ASSESSMENT OF HARMFUL CHEMICAL FACTORS IN MAINTENANCE OF BATTERIES

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ABSTRACT

The article analyzes the specifics of the aspects of occupational risk to the health of workers in the battery compartment of a passenger car depot caused by chemical contamination of the industrial environment. The results of the research of the heavy metal content in workrooms are presented, the issues of monitoring and normalizing labor conditions in the presence of harmful chemical factors are considered.

Keywords: railway, car depot, storage batteries, chemical factor, heavy metals, control and rationing, production environment.

Background. *Obligatory aspects of ensuring safe working conditions of the working population are the deciphering of the etiological conditionality of human diseases, identification of risk factors for health disorders both for an individual and for certain professional organized groups of people. In the framework of modernizing the system of labor protection, conducted today at the state and sectoral level, the tasks of transition to a preventive system of preserving the health of citizens and the labor potential of the country should be resolved [1]. Until now, insufficient attention has been paid to assessing the harmful effects of factors of the operating environment of battery compartments, there is no reliable data on the degree of chemical contamination of maintenance and charge facilities of accumulator batteries (AB) of rolling stock.*

A separate task in this regard is the study of adverse chemical effects on personnel in the process of servicing AB in passenger wagon depots.

Objective. *The objective of the authors is to consider assessment of harmful chemical factors in maintenance of batteries.*

Methods. *The authors use general scientific and engineering methods, statistical analysis, chemical methods, comparative analysis.*

Results. *The park of passenger cars of locomotive traction in the Russian Federation has more than 23 thousand units [2, 3]. Works with AB are made for all types of maintenance, capital and depot repairs (CR and DR) of cars, and the quality of battery maintenance depends on the qualifications of the personnel and the conditions in which employees perform their duties.*

In the process of repair and maintenance of AB and battery boxes, such professions as battery-holders, slingers, carpenters, painters of the chassis and masters of the electrical department are involved. In addition, the servicing of these operations includes washing-cleaners of battery compartments. En route, the control of the AB state is ensured by the train electrician.

Operational types of AB are subdivided into serviced ones (they require replenishment of the electrolyte and periodic cycles of full charge / discharge), low maintenance (require refilling of only distilled water, maintenance is done without removing AB from the car) and maintenance-free (do not require maintenance for the entire service life). Maintenance-free AB must be completely sealed, so that the release of any harmful substances into the environment during their operation is initially excluded. Batteries of this type are considered to be the most environmentally friendly in their groups, when using them, the problem of protecting battery-holders from exposure to a harmful chemical factor is virtually eliminated.

Because of this, often the leading direction in combating the harmful effects of AB is the transition to a maintenance-free type of batteries. In the cars of the new construction mainly the AB of this type is used [2]. The methodical recommendations on the environmental safety of passenger cars of locomotive traction produced by JSC TVZ, developed by VNIIZhG Rospotrebnadzor, provides for replacement and installation of maintenance-free AB as a measure of ensuring the environmental efficiency of passenger rolling stock [4].

However, it is noted that such a transition may be inexpedient today from the economic point of view. In addition, an assessment of environmental risks associated with the increase in the gross amount of battery waste due to their lower actual service life has not yet been given [5]. Most of the batteries currently in use make up AB of a serviced and low-maintenance type.

The working process of AB maintenance consists of carrying out a number of preparatory and basic operations. Most operations (disassembly, flushing AB, draining and replacing electrolyte, etc.) involve the possibility of contact of the worker with electrolyte.

The amount of electrolyte and its components that pass into the environment when the batteries are charged, is normalized both in the development of measures for labor protection and the design of ventilation systems for battery compartments, and in assessing the impact of the enterprise on the environment. Calculation of the amount of harmful substances, as a rule, is carried out according to the methodology developed and approved in 1998 by the Ministry of Transport for motor transport enterprises [6]. At the same time, the amount of heavy metals in the working environment of the battery compartments is not estimated.

Let's consider the arrangement of alkaline and acid batteries. Current-forming reactions of the nickel-cadmium system are represented by equations (1–3). Nickel-cadmium and nickel-iron electrochemical systems are very similar: the main difference is the different material of the negative electrode. The electrolyte, in which the aqueous solution of potassium hydroxide appears in the operated AB, with the addition of lithium hydroxide and caustic soda, does not participate in current-forming reactions. The active mass of the positive electrode also includes graphite (20–40% by weight to Ni), barium (1,7–2,7% by weight to Ni) and cobalt (1,5% by weight to Ni), may contain sulfate-chloride,

Table 1

Results of analysis of washings from the walls of battery rooms in the passenger car depot of Chelyabinsk for lead, nickel and cadmium

Place of washings	Meas. units	Cadmium	Nickel	Lead
		Result $*10^{-3}$	Result $*10^{-3}$	Result $*10^{-3}$
Rear from the entrance wall of the battery compartment	mg/cm^2	0,005	0,02	0,07
Frontal from the entrance wall of the battery compartment	mg/cm^2	0,0061	0,054	0,023
Right from the entrance wall of the battery compartment	mg/cm^2	0,003	0,017	0,013
Left from the entrance wall of the battery compartment	mg/cm^2	0,007	0,020	0,033
Floor of the charging chamber	mg/cm^2	0,63	5,2	1,8

nitrate ions (up to 2% by weight to Ni). The cathode active mass along with cadmium (II) oxide contains nickel (II) hydroxide, manganese dioxide (IV) and industrial I8A oil (with a sulfur content of not more than 1 mass%) [7, p. 19–31; 8, p. 204–205].

When the battery is discharged, cadmium is oxidized, and NiOOH is restored:

$$Cd + 2OH^- \to Cd(OH)_2 + 2e^-. \quad (1)$$

$$2NiOOH + 2H_2O + 2e^- \to 2Ni(OH)_2 + 2OH^-. \quad (2)$$

When charging on the electrodes, reverse reactions occur. The total reaction of the current-forming process of the nickel-cadmium electrochemical system can be represented by the following equation:

$$2NiOOH + Cd + 2H_2O \leftrightarrow 2Ni(OH)_2 + Cd(OH)_2. \quad (3)$$

The total reaction of the current-forming process of the nickel-iron electrochemical system is analogous to the considered nickel-cadmium process:

$$2NiOOH + Fe + 2H_2O \leftrightarrow 2Ni(OH)_2 + Fe(OH)_2. \quad (4)$$

In a lead-acid battery, unlike alkaline batteries, the electrolyte, which is an aqueous solution of sulfuric acid, takes part in the current-forming process:

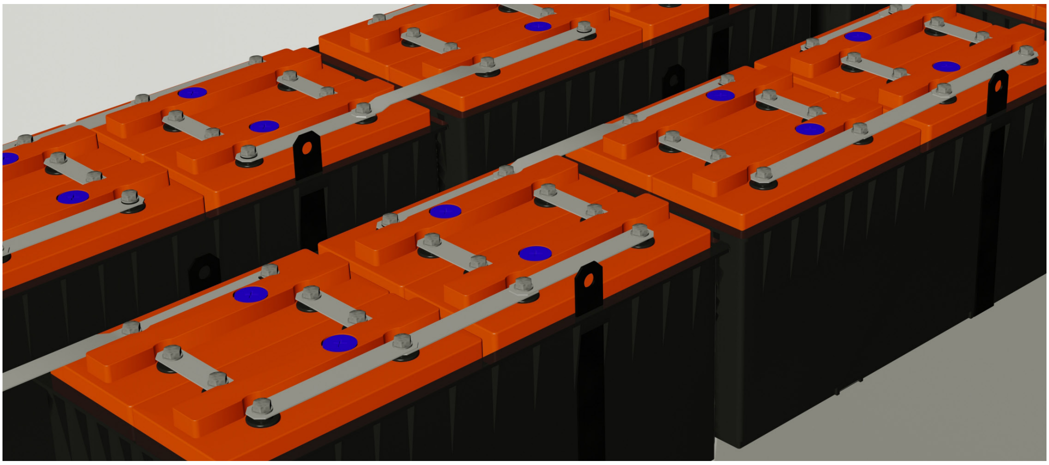
$$PbO_2 + Pb + 2H_2SO_4 \leftrightarrow 2PbSO_4 + 2H_2O. \quad (5)$$

The active mass of the charged negative electrode of the acid accumulator consists of lead powder, to which depassivators (BaSO4) and organic substances (humic acids, potassium lignosulfonate, carboxymethylcellulose, etc.) are added. The active mass of a positively charged electrode consists of a powder of lead dioxide. To improve the mechanical and casting properties, a small amount of antimony is usually added to the composition of the current collectors [8, p. 199]. Separators are used to separate positive and negative electrodes: microporous ebonites, polyvinyl chloride, etc. [8, p. 200].

Based on the analysis of the component composition of batteries used in passenger rolling stock, it can be assumed that not only the compounds that are part of the electrolyte, but also the compounds of heavy metals that make up the battery electrodes: nickel, cadmium and lead can reach the environment during maintenance of batteries.

The entry of heavy metals in the environment of battery shops were confirmed by the data received by VNIIZhG Rospotrebnadzor. The monitoring of nickel, cadmium and lead ions was carried out in washings from the surfaces of the walls and the floor of the battery compartment in the passenger car depot of Chelyabinsk. The test results are shown in Table 1. According to the data obtained, nickel, cadmium and lead compounds are present in all samples taken. The battery charger compartment is contaminated with heavy metals mostly. This is explained by the fact that the main part of pollutants passes into the air of the working zone when hydrogen and oxygen are released during the electrolysis of water during the charging of AB. The resulting gases float up in the form of bubbles and burst on the surface of the electrolyte. In this case, the smallest droplets of electrolyte containing metal impurities fall into the air, forming an aerosol.

When the batteries are charged, the following substances can also enter the air of the working area: sulfur oxides (IV, VI), hydrogen chloride, antimony hydrogen (stibin), arsenic hydrogen (arsine). Stibin in acidic batteries is formed as a result of the



interaction of atomic hydrogen with metallic antimony, which is present on the negative electrode and as an integral part of the lattice. In the air of the room, it gradually (for tens of hours) decomposes to antimony anhydride – a white crystalline powder. As a result of the reaction between arsenic contained in lead plates and electrolyte and sulfuric acid, arsenic hydrogen is formed in a small amount. The formation of sulfurous anhydride occurs by the interaction of sulfuric acid and hydrogen released during the charging of acid batteries. However, the content of these substances in the air of the working area is insignificant. So, for example, the content of sulfur dioxide in the air of the battery compartment does not exceed 1/80 of the sulfuric acid content [9, p. 5–7].

Thus, when servicing AB in the environment in quantities that can affect the health of staff, the following substances are transferred:

- *nickel and its compounds;*
- *cadmium and its compounds;*
- *lead and its compounds;*
- *potassium hydroxide;*
- *lithium hydroxide;*
- *sodium hydroxide;*
- *sulfuric acid.*

Nickel, cadmium, lead and their compounds refer to heavy metals, are highly toxic and dangerous substances. Their effect on the body can cause, in particular, disorders of the nervous system, diseases of the cardiovascular system, lungs, musculoskeletal system, kidneys, liver and other body systems. The exposure of nickel and lead to the human body is an established carcinogenic factor. The carcinogenic effect of cadmium has not been proven to date, but many studies indicate its presence [10].

The most active process of gas evolution takes place during the charge of AB. The «boiling» of the electrolyte, at which the gas evolution becomes particularly intense, can begin after reaching 60% of the nominal voltage and is amplified as it approaches the end of the charge. However, to some extent, electrolysis of water occurs in all states of AB: during charge, recharge, discharge and inactivity. In unattended models of AB, gas evolution occurs much more slowly due to the recombination of oxygen and hydrogen. Nevertheless, the transition of pollutants to the environment is possible not only with the «boiling» of the electrolyte, but also in the event of leakage or damage in the battery case.

Conclusion. *Based on the conducted studies, it can be concluded that the maintenance of AB is associated with a risk to the health of personnel due to a negative chemical factor, including carcinogenic – due to the presence of heavy metals in the working environment of the battery compartment. In such conditions it is necessary to develop measures to control and normalize the content of heavy metals in the production room, as well as to reduce the impact of the chemical factor directly on workers.*

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