

Impact of environmental conditions in West Europe, Poland and Algeria on outdoor insulators performance and selection

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Abstract: This paper presents the data of environmental conditions in France, Germany, Poland and Algeria. The trends in industrial contamination emission were given, especially of dust, SO₂, NO_x, rainfall conductivity and acidity. The large environment improvement, especially decrease of dust deposit density in Europe should be taken into account during selection of insulators according to IEC Publication 60815. On the other hand the natural contamination in Algeria (Sahara dust or sea salt) is a dominating factor in this country, therefore no changes here are expecting.

1 INTRODUCTION

The specific leakage distance of outdoor insulators should be longer than 1,6 cm/kV even in clean areas (pollution zone I) [1]. In extremely contaminated sites, the specific leakage distance as long as 55 mm/kV is needed [2]. The pollutants are of natural (sea salt, desert sand) or man made (industrial, agriculture, transport) origin. The industrial pollution concentrates mainly around the industrial centres creating the "black triangles". The sea salt contamination dominates in the coast vicinity. A special care should be paid at the distance smaller than 10 km from the sea. The desert or arid territories occupy big areas in many countries of the world.

The natural contamination is relatively stable in time. On the contrary, the industrial pollution changes according to different phases of national economy. First, in the development phase, the industrial dust emission increases and later decreases in the post-industrial era. As a result the old insulation installed on overhead lines many years ago could be over-dimensioned now. This paper compares the environmental pollution in three European countries with that in Algeria. The situation in these countries is similar to other European countries or to other countries from North Africa.

2 EMISSION OF INDUSTRIAL DUST AND GASES

The dust, sulphur dioxide and nitric oxides are the main industrial pollutants. The dust emission in Poland

decreases continuously since 1985 (fig. 1). After unification of Germany in 1989 the dust emission dropped rapidly because of industry restructure in the east part of the country, former German Democratic Republic (DDR). The electricity generation in Poland and in DDR has based on coal firing. On the contrary, France has many nuclear power plants. Therefore dust emission there is still lower than in Poland and in Germany.

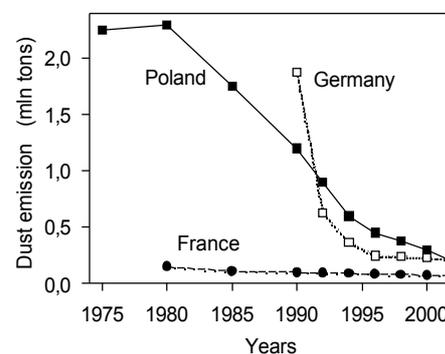


Fig. 1. Dust emission in Poland [3], Germany [4] and France [5].

The sulphur dioxide and nitric oxides emissions had an increasing trend in Poland and France up to 1980-1985 (fig. 2, fig. 3). The decrease of SO₂ and NO_x emissions has been noted for about 20 years. There is often a close relationship between the emission of industrial gases and the emission of industrial dust. SO₂ and NO_x are responsible for creation of acid of rains.

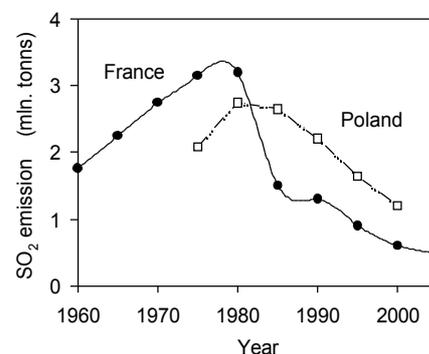


Fig. 2. SO₂ emission in France and Poland

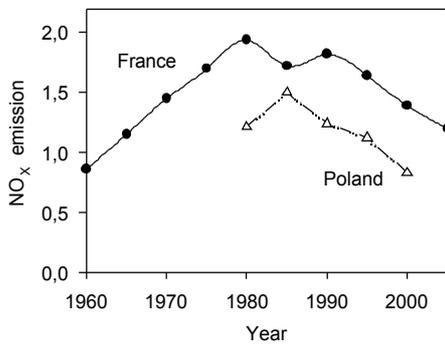


Fig. 3. NO_x emission in France and Poland

3 DUST PRECIPITATION

The dust emission shown in fig. 1 describes the total emission from a whole country. The dust deposition at a particular location is related directly to the pollution severity by increasing of dust deposit density (DDD) and equivalent salt deposit density (ESDD) on outdoor insulators. Dust deposit density measured by means of Directional Dust Deposit Gauges became a criterion for selection of insulator to polluted conditions [1].

Due to the reduction of dust emission in many European countries the dust precipitation has been also decreased as compared to the past. One of the best examples is the cement industry which reduced 150 times its dust emission in Poland from 226 000 tonnes in 1981 to only 1500 tonnes in 2005 !. The maximum values of dust precipitation in the industry basin of Upper Silesia in Poland were 30 g/m²-day in 1950s and caused many flashovers on outdoor insulators that times. No higher values as 1 g/m² day could be found there today [6].

A gradual decrease of dust precipitation was also noted at Glogow pollution test station situated at a copper smelting plant in Poland (fig. 4). Under very heavy pollution (dust precipitation in the range of 12 g/m²-day) flashovers occurred there in 1979. The withstand specific leakage distance estimated for porcelain insulators under natural conditions amounted 2,6 cm/kV in 1987 and 1,3 cm/kV in 2002 as a result of environmental improvement [7].

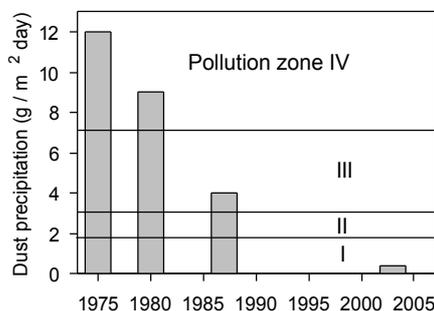


Fig. 4. The dust precipitation at the Glogow test station in the period of 1980-2003.

The highest dust precipitations in Nordheim-Westfalen, Germany (medium values a year) are shown in fig. 5. The measurements were carried out at over 250 test points. For only two points dust precipitations was greater than 1,8 g/m² day. Usually, the dust precipitation in Poland, Germany and France is in the range of 0,1 - 0,3 g/m²-day.

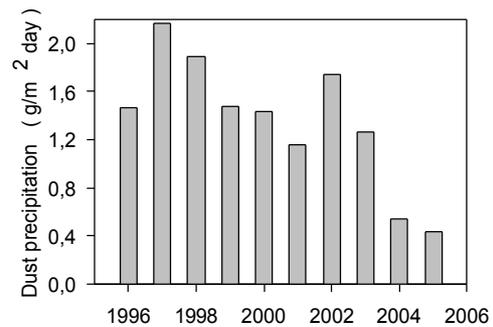


Fig. 5. The highest values of dust precipitation found in Germany in a place located in Ruhr Basin [8].

4 RAIN PRECIPITATIONS

In the 1960s, the environmental contamination increased to a point that the rain conductivity had reach a value of 4000 μS/cm [9]. In Upper Silesia (Poland) the rain conductivity was at a level of 1000 μS/cm, while drizzle was up to 2000 μS/cm. Conductivities in the vicinity of chimney cold storage were at a higher level of 3000 μS/cm [10].

In the 1960s it was found that rain precipitation had not only a high conductivity but also a low pH value (smaller than 5,6). Clean rainwater is slightly acidic (pH = 5,6) due to the presence of CO₂ in the atmosphere. The lowest pH value of 1,5 was detected in 1979 in Wheeling (West Virginia, USA). In Europe, the lowest pH value was 2,4, and occurred in Pitlorchy (Scotland, 1974) [10].

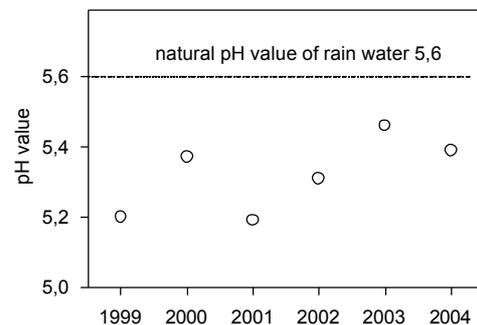


Fig. 6. The mean pH values of rains measured in Poland last years [11]

The negative influence of acid rains on soil, forest, buildings, and steel constructions was recognised a long

time ago. To limit catastrophic environmental disaster, SO₂ and NO_x emissions were gradually decreased in many countries. This effort produced measurable effects. The pH values in Poland increased last years and have reached the level of 5,4 (fig. 6). The same trend is observed in Germany where the mean pH increase from 4,4 in 1990 up to 4,9 in 2001 [12]. In spite of this, in some regions of the world the pH value of rainwater remains lower than 4,5 [13].

Because of cleaner and cleaner environment in Europe the rainfalls conductivity is in the range of 20 – 40 μS/cm. The minimum values are even less than 10 μS/cm, the values greater than 100 μS/cm could be found very rarely (fig. 7).

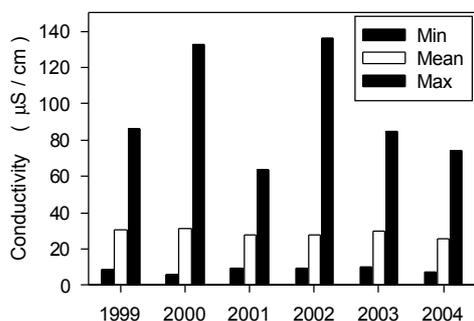


Fig. 7. Minimum, mean and maximum conductivities of rain precipitations in Poland last years [11].

The conductivity of rainwater is initially greater and usually decreases with time. On the other hand, the pH value can initially be of low value and then increase to a higher value. Both processes are caused by contaminant washing and neutralising reactions of rainwater and alkaline particles. The mean conductivity of rainwater measured after the end of rainfall is usually lower than its maximum (fig. 8). Additionally, the conductivity of a sample collected during rainfall and subsequently measured can be smaller than the weighted mean value from continuous measurements (as seen in fig. 8). This effect can be explained by neutralisation reactions.

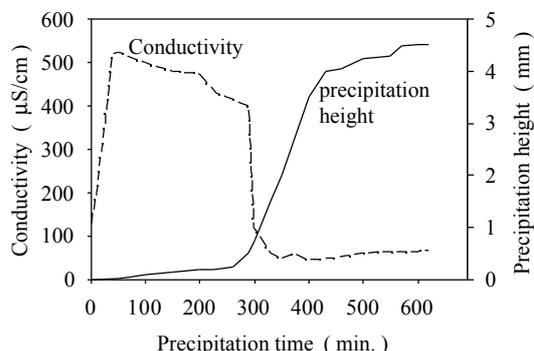


Fig. 8. Conductivity and precipitation height of rain in Cracow on 27.09.1995 [10]

5 SEA SALT

The insulators on lines situated close to the sea coast are exposed to salt contamination. There are many reports about outages caused by this natural pollution [14, 15]. The ocean water with the salinity of 3,5% has the conductivity of 50 mS/cm. The salinity and conductivity of seawater around the Europe is given in the tab. 1.

Table 1. Salinity and conductivity of the sea water

Sea	Salinity (g/l)	Conductivity (mS/cm)
Atlantic	36	50
Mediterranean sea	38	
Black sea	14 - 19	
Baltic sea	3 - 8	4 – 12
Caspian sea	1 - 13	

During the storm whether the sea wave reach the height of 14 m. The salt aerosol is transported over the coastal zone. The aerosol concentration C in the air depends on the wind speed v :

$$C = a \cdot \exp(b \cdot v) \quad (1)$$

where:

C is given in [$\mu\text{g} / \text{m}^3$], v in [m/s].

a and b – parameters which depend on the sea distance, the height above the sea level and the terrain shape.

The measurements carried out in different countries have shown that very close to the sea the ESDD on cap and pin insulators can reach 0,3-0,4 mg/cm^2 [16, 17, 18]. The maximum and medium values found on insulators in South Africa shows fig. 9.

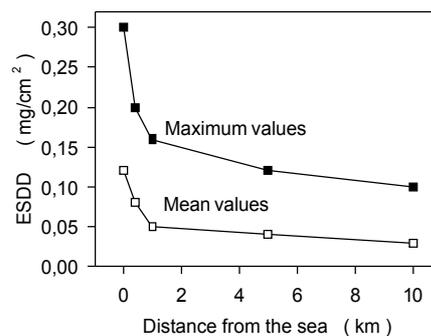


Fig. 9. Maximum and medium ESDD on cap and pin insulators as a function of the distance from the sea. Results from South Africa [17].

The water conductivity in the Baltic Sea is about 5 times smaller than in the Ocean (tab. 1). The salinity in the west Baltic part at Denmark coast is 20 ‰ and in the north part, in the Gulf of Finland and the Gulf of Bothnia, only 3 ‰ (fig. 10). Therefore it is possible to build here the lines close to the seacoast.

The 15 kV line on Hel Peninsula in Poland has been built close to the Bay of Puck coast. A part of this line is situated only 10 m from the water (fig. 10, location A, fig. 11). The 15 kV line on Vistula Peninsula is situated about 100 m from the seacoast line (fig. 10, location B). The porcelain insulators with 47 cm leakage distance were applied on both lines. The seawater at these locations has the conductivity of 10 mS/cm. The specific leakage distance of 30 mm/kV assures reliable operation of both lines.

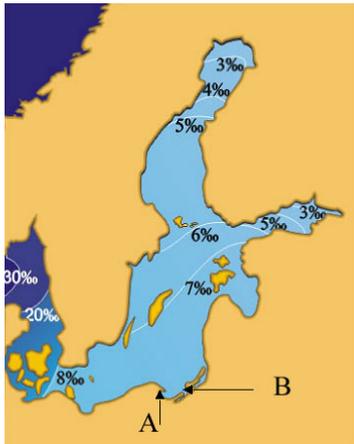


Fig. 10. The salinity of the Baltic sea



Fig. 11. The 15 kV line on Hel Peninsula situated a few meters from the coast of Puck Bay, Poland.

6 DESERT CONDITIONS IN ALGERIA

There are three types of contamination in Algeria: industrial, sea salt and desert. The heavy industries of Algeria, which traditionally have been concentrated around Algiers and Oran, have included, cement factories, chemical plants, oil refineries. The influence of industrial contamination on outdoor insulation is limited to a few kilometres from the emitters. Therefore, the role of natural pollution for the transmission and distribution system of the country is more important.

About one-sixth of the country, comprising the Mediterranean coastlands and the northern mountains, has a typical Mediterranean climate with winter rainfall. The rest of the country, to the south of the Saharan Atlas Mountains, is almost rainless and is part of the great Sahara desert.

Northern Algeria has a varied relief with two ranges of moderately high mountains: the Tell Atlas and the Saharan Atlas, separated by a region of elevated plains and interior basins - the Plateau of the Chotts. There are Chott Melghin, Merouan, el-Hodna, ech Chergul in Algeria and Chotts el-Djerid, el-Gharsa in Tunisia. Bedded crusts are found around these ephemeral lakes and lagoons. They are characterized by size-graded beds, gypsum contents of 50–80% by weight and comparatively high concentrations of sodium, potassium, magnesium and iron. They are interpreted as shallow-water evaporites which accumulate when saline pools evaporate to dryness. Desert rose crusts or *croûtes de nappe* generally contain 50–70% by weight gypsum, and have high sodium concentrations [19, 20].

The chemical analyzes of insulator pollution from different part of Sahara show different components [20, 21, 22]. The amount of calcium and gypsum (CaSO_4) is very important in respect to the electrical conductivity of aqueous dust solution [23].

The dust storm is very dangerous phenomenon that can disturb the reliable operation of mechanical and electrical devices including the outdoor insulation. Usually, a dust storm is a result of convection currents forming from hot ground. These currents can create winds that blow up to 120 km/h. Dust storms can carry large amounts of dust, so much so that the leading edge of one can appear as a solid wall of dust (fig. 12). Dust storms occur in many parts of the world, especially on desert and arid areas. Drought and wind contribute to the emergence of dust storms, as do poor farming and grazing practices by exposing the dust and sand to the wind [24].



Fig. 12. African dust storm [25]

Transport of suspended particles on long distances during the dust storms influences the air conditions at distant places. Such episodes are noted in Alger or

Beijing, where dust concentration in air can reach the value of 1500 – 2000 $\mu\text{g}/\text{m}^3$ (fig. 13) [26, 27].

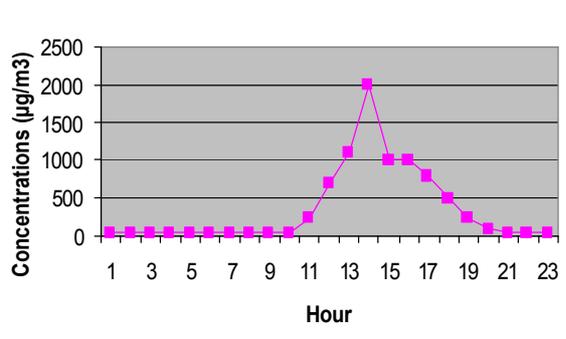


Fig. 13. Dust concentration in Alger on 15/11/2005 [26].

Very often, this specific type of environment can lead to ESDD levels over 1 mg/cm^2 on standard cap and pin insulators. Little rain, frequent sand storms, condensation phenomena and early dew resulting from large temperature fluctuations between day and night, all worsen the situation for transmission and distribution system. In spite of very long leakage distances employed in Tunisia in affected areas (up to 37 mm/kV for transmission lines and as high as 42 mm/kV for distribution lines) as well as very costly washing, flashover still occur [28].

7 CONCLUSIONS

The emission of industrial dust in Europe decreased many times last years. Therefore, the nearly whole of European interior belongs to the pollution class “light”.

The line with the specific leakage distance of 30 mm/kV can be built very close to the brackish Baltic Sea.

Due to the salt sands and dust storms in the desert areas, the very long specific leakage distances have to be applied on outdoor insulators.

8 ACNOWLEDGMENTS

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