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ACCUMULATIVE SAFETY PERIOD OF PREMISES IN THE CASE OF THEIR POLLUTION WITH TOXIC MERCURY VAPORS

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Abstract. *An ecological indicator is determined – accumulative period of safety in premises which means duration of the relative safety of the premises after occurrence of their pollution with mercury vapor or other toxic substances.*
Keywords: danger for human; mercury; vaporization.

1. Introduction

Nowadays, one of most widespread and very harmful for people contaminants, attributed to the 1st hazard class, is mercury and especially its vapors [Hygienical…1992]. It should be noted, that the hazard of mercury distribution in the environment and the mercurialism of living organisms is considerably induced by specific physical and chemical properties of metallic mercury, as mercury is characterized with relatively high volatility and stability in the environment, it also dissolves in atmospheric precipitations, and is easily absorbed by soil and green plants. It relatively easily penetrates through the build materials (various concretes and solutions, building blocks, ruberoid, linoleum, mastics, paint-and-lacquer coating, etc.), it is also well adsorbed by plaster, carpets, fabrics (especially woolen ones), fur wares, shoes and hairs. Due to high mobility and large surface tension spilled metallic mercury forms little drops and spread over different surfaces, easily gets into the cracks and surface inequalities, thus increasing the area of contamination [Kosorukova, Yanin 2002].

Unfortunately, the above-stated properties of mercury create exceptional pre-conditions for its harmful effect on living organisms, even small concentration in the environment can result in frightful consequences.

Maximum Permissible Concentration (MPC) of mercury in the midair of residential areas is very small and makes only 0,0003 mg/m^3, and for the midair of various industrial facilities it should be not over 0,005/0,01 mg/m^3.

The prevention of people poisoning with mercury is complicated due to the fact that serious and even incurable illnesses are usually caused by accumulation of mercury in human organism and show up much later, even years after the exposure.

Therefore most people do not care about such situations and special demercurization of premises with small spills of mercury is almost never executed.

As it was marked at International scientific conference "Mercury Hazards – Problem of the XX Century", held in Saint Petersburg, the most substantial pollutants of environment are depressurized mercury discharge lamps and especially Luminescent Lamps (LL), which are used everywhere for illumination of various premises and production facilities. The world production of these lamps already exceeds 1.5 milliard pieces a year and is growing constantly, and that, in turn, results in subsequent growth of environment mercury hazard for people.

Destructions of discharge lamps are more frequently caused by careless handling, especially, when they have already worked out the service period. They are often broken during premises renovation, replacement, during storage and utilization of lamps in places unforeseen for this purpose. In Ukraine the whole system of utilization of discharge lamps, which contain mercury, is very inefficient and so far almost not controlled.

The total number of lamps, which contain mercury and are stored on the territory of enterprises in Ukraine, reaches 1,7 million pieces [Yanin 1997]. And even if the content of mercury is the lowest, which, in particular, in compact LL makes up from 2,5 to 5 mg, the destruction of one of this lamps in any premises will lead to the formation of mercury vapors concentration 30–50 times over MPC. The most widespread linear LL contain much more mercury and their content reaches 60–120 mg and over.

However, evaporation surface of spilled mercury is so small, that it takes a lot of time for its vapors to achieve MPC level in case of such lamps destruction. And it is very important for prevention of possible mercury poisoning of people, who stay in this premises.

The **purpose** of this work is the study of mercury pollution dynamics in the environment and prevention of people poisoning.

2. Problem solution

Distribution of mercury vapors in all premises is determined to a great extent by efficient action of mercury molecules diffusion intensity in certain direction x, which is defined from the equation

$$z = -D\frac{dc}{dx},$$

where z – the density of diffusive flow of mercury molecules;

D – index of its diffusion (at temperature 0°C and atmospheric pressure of 760 mm of mercury column);

c – mercury concentration in the midair.

Thus, the value of diffusion index for the mercury vapors in the midair (at temperature 0°C and atmospheric pressure of 760 mm of mercury column D_0 = 0,1124 m^2/s) is even over that for the vapors of ethyl spirit (D_0 = 0,102 m^2/s) and is only approximately twice less than that of water vapors (D_0 = 0,22 m^2/s).

To determine the values of diffusion index D at different values of temperature the following formula is used [Cohar 1998]:

$$D = D_0\left(\frac{T}{T_0}\right)^m \frac{760}{p},$$

where D_0 – the value of diffusion index of molecules (particles) of D at the temperatures of t_0 = 0ºC;

$T_0 = t_0 + 273 = 273$ and pressure of p = 760 mm of mercury column;

m = 1,75–2.

However, the mercury vapors spread in premises space even quicker together with the air as a result of convection motion, predefined by premises heating and sun radiation. This motion is caused by warmer air elevation and colder air descending. Motion of air is promoted in premises during draughts, doors opening and closure and other forced influences on the air. Besides, at real values of mercury vapors concentration in the polluted midair of premises this air becomes heavier by only by 0,001%, although mercury vapors are almost 7 times heavier than air. Therefore air polluted with the mercury vapors practically does not accumulate in the lower areas of premises, as it is widely thought, and relatively quickly spreads all over the premises.

Basic equation for the determination of polluting vapors concentration dynamics in the space of production and other premises, including the cases of destruction of discharge light sources containing mercury, is presented in [Dmitrucha 2010]. It is an exponential dependence of the following structure:

$$c = c_y - \left(c_y - c_p\right)e^{-\frac{\tau}{T_{es}}}, \quad (1)$$

$$T_{es} = \frac{V_p c_y}{W_e S_e}, \quad (2)$$

where c_y for the cases of mercury contamination means stable value mercury vapors concentration, which correspond to the temperature of the coldest area of premises;

c_p – initial concentration of mercury vapors in the premises midair;

τ – moment of time as an initial one;

V_p – volume of the premise;

W_e – evaporation rate of mercury at the premises temperature.

Value T_{es} could be considered as the parameter, which characterizes motion and intensity of the process of mercury vapors concentration changing in the premises midair with passing time. It has the dimensional units of time. By analogy with other physical transitional processes this index could also be considered temporal constant and in relation to relation to mercury has been given the name of mercury safety period constant in the paper [Dmitrucha 2010] based on its essence.

Physically the mercury safety period constant T_{es} is obviously the time interval, during which the concentration of mercury, evaporating in some not ventilated premises of volume V_p at W_e rate, would reach the stable value c_y, if its condensation was absented.

Indeed, the volume of mercury which will evaporate from the contaminated area with the surface of evaporation S_e for some time τ is defined from the ratio

$$G_e = W_e S_e \tau.$$

If the condensation of vapors of certain pollution didn't take place, the concentration of the pollution after time τ would reach the level of

$$c = \frac{G_e}{V_p} = \frac{W_e S_e \tau}{V_p},$$

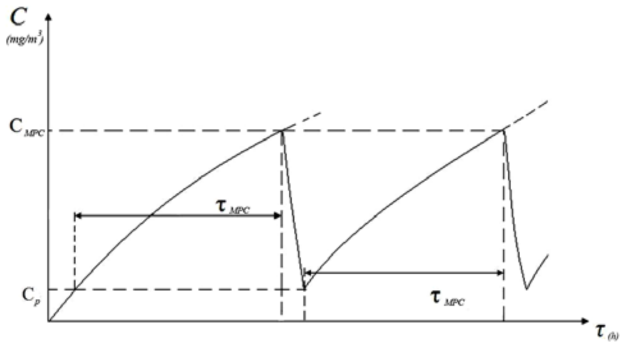
if the volume of this premises is V_p; if $c = c_y$, then $\tau = T_{es}$ (see formula 2).

However, the following parameter is more informative for the assessment of mercury or other safety of premises and it also depends on the index T_{es}. To calculate this parameter it is necessary to suppose that $c = c_{MPC}$ in the equation (1), where c_{MPC} is maximum permissible concentration of mercury vapors in this premises. Then

$$c_{MPC} = c_y - \left(c_y - c_p\right) e^{-\frac{\tau_{MPC}}{T_{es}}}, \quad (3)$$

where τ_{MPC} – time period, during which the concentration of mercury or other pollution reaches MPC (original "latent" period).

So, in time $\tau = \tau_{MPC}$ after destruction of discharge lamp with the content of mercury, a person can stay in this premises polluted with mercury without substantial harm for his health and perform carefully certain works and in particular demercurization. Longer stay of people in these premises can be possible only in case of intensive ventilation provision for the removal of accumulated mercury vapors together with the air. The whole process is illustrated at Figure.



Dynamics of mercury vapors concentration changes in the room polluted with mercury in the case of regular ventilation

However, ventilation of polluted premises leads to distribution of mercury vapors to the nearby premisess and the environment, that from the position of environment protection can not be considered a normal operation.

The index τ_{MPC} was named accumulative period of premises safety in the study and it can be considered an important parameter, which characterizes the environment safety in case of its pollution with toxic substances and, in particular, mercury vapors.

Based on the equation (3) we assume that

$$-\frac{\tau_{MPC}}{T_{es}} = \ln\frac{c_y - c_{MPC}}{c_y - c_p},$$

$$\frac{\tau_{MPC}}{T_{es}} = -\ln\frac{c_y - c_{MPC}}{c_y - c_p}.$$

As ln 1 = 0, then it is possible to write down

$$\frac{\tau_{MPC}}{T_{es}} = \ln 1 - \ln\frac{c_y - c_{MPC}}{c_y - c_p} = \ln\frac{1}{\dfrac{c_y - c_{MPC}}{c_y - c_p}},$$

$$\tau_{MPC} = T_{es}\ln\frac{c_y - c_p}{c_y - c_{MPC}} \quad (4)$$

or

$$\tau_{MPC} = \frac{V_p c_y}{W_e S_e}\ln\frac{c_y - c_p}{c_y - c_{MPC}}.$$

Consequently, the accumulative period of premises safety is determined by the duration of relative safety of premises (not accounting relatively insignificant time of ventilations) in case of their pollution with mercury vapors or other toxic materials depending on the initial concentration of vapors of these pollutants (c_p), volume of premises (V_p), temperature of their coldest area (c_y), evaporation area of contaminations (S_e), temperature of these contaminations (W_e) and MPC of their vapors in the midair of these premises.

As mercury is breaking into small drops 0,1 mm in diameter at falling at solid surface or under any other mechanical influence, the evaporation area of mercury S_e can be presented as:

$$S_e = \pi D_к^2 n_к = \pi D_к^2 \frac{V_m}{V_к} = \pi D_к^2 \frac{G_m}{\rho_m V_к},$$

where $D_к$ – average diameter of drops;

$n_к = \frac{V_m}{V_к}$ – number of drops, when all of them have a diameter $D_к$;

$V_m = \frac{G_m}{\rho_m}$ – total volume of mercury pollution;

G_m – general amount (weight) of mercury contamination;

$\rho_m = 13{,}6$ g/cm^3 – specific weight of mercury;

$V_к = \frac{\pi D_к^3}{6} = 0{,}524 D_к^3$ – volume of one drop.

Consequently, in case of mercury pollution mercury safety period constant T_{es} could be defined from the following formula (2):

$$T_{es} = \frac{V_p c_y}{W_e\left(\pi D_к^2 \dfrac{G_m}{\rho_m V_к}\right)} = 0{,}167\frac{V_p c_y \rho_m D_к}{W_e G_m}. \quad (5)$$

If, as usually, the volume of premises is measured in m^3, concentration of mercury in the midair – in g/cm^3, specific weight of mercury – in g/cm^3, diameter of mercury drops – in mm, mercury evaporation rate – in mg/hour·m^2, weight of mercury pollution – in mg, and if $D_к$ = 0,1 mm, then equation (5) will be such:

$$T_{\text{es}} = 2{,}27 \cdot 10^5 \frac{V_p c_y}{W_e G_m}. \quad (6)$$

Equation (6) is considerably more applicable for the determination of mercury safety period constant, than the previous index, as it includes total volume (weight) of spilled mercury instead of mercury evaporation area. As a result the calculation of accumulative period of premises safety would also be easier (see formula 4).

3. Conclusions

The new environmental parameter (accumulative period of premises safety) defines the duration of relative safety of premises after the start of their pollution with the vapors of toxic substances and, in particular, mercury vapors in case of discharge lamps destruction in these premises.

Simple equation is obtained for the calculation of this parameter values.

Resulted equation for the determination of premises mercury safety period constant is more applicable, than the one presented in the paper [Dmitrucha 2010].

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Т.І. Дмитруха. Акумулятивний період безпеки приміщень у випадку їх забруднення токсичною парою ртуті
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Показано небезпеку розповсюдження ртуті в довкіллі, її фізико-хімічні властивості. Розглянуто негативний вплив ртуті на людей. Описано акумулятивний період безпеки приміщень, який визначає тривалість відносної безпеки приміщень у разі їх забруднювань парою ртуті залежно від початкової концентрації пари забруднень, об'єму приміщень, температури найхолоднішої їх ділянки, площі випаровування забруднень, температури забруднень та гранично допустимої концентрації їх пари у повітрі приміщень.

Ключові слова: випаровування; небезпека для людей; ртуть.

Т.И. Дмитруха. Аккумулятивный период безопасности помещений в случае их загрязнения токсическим паром ртути
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Показана опасность распространения ртути в окружающей среде, ее физико-химические свойства. Рассмотрено негативное воздействие ртути на людей. Описан аккумулятивный период безопасности помещений, определяющий продолжительность относительной безопасности помещений в случае их загрязнения парами ртути в зависимости от начальной концентрации паров загрязнений, объема помещений, температуры их самой холодной точки, площади испарения загрязнений, температуры загрязнений и предельно допустимой концентрации их паров в воздухе помещений.

Ключевые слова: испарения; опасность для людей; ртуть.

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