landscapes (agricultural, industrial and urbanised landscapes as well as in deforested lands). These processes also occur in open-mined excavations, at plough lands and in mountainous areas of intensified tourist traffic. They happen during strong winds of velocities above 5 m/s, most often 10 - 15 m/s, and they are observed during the whole year, especially in autumn and winter. Contemporary processes caused by wind are responsible for the accumulation of series of aeolian deposits of different thickness and range, and for the present shaping of aeolian landforms. Deflation processes occur in subnival belt of the Tatra Mts. in areas of intensified tourist traffic. They can also be considered to be one of the most important processes modelling dividing ranges. Deposition of blown sands also follows behind barriers in aerodynamical shadow or on meadows in lowlands. It often causes the covering up of draining ditches, roads, cereal crops and meadows. Present-day aeolian processes also influence periodically uncovered sandy horizons in the neighbourhood of artificial water reservoirs. The intensity of aeolian processes is very important from the geomorphological point of view because of its effects (e.g. permanent changes in morphology, large air pollution, covering of plough lands, the occurrence of dust storms and black winters). The occurrence of intensive aeolian processes on dumps is very arduous and often very harmful for the neighbouring environment. The paper is an attempt to present the known data on intensity of aeolian processes in Poland on the base of accessible literature. It appears that investigations on the intensity of processes caused by wind are accidental and estimated for the whole country, but even so they do indicate the wide range of the process. For example the average RAP intensity of aeolian processes in the agricultural landscape amounts to 300 tons/km²/year (maximum values - 10 000 — 12 000 tons/km²/year (the Carpathians, Lublin Upland)). Unfortunately, there is the lack of methodological approach to this problem and applying of uniform methods and measures to obtain the objective and comparable character of research. Presently there is the necessity to convert between different measure units.

Key words: aeolian processes, intensity, Poland

INTRODUCTION

Present-day aeolian processes can be divided into processes happening under natural conditions and in cultural landscapes. Aeolian processes under natural conditions occur at seashore, in valleys of large rivers and in mountains above the upper forest boundary (BORÓWKA 1980, IZMAIŁOW 1984, KOTARBA 1983 and MISZALSKI 1973). Among cultural landscapes, processes in agricultural, industrial and urbanised landscapes as well as in deforested lands are numbered (WOJTANOWICZ 1990 and 1999). WOJTANOWICZ (1999) also separates autochthonous and allochthonous processes caused by wind. The first group has local or regional character (short transport), the second one refers to continental or intercontinental processes (long transport), where the source of dust is located far, beyond the territory of Poland (WOJTANOWICZ 1972, WOJTANOWICZ and ZINKIEWICZ 1966).

The intensity of aeolian processes and landform formation is influenced by physico-geographical features of the environment and anthropogenic factors. To the first group belong anemological conditions, relief, character of substratum deposits and vegetation cover (BORÓWKA 1980). In the case of human activity the factors creating conditions for the ground drying (improper agrotechnical measures, uncovered soil, excessive intake of underground waters, draining etc.) as well as intensifying the deflation through traffic, agrotechnical measures, open cast exploitation of raw materials, dumping grounds, settlement tanks and others are very important (JÓZEFACIUK and JÓZEFACIUK 1999).

Wind processes occur at strong winds of velocities above 5 m/s, most often 10-15 m/s, and they happen annually, especially in autumn

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and winter (WOJTANOWICZ 1999), while in the industrial and urbanized areas - throughout the year.

In Polish geomorphological literature studies concerning the velocities initiating sand movement, spatial, temporal variety and lithodynamics of aeolian deposits, attempts to determine the intensity of aeolian processes in the Pleistocene are known (BORÓWKA 1980, NOWACZYK 1986 and 2002, PEŁKA-GOŚCINIAK 2000, SZCZYPEK and WĄCH 1991b, WORONKO 2007 or ZIELIŃSKI 2001), but there is a small number of publications on the intensity of present-day processes caused by wind. In the last years some studies, concerning niveo-aeolian processes were also published (GERLACH 1986, KIDA and JARY 2002, KIDA 2004, RODZIK and SIWEK 2008, SZPIKOWSKI 2008 or ZWOLIŃSKI 2008). Till now only WOJTANOWICZ (1999 and 2004) made the attempt to sum up these considerations and to draw some conclusions. The paper is an attempt to present the accessible data on it on the base of literature and to complete these considerations.

INTENSITY OF AEOLIAN PROCESSES IN POLAND

The intensity of aeolian processes in Poland is relatively weakly known. The researches are rather accidental and estimated for the whole country, but even so they do indicate the wide range of the process.

According to WOJTANOWICZ (1999) not numerous measurements of present-day aeolian accumulation or deflation amounting to from several hundred up to a dozen or so thousand tons per km^2 prove that the scale of process is large. Taking into account the wind velocity (above 5 m/s), lithological variety and the index of terrain relief, in Poland three types of region of different intensity of aeolian processes in agricultural landscapes are divided. There are as follows (**Fig. 1**):

- of very strong intensity of aeolian processes – 500-1000 tons/km^2/year, on average 600 tons/km^2/year (areas of mountains, foothills and uplands with loess and dusty covers),
- of medium intensity 200 - 500 tons/km^2/year, on average 300 tons/km^2/year (part of the Sudety Mts., uplands with not dusty covers, more diversified lakeland areas),
- of weak intensity 50-200 tons/km^2/year on average 100 tons/km^2/year (mainly Middle Polish Uplands and West Pomeranian Baltic Coast.

The average intensity of aeolian processes in the agricultural landscape amounts to 300 tons/km^2/year at maximum values up to 10 000 - 12 000 tons/km^2/year (the Carpathians, Lublin Upland) (GERLACH and KOSZARSKI 1968, STRZEMSKI 1957, WOJTANOWICZ 2004). The value of 300 tons/km^2/year as the mean value of RAP (Recent Aeolian Process) for the whole territory of Poland is also characteristic for the European temperate forest zone, which contemporarily is mostly represented by agricultural landscapes (WOJTANOWICZ 2004).

In the 1950s, owing to agriculture, transformation of dunes often happened. But aeolian processes also developed on soils of larger cohesion. Agrotechnical exertions undertaken in autumn favour the formation of soil aggregates, especially during dry winters. In the period of autumn-winter winds, these are blown from fields and transported by wind to different distances. They were often deposed on snow in the form of niveo-aeolian covers (GERLACH 1977 and 1986 or JAHN 1969). Large intensity of aeolian processes caused by such activity of humans is observed in the Carpathians and Sudety Mts. and occasionally in Wielkopolska. Under proper weather conditions soil aggregates and weathered material are blown from windward slopes of mountainous ridges and then deposed on leeward slopes at snow cover (niveo-aeolian deposits) or at meadows (GERLACH 1977, GERLACH and KOSZARSKI 1968, JAHN 1969, NOWACZYK 2002 or WELC 1977).

The area of Poland – in the whole landscape profile - can be considered to be representative to observe the role of niveo-aeolian processes. These processes, especially these occurring at plough lands, can play the important role in soil deflation and finally in the process of denudation (JAHN 1969 and 1972).

Niveo-aeolian process in the Sudety Mts. Foreland were described by JAHN (1969 and 1972), and in the last years by KIDA and JARY (2002) or KIDA (2004 and 2009). For other parts of Poland results of investigations on niveo-aeolian processes were presented by GERLACH (1977 and 1986), GERLACH and KOSZARSKI (1968), JANIGA (1975), JÓZEFACIUK and NOWOCIEŃ (1994), NIEWIADOMSKI and PORADOWSKI (1959), REPELEWSKA-PĘKALOWA and PĘKALA (1988), RODZIK and SIWEK (2008), SZPIKOWSKI (2008) or STRZEMSKI (1957).

Niveo-aeolian accumulation in the Sudety Mts. amounted to 34.5 – 410.1 tons/km^2 in 1963 year and 12.1 – 31.9 t/km^2 in 1965 year (JAHN 1969). For the neighbourhood of Lub-

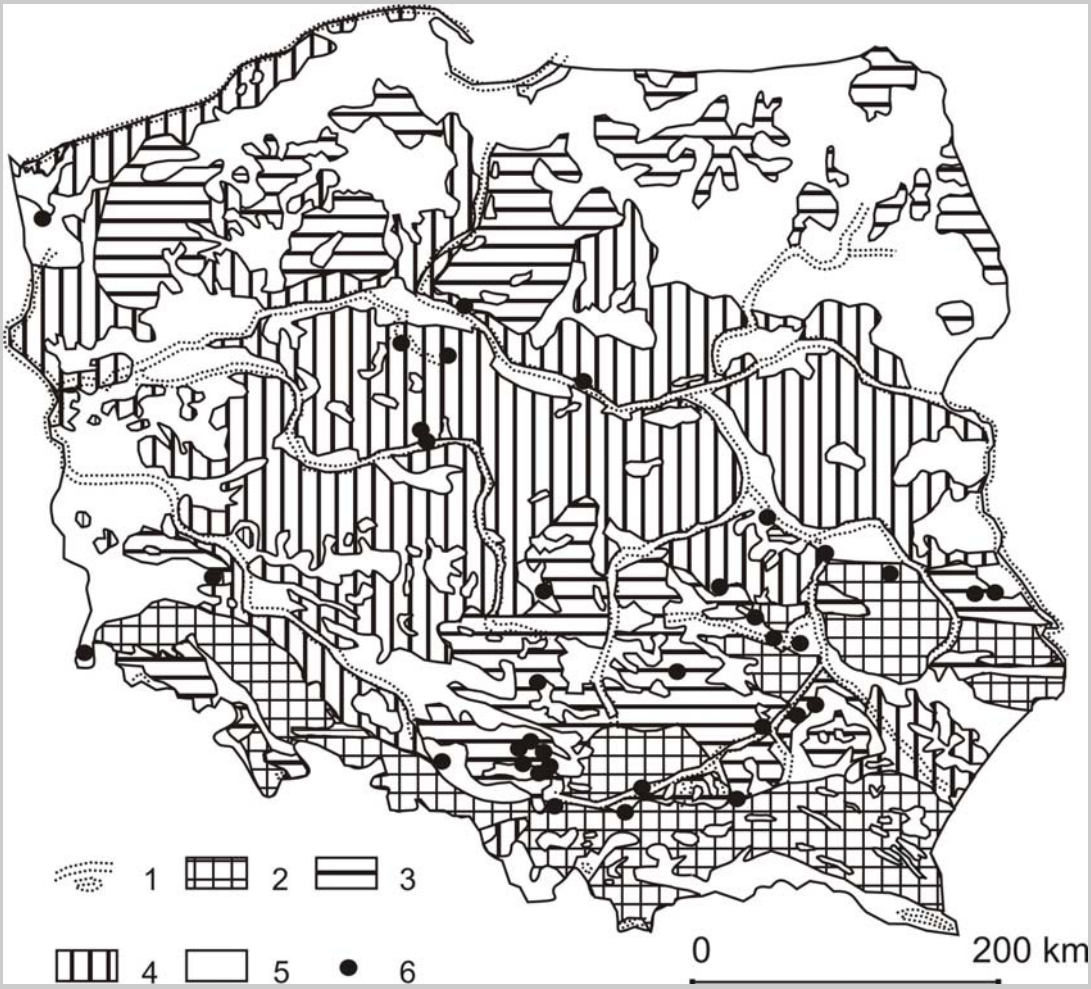

Fig. 1 The intensity of present-day autochthonous aeolian processes in Poland (after WOJTANOWICZ 1999)

1 – the occurrence of process under natural conditions, 2 - very strong intensity of aeolian processes in the agricultural landscape, 3 – medium intensity of aeolian processes in the agricultural landscape, 4 – weak intensity of aeolian processes in the agricultural landscape, 5 – the process does not occur or happens accidentally, 6 – intensive aeolian activity in large sandpits, at dumps, in urbanised areas in cities

lin RODZIK and SIWEK (2008) calculated the value of 230 t/km^2, whereas JÓZEFACIUK and NOWOCIEŃ (1994) gave the value of 2056 t/km^2 for loess terrain. SZPIKOWSKI (2008) presented it for the young-glacial area of Drawsko Lakeland (30 t/km^2 and 58 t/km^2). At this lakeland the concentration of pollutants in snow cover amounted on average to 6.5 kg/m^2, whereas the maximum value was 14 kg/m^2 (ZWOLIŃSKI 2008). GERLACH (1986) presented the table summing up the investigations on annual aeolian deposition for different regions of Poland (70 – 241t/ha/year in the Low Beskid, 1.9 – 10.7 t/ha/year at the Ciężkowice Foothills, 6 – 115 t/ha/year in the Lublin Upland, 87 500 – 242 500 t/ha/year at the Baltic Coast).

Transport of sands and loose soil aggregates takes place in mining excavations (STANKOWSKI 1963), at plough lands (GERLACH 1977, KOBENDZA and KOBENDZA 1958, STACH 1995 and WELC 1977) and in mountainous areas of intensified tourist traffic (KOTARBA 1983). One of the best examples of present-day wind morphological effectiveness are sandpits (at Bukowno, Skwierzyna) or open-cast mine of brown coal in Bełchatów (DULIAS et al. 2008, GOŹDZIK et al. 2009, STANKOWSKI 1963, SZCZYPEK and WACH 1991a). For the Silesian-Cracow Upland some attempts to determine the intensity of aeolian processes were made in sandpit at Bukowno for anthropogenic scarp dune (SZCZYPEK and WACH 1991a and b). The

Conditions	Area	Intensity of process	Author
natural	Tatra Mts. (above the upper forest border)	1-265.1 t/km^2/year on average 75.8 t/km^2/year	B. Izmaiłow (1984)
natural	seaside near Świnoujście and Kołobrzeg	40-160 tons per 1 meter of the width of sandy area on average 100.8 tons per 1 meter	R. K. Borówka (1980) K. R. Borówka and K. Osadczuk (2001)
agricultural	Sudety Mts.	0.0027-0.024 mm/year on average 500 t/km^2/year maximum 4000-5000 t/km^2/year	A. Jahn (1969)
agricultural	Carpathians (Jasło-Krosno Basin)	2000-12 000 t/km^2/year	T. Gerlach and L. Koszarski (1968)
agricultural	Carpathians (Low Beskid)	5 mm/year 1000-3500 t/km^2/year on average 1400 t/km^2/year	S. Janiga (1971)
agricultural	northern part of Lublin Upland (Puławy)	600-10 000 t/km^2/year	M. Strzemski (1957)
agricultural	Lublin Upland Roztocze Lublin Polesye Mazovian Lowland	70.1-508.6 t/km^2/year on average 244.6 t/km^2/year 74.7-473.5 t/km^2/year on average 301.5 t/km^2/year 47.4-298.8 t/km^2/year on average 155.6 t/km^2/year 39.1-181.1 t/km^2/year on average 115.5 t/km^2/year	J. Repelewska-Pękalowa and K. Pękala (1991)
agricultural	Central Wielkopolska	351.4-6393.1 t/km^2/year on average 588.4 t/km^2/year or 282.8 t/km^2/year	A. Stach (1995)
agricultural	Drawsko Lakeland	90.8-452.3 t/km^2/year on average 295.8 t/km^2/year	A. Piechura (1995)
agricultural	Western Pomerania	57.0-753.4 t/km^2 on average 119.6 t/km^2	A. Kostrzewski and J. Szpikowski (1993)
industrial	Bukowno (sandpit)	0.30 kg/m^2/h - 8.78 kg/m^2/h at wet substratum, 0.124 - 1094.61 kg/m^2/h at dry substratum	T. Szczypek and J. Wach (1991a)

Tab. 1 Present-day intensity of aeolian processes in Poland (according to WOJTANOWICZ 2004, changed and completed)

results obtained showed that the amount of material accumulated fluctuated from 0.30 kg/m^2/hour to 8.78 kg/m^2/hour at wet substratum and from 0.124 to 1094.61 kg/m^2/hour at dry substratum with ripple marks (**Tab. 1**).

The empirically proved dependence between aeolian transport intensity and wind velocity was used to calculate the intensity of potential aeolian transport in the natural landscape on sandy beaches near Świnoujście and Kołobrzeg at Polish West Pomeranian Baltic Coast (BORÓWKA 1980, BORÓWKA and OSADCZUK 2001). The potential aeolian transport is characterised here by rather significant intensity. In particular years it fluctuates between 40 – 160 tons per 1 meter of sandy area width at average value of 100.8 tons per 1 meter (**Tab. 1**).

According to NOWACZYK (2002), contemporary aeolian processes are responsible for the deposition of series of aeolian deposits of different thickness and range, and for the present shaping of aeolian landforms.

Deflation processes also occur above the forest boundary in the Tatra Mts. in sub-nival belt in areas of intensified tourist traffic. They can also be regarded as one of the most important from processes modelling dividing ranges (KOTARBA 1983). On contrast, the size of aeolian accumulation varies there within the range of 1 – 265 tons/km²/year (IZMAIŁOW 1984). Wind processes are also present on lowlands. Deposition of blown sands or aggregates follows on meadows or in aero dynamical shadow of barriers. It often causes the covering up of draining ditches, roads, cereal crops and meadows (STACH 1995). The registered extreme falls of deflates made the multiplicity of average annual sums and amounted to from about 4502 tons/km²/year up to about 2287 tons/km²/year. The largest deflation is usually noted in periods of „black" (without snow) winters (JÓZEFACIUK and JÓZEFACIUK 1999). Contemporary aeolian processes shape periodically uncovered sandy horizons in the neighbourhood of retention water reservoirs (TEISSEYRE 1991).

CONCLUSION

Investigations on the intensity of aeolian process are accidental and estimated for the whole country, but even so they do indicate the

wide range of the process. Unfortunately, there is also the lack of methodological approach to this problem and applying of uniform methods and measures to obtain objective and comparable character of research. Presently they require the necessity to convert between different units. The intensity of aeolian processes is very important from the view of geomorphological effects of these phenomena. Large intensity causes permanent changes in morphology (the contemporary aeolian processes are responsible for the deposition of series of aeolian deposits of different thickness and range, and for the present shaping of aeolian landforms), large air pollution, covering of plough lands, the occurrence of dust storms and „black" winters. The occurrence of aeolian processes on dumps is very arduous and often very harmful for the neighbouring environment. Finally, they are also of large importance in the process of denudation.

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