STRUCTURE OF THE AEROCHEMICAL COMPLEX OF THE ATMOSPHERE AT COASTAL CORROSION STATIONS OF THE INSTITUTE OF PHYSICAL CHEMISTRY OF THE ACADEMY OF SCIENCES OF THE USSR, AND ITS INFLUENCE ON THE CORROSION RATES OF METALS

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On the basis of many years of observations, the character of the seasonal variation in the concentration of the seawater aerosols in the atmospheres of the Murmansk, Vladivostok, and Batumi corrosion stations is elucidated. It is shown that the mean sedimentation rates of chlorides in these regions range from 20.5 to 2.4 mg/m^2•day. The velocity (intensity) of the sea winds is the main factor governing the rate of conveyance of aerosols. The quantity of aerosol in the atmosphere decreases with distance from the shoreline. There is a single-valued relation between metal corrosion rates and the surface concentrations of deposited sea salt.

One of the main factors governing the corrosive aggressiveness of the atmosphere in coastal regions is the concentration of seawater aerosols in the air. When deposited on a metal surface, the aerosol particles promote the formation of films of electrolytes with various concentrations, leading to a marked increase in the rate of atmospheric corrosion in comparison with a clean atmosphere. The salt content of the atmosphere depends on many meteorological factors; their influence can be determined by means of statistical investigations.

In this article we give the results of a study of the structure of the aerochemical complex in the coastal atmospheres of the Murmansk, Batumi, and Vladivostok stations of the Institute of Physical Chemistry of the Academy of Sciences of the USSR. We elucidate the relation between the rate of sedimentation of seawater aerosols, on the one hand, and the wind pattern and the distance to the shoreline, on the other.

METHOD OF INVESTIGATION

The amount of deposited seawater aerosol (mainly chlorides) was determined by the dry linen method after exposure under a canopy for 15-60 days [1]. The rates of sedimentation of chlorides were expressed in mg/m^2•day. Analysis samples were collected at various distances from the shoreline.

The wind velocity and direction were registered continuously by an automatic recorder (M-12). The corrosion of the metals was measured by means of the mass loss of standard specimens (measuring 100 × 150 mm).

CHARACTERISTICS OF COASTAL CORROSION STATIONS OF THE INSTITUTE OF PHYSICAL CHEMISTRY OF THE ACADEMY OF SCIENCES OF THE USSR

The northern (Murmansk) station lies 300 m to the west of the southwest shore of a bay 1.5 km wide which stretches 1.5 km to the south into the mainland. This bay connects with the Barents sea via straits between islands lying at its center. The relief in the region of the station is hilly and sharply broken. The prevailing winds are southerly (southeasterly), i.e., blowing off the continent (60% of the time). The annual average wind velocity is 8.2 m/sec; the minimum velocities (5-6 m/sec) are observed from off the sea in the summer months (May to August), and the maximum velocities (12-14 m/sec) in the winter.

*T.I. Polyudova took part in the experiments at the Batumi station.

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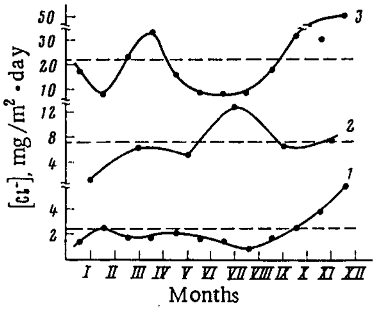

Fig. 1

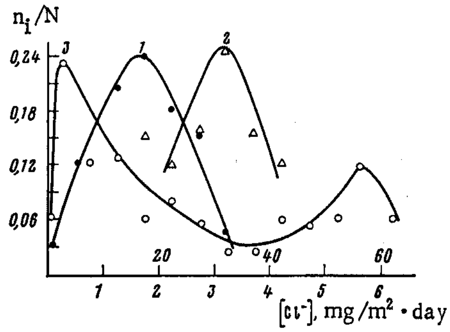

Fig. 2

Fig. 1. Seasonal variation in Cl^- concentration in atmospheres. 1) Southern corrosion station; 2) eastern; 3) northern.

Fig. 2. Distribution of frequencies n_i/N of deposition of various chloride concentrations at southern station (1, 92 m from shoreline; 2, 145 m from shoreline) and at northern station (3).

The southern (Batumi) station lies on the eastern shore of the Black Sea which forms a broad concave arc adjoining the Kolkhida lowlands. The shore and the region of the station are flat and level. The prevailing wind direction is southwest. The annual mean wind velocity is 2.1 m/sec. The probability of velocities above 10 m/sec is not more than 4%.

The eastern (Vladivostok) station lies on the northern shore of a bay in the Ussuri bay. The region of the station is broken territory, in places craggy. The prevailing wind direction is northerly (from November to February) or southeasterly (from May to August). The annual mean wind velocity does not exceed 3-4 m/sec.

EXPERIMENTAL RESULTS AND DISCUSSION

Figure 1 plots curves characterizing the changes in deposition (sedimentation) rate of chloride aerosols at the stations during the year (on the basis of observations made over 5-10 years). At the southern station (curve 1), the maximum conveyance of aerosols is observed in the fall and winter; the surface concentration of salts does not exceed 5-6 $mg/m^2 \cdot day$. In the rest of the year the rate of sedimentation of aerosols is 1-2 $mg/m^2 \cdot day$ (annual mean 2.4 $mg/m^2 \cdot day$, see dashed line).

At the eastern station the greatest conveyance of salts takes place in the summer (May to September) with a maximum concentration of 12-13 $mg/m^2 \cdot day$ (annual mean 7.3 $mg/m^2 \cdot day$).

In the region of the northern station there are two periods in each year with maximum aerosol conveyance — spring and fall. At this station we recorded the greatest degree of salt contamination in the atmosphere, reaching 35-50 $mg/m^2 \cdot day$ (annual mean 20.5 $mg/m^2 \cdot day$).

Figure 2 shows histograms of the frequency distributions of various Cl^- concentrations at the southern and northern stations. In the atmosphere of the southern station Cl^- concentrations of 1.75 and 3.25 $mg/m^2 \cdot day$ occur most frequently at 145 and 92 m from the shoreline, respectively. The histogram of the northern station displays two frequency maxima at 2.5 and 57 $mg/m^2 \cdot day$. These are evidently due to aerosol conveyance by regular and irregular sea winds.

The close relation between the rate of conveyance of seawater aerosols and the sea-wind parameters is confirmed by investigations made at the southern and northern stations. Figure 3 compares the seasonal changes in the rate of Cl^- deposition (curve 1) with the wind intensity (i.e., the velocity of the wind multiplied by the duration of its action) from the sea (curve 2) (based on fortnightly measurements at the Batumi station). We see that maximum chloride conveyance occurs during the period of prevailing sea winds (September through January). Figure 4 illustrates the correlation between the amount of deposited Cl^- and the intensity (or mean velocity) of the winds. Despite the marked scatter of the experimental points, there is a clear tendency for the aerosol sedimentation rate to increase with the sea-wind velocity (curve 1, for northern station) or intensity (region 2, for southern station).

Corrosion tests on various metals at these stations revealed that the rates of corrosion of steel, copper, zinc, and other metals depend on the Cl^- concentration, which varies from station to station or with the distance from the shoreline.

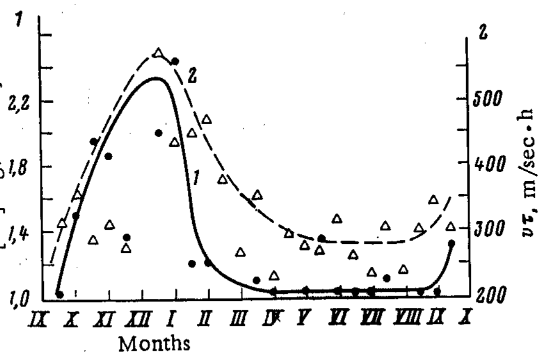

Fig. 3

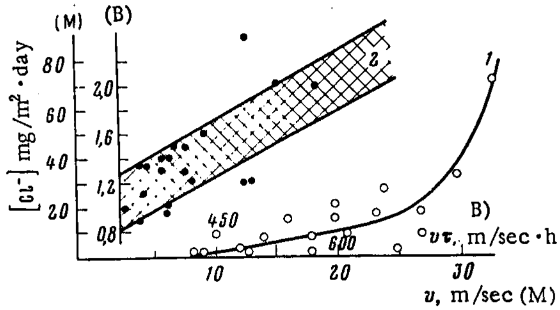

Fig. 4

Fig. 3. Seasonal changes (in 1976-1977) in rate of Cl^- deposition (1) and wind intensity Vτ (2) at southern station.

Fig. 4. Amount of chlorides conveyed by sea-winds. 1) Versus wind velocity at Murmansk, M; 2) versus wind intensity at Batumi, B.

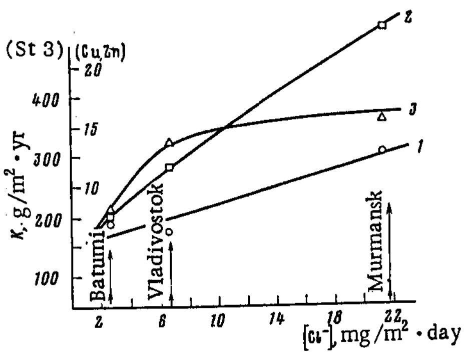

Fig. 5

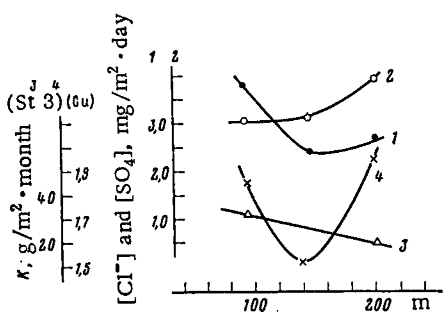

Fig. 6

Fig. 5. Corrosion rates of steel (1), copper **(2)**, and zinc (3) vs Cl^- fallout from atmospheres at coastal stations.

Fig. 6. Monthly mean concentrations of Cl^- (1) and SO_4^{2-} (2) and corrosion rates of steel (3) and copper (4) at various distances from the shoreline at Batumi.

Figure 5 plots the observed rates of corrosion of steel (1), copper (2), and zinc (3) vs the mean Cl^- concentrations at these stations. Since the humidity characteristics of the atmospheres at the stations are identical, the observed differences in the rates of atmospheric corrosion of the metals must be mainly due to the marked differences in the mean Cl^- concentration in the atmospheres of the stations.

Investigations made at the southern station also revealed that the annual seasonal changes in the rates of corrosion of steel, copper, and aluminum repeat the seasonal changes in Cl^- deposition rate (curve 1 in Fig. 3).

The rates of corrosion of metals vary correspondingly with the distance from the shoreline. From Fig. 6 we see that at the southern station, when the distance is increased from 92 to 145 m the Cl^- concentration decreases (curve 1) and that there is a corresponding decrease in the rates of corrosion of steel and copper (curves 3 and 4). However, at a distance of 200 m the Cl^- concentration slightly increases, and there is a marked rise in the SO_4^{2-} concentration (curve 2). The increase in Cl^- concentration over that at the 145 m point is perhaps due to atmospheric circulation in the piedmont part of the territory of the station. The rise in the SO_4^{2-} concentration is due to approach to a source of atmospheric pollution (a motor road and an oil refinery). At this point the corrosion rate of copper increases (apparently owing to the rise in the SO_4^{2-} concentration). The corrosion rate of steel remains less than at the 92 m point.

Our analysis shows that the corrosion reliability of metal structures in coastal regions is governed mainly by the wind characteristics (direction and velocity). The coastal seawater is essentially a source of corrosion-active substances which are transported by moving air masses (wind). Therefore the corrosion aggressiveness of the atmosphere in coastal regions must be assessed not only in relation to the temperature-humidity complex but also in relation to the wind parameters

LITERATURE CITED

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EFFECT OF HEATING ON SERVICE LIFE OF AN ARTICLE IN AGGRESSIVE GASES

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It is shown that the corrosion of electrical components in an aggressive atmosphere is reduced by heating them with an electric current. The possibility of predicting their service lives by extrapolation is analyzed.

It is known [1, 2] that the service or shelf lives of products (components, coatings, or materials) in aggressive gases in operation or tests can be approximately related to the absolute temperature T, the concentration C of the aggressive component, and the relative humidity η of the medium as follows:

$$L = Ae^{B/T}C^{-m}\eta^{-n} \tag{1}$$

or in logarithmic form

$$\lg L = a_1 + a_2/T + a_3 \lg C + a_4 \lg \eta. \tag{2}$$

Equation (2) is used as a mathematical model of the durability in accelerated tests. It also holds good for pure moist air [1, 3] where m = 0.

During operation of heated articles under load, the temperature of the article exceeds that of the surrounding medium. For this reason, the adsorption of moisture and of the aggressive component of the gas on the surfaces of heated articles is reduced, and the flow of moisture and the aggressive component is directed from the article to the medium. In the case of pure moist air this leads to drying of the material or unit and to a sharp reduction in the action of moisture. Therefore, while the heated articles are under load, the action of atmospheric moisture on their insulation and coatings can practically be neglected, so that here internal heating increases rather than reduces their service lives; this has been confirmed experimentally. For the case of an aggressive gaseous medium the above considerations also apply, but it has been feared that the acceleration of chemical reactions at elevated temperatures might nullify or even reverse the advantageous action of internal heating.

To test these ideas, we made comparative tests on electrical components (relays) with and without load. The tests were made in chambers in accelerated conditions: temperature, 70 ± 2°C; relative humidity, 98 ± 2%; concentration of oxides of nitrogen, 10 ± 2.5 g/m³ (regime *a*) or 2 ± 0.5 g/m³ (regime **b**); we experimentally determined the dependence of the service life on the concentration and extrapolated to the region of working values of the concentration by means of Eq. (2). The possibility of extrapolation by means of this relation for gaseous media in a range of aggressive component concentrations (oxides of nitrogen) differing by a factor of 10^4-10^5 was demonstrated in [5, 6].

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