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Health Risks And Safety Management Of Scientific And Research Laboratories' Staff When Working With Nanomaterials.

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ABSTRACT

The human health risks are the core ecological problem within the expanding application of nanomaterials and -technologies. The continuous studies on how nanomaterials affect the human health and safety demonstrate a wide range of hazards, however, there is still a few investigations that show health status dynamics of scientific and research laboratories' staff which is in touch with nanoparticles. There is still a lot of gaps when it comes to the occupational safety in the laboratories that use complex nanopowder mixtures, for which no complete picture of potential risks exists. This problem applies both the ways how to lower adverse effects on employees' health, and to create occupational safety mechanisms, capable to provide appropriate behavioral patterns of employees when working with such nanomaterials. In this regard, the paper sets two complementary objectives: first, to find and prove the relation between the long-term exposure of harmful factors and the probability of investigator's personal injury when working with nanomaterials, and second, to put extensive measures to lower health risks of scientific and research laboratories' employees. A complete physical examination of scientific and research center employees who are always in contact with various mixtures of nano- and ultrafine metal powders (laboratory and instrumental examinations, consultations by medical specialists, employees' interviews). The laboratories' employees were found to have chronic symptoms of rhinitis and pharyngitis, a bronchitis liability, slight alterations on the part of excitatory and cardiovascular system, the evidence of which is a function of labor staff occupancy in the scientific center. Based on employees' morbidity level and analysis of additional health risk factors, a risk matrix was developed to make it possible to identify staff groups by a susceptibility to nanopowders adverse effects (depending on employee chronic decease, age and occupancy), to select tailored preventive measures for lowering the laboratory staff morbidity rate. Moreover, labor safety culture measures are suggested. The study results and suggested measures may be used in the practice of labor safety management in scientific and research laboratories.

Keywords: powder mixtures of metal nanoparticles, nanoparticles of oxide powders, health indicators, risk groups, operational safety culture.

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INTRODUCTION

Issues of safe operation with nanomaterials are among the high-priority environmental and social problems, causing a deep concern about the negative impact of nanoparticles on human health (8). The detection of nanoparticle unique properties substantially immediately set a task for examining its toxicity and health effects. The nanomaterials are known to not influence the human body separately, but in combination with contaminants of natural environments of traditional dispersity (8; 14; 15). Circulating in the blood stream, the nanoparticles accumulate in organs and tissues, including brain, liver, heart, kidneys, spleen, marrow, excitatory and lymphatic systems (Antsiferova, 2013). At the same time, the poisonous effect enhancement (synergism), or, instead, its alleviation (antagonism) are determined by a cumulative impact of harmful factors that are different in their actions, with various nanoparticles routes into the human body (Damgaard, 2010).

Nanotechnologies lie at the interface of many scientific disciplines, such as chemistry, biology, physics and electronics. Of specific importance are the construction materials based on different powder mixtures of metal powder ultra- and nanoparticles and their compounds. These materials are widely used in powder metallurgy, production of metal constructions and engineering materials, power industry, biomedicine, oil and gas industry, in solving environmental problems. Of specific interest is to investigate the environmental image of composite mixtures of metal powders, aerosols, colloid systems and nanofibers, that are recommended for use and widely used in powder metallurgy scientific and research institutions. The picture of potential health and safety risks for study stuff is still incomplete due to the fact that the dangers at laboratories may take place both at a short-term exposure, and be resulted from specific conditions while conducting some laboratory-based works (21).

The literature data analysis showed that the most studies conducted so far were concerned with the examination of toxicity/carcinogenicity in nanofiber production (nanomaterials with L/D ratio), operation with nanoobjects in suspensions, powder or solid state. At the same time, the field of intensive study of human health hazards, when operating with nanofibers, is largely limited to carbon nanotubes, as some of them are very close to the asbestos in size, chemical composition or surface properties, suggesting that the laboratories which use them may be labelled with the third, highest hazard category.

The exposure rate in operation with powder nanoobjects is a function of its level and duration. In the traditional risk assessment, the exposure rates are comparable to the maximum allowable concentration (MAC). If the material is classified in a larger form as a cancerogenic, mutagenic, asthmogenic toxin or toxin affecting the genital system, and its MAC is known, its nanoform will have MAC of 10 times lower. The laboratories where a significant number of powder particles is observed in the research environment, belong to the 3rd risk group. Stable agglomerates and aggregates do not have specific transport routes (an «ordinary» transport may be still available) and are expected to affect the health more as «classical» air pollutants. Therefore, the actions with agglomerates are classified as the 2nd hazard category. If the particles stay in suspension or solid, the laboratory belongs to the 1st hazard level (3; 18; 25).

In scientific and research laboratories, however, there is often a lack of information, which may be basic to the concept of risks of nanoparticles or -materials for human health and environment, embarrassing both the risk assessment and, actually, the classification of laboratories based on an assumed toxicity of nanoparticles, as well as the selection of appropriate labor safety measures (Groso et. al., 2010). Although there is a lot of research findings about the effect of nanomaterials on human body being published annually, there is a very limited scope of papers about the health risks for research laboratories' employees at the university scientific centers, who operate with compound nanopowder mixtures (2013). There are still significant gaps in the conversion of these findings into occupational safety practices (Kuempel et. al., 2012).

For example, a study conducted in scientific and research laboratories in China demonstrated high organization standards in the general labor safety at the insufficient specificity of safety measures with regard to the nanomaterials used (Zhang et. al., 2014). It is largely related to the fact that in regular labor safety systems at scientific and research centers, while carrying out several scientific projects simultaneously with the use of different nanomaterials combinations, the wide and continually changing range of potential risks of employees' safety is hard to consider. Moreover, the implementation of precautionary principle while operating with nanomaterials is, unfortunately, being often considered by researchers as a factor that prevents the scientific activities (Groso et. al., 2010).

The study of several universities in Great Britain (Wheeler & Polak, 2013) showed that the scientific and research laboratories generally set stringent internal safety and labor hygiene standards while using nanomaterials. Also, some research groups have been found to not achieve satisfactory standards in certain health care and safety aspects. In some cases, there was no general risk assessment or COSHH, the information and conducted preparations were insufficient, and the use of engineering inspection means was incomplete.

A survey among 240 employees of academic and state scientific and research laboratories in different countries (Balas et. al., 2010) found that not all of them realize the importance of labor safety measures when operating with nanomaterials: only 25% of organizations took special rules, while almost half of laboratories use general labor safety rules and procedures. In the absence of special rules, almost 30 % of laboratories employees do not use any respiratory protective equipment, and 36 % use filter masks, irrelevant to the nanoparticle size. It is remarkable that among the survey participants there were both front-line employees, and head of laboratories or research groups (35 %). It is clear that any neglect of labor safety measures would enhance all possible security risks for the study staff, on one hand, and focus on the problem of employees' responsible attitude to their own health and health of other people – on the other hand.

In view of the above, we may talk of two interdependent issues of labor safety for regular staff of scientific and research laboratories: first, to reveal a fact that the researcher health will be probably harmed when operating with different mixtures of nano- and ultrafine metal powders; second, to select organizational measures reducing the employees' health hazards.

Methods

The study on how nanopowders affected the research staff health has been carried out at the premises of the Research Center of Powder Materials Science at Perm National Research Polytechnic University (3), and included the following objects:

1. Disperse metal powders (Fe, T, Mo, M) + concentrated acids and alkali;
2. Hydroaerosols of metal powders (Fe, CO, A);
3. Salts Fe, CO, A, C + concentrated acids and alkali.

We observed 96 laboratory employees – 49 women and 47 men at the age of 23 to 55, the average age - 35,8. 65 employees – 44 women and 21 men at the age of 23 to 49 are being exposed to occupational hazards.

The following three target groups took part in the study:

Group A – laboratory employees (34 persons) who were in persistent contact with the harmful factor. According to the nature of occupational hazards, those employees has been divided into 3 subgroups. The first subgroup has been exposed to disperse metal powders and concentrated acids and alkali, the second – to metal powders and their hydroaerosols, the third – to metal salts, concentrated acids and alkali. The contact with the above hazards has been observed from 1 to 11 years. The most employees stayed under the influence of occupational hazards for 4-7 years.

Group B – the rest of laboratory employees (62 persons) who were in occasional contact with decease-producing factors.

Group C – the control group that included 67 residents of Perm, 27 men and 40 women at the age of 21 to 46, who were not in contact with metal powders and their salts.

Diagnostic maneuvers have been carried out at the medical station of Center's research laboratory fitted with all the appropriate equipment, preparations and appliances, since the laboratory has harmful factors for staff health by default.

Methods used to study:

1. Survey of participants of all groups using a specially prepared check-list that included questions concerning different aspects of body system functions.
2. Examination of respiratory system.
3. Consultations of specialized doctors: eye physician, neurologist, OTR, roentgenologist etc.
4. Laboratory tests: CBC, lymphocyte membrane NAD antibody titer.
5. Instrumental examination: blood pressure measurement, electrocardiography, fluoroscopy and XRD of Thoracic organs.

Blood values, functions of respiratory, myocard and hemodynamics obtained at the examination of virtually healthy children, have been used to determine normal parameters of these body systems in the climate of Perm (control group).

In order to investigate possible health risk reduction when operating with nanomaterials, the behavior of Center's laboratory employees has been observed at the direct operation with nanopowders, contacts to other Center's employees, as well as the perception of labor safety practice accepted in the Center has been examined.

RESULTS

In the examination of respiratory system, during the first years of working, 10 and 72 employees mentioned a good general condition, normal sleep, considered themselves steady, quiet, only two employees noted a superficial sleep and slight irritability.

The medical examination of cardiovascular system showed that 5 persons were found to have long-standing stabbing and aching pains in the heart apex without reference to the physical activity and irradiation-free, three of them were found to have cardiac pains in combination with heartbeats and two – dyspnea when excited. The pulse of 6 examined was rhythmical, symmetrical – 66-80 BPMs (on the average – 72 BPMs), 6 of 72 employees (all women) were found to have tachycardia to 84-88 BPMs.

Brachial arterial pressure of 7 examined varied within normal limits, three women were found to have arterial hypertension to 155/90 mm Hg. All examined had cardiac borders within normal limits. According to the electrocardiography, 4 persons were found to have moderate myocard muscular changes.

Three years later, 4 of 12 employees were found to have superficial sleep and irritability, 8 persons continued complaining about heart stabbing pains. Four persons demonstrated heart beating episodes when excited. The heart pulse rate was 73.8 BPMs, at the same time the women's average pulse rate was higher and amounted to 81.3 BMPs during the examination. Seven examined were found to have the normal arterial pressure. Four women were found to have an arterial hypotonia, two employees – an arterial hypotonia with the average systolic pressure of 151,3+-4,7 mm Hg.

The pulmonology clinical aspects of 18 sick persons fitted in 3 forms: bronchitis (8 pers.), pneumonia (5 pers.) and chronical pneumonia (5 pers.). The sick persons complained about a paroxysmal moist cough, asphyxia accompanied by a difficulty in expiration. The decease progressed gradually, all started from coughing with a hard-separable moisture. Later, the cough grew stronger, and during the last year there were asthma attacks before the hospitalization. A slight chest expansion, as well as lungs borders ptosis have been observed. In the X-ray examination, the employees were found to have an increased pulmonary vascularity, a slightly limited diaphragm excursion, sinuses are clear. The cough and asphyxia attacks emerging in patients have been reversed with ephedrine and adrenaline injections. Asphyxia terminated in 7 patients after they stopped contacting to occupational dust.

On the side of cardiovascular system, there was not any evident pathology, the arterial pressure was normal. When examining the effect of laboratory and occupational factors on the cardiovascular system of investigators, the arterial hypotonia was found to prevail (23%), the high blood pressure has been found in 22% cases.

The employees with a short laboratory work experience were found to have hypertrophic forms of rhinitis and pharyngitis, when the experience was longer, diseases of epipharynx and larynx became more frequent. 12,5 % of examined were found to have an olfactive sensitivity decrement.

The most investigators after health survey were found to have changes on the side of nervous system, hypotensive type dystonia, more rarely – vegetoendocrinic dystonia. The effect general for all study participants (excluding the control group) was found to be that of the accumulation of adverse effects depending on exposure intensity and time of harmful factors or otherwise, dose-effect relationship. When the exposure intensity and time increase (i.e. dose), the effect grows.

The third subgroup that is related directly to metal salts (Table 1) is found to have high morbidity rates of hypertensive type VVD (vegetovascular dystonia), which presents in headache, browache, and difficulty in breathing. The contact dermatitis such as hand itching, shall we say, may be manifested immediately and normally does not change over time. The indicators of hypertensive type VVD (vegetovascular dystonia) that generally depend on defatigation and incorrect daily schedule virtually stay at the normal level. The gastric ulcer was not found, since yet the nanopowders have been examined only in the laboratory.

Table 1: Morbidity rates of laboratory employees who are in a direct contact to occupational hazards (in % of sampling)

Disease	1 subgroup			2 subgroup			3 subgroup		
	1	2	3	1	2	3	1	2	3
Hypertensive type VVD	16.	20	22	8	11	20	12	12	15.8
Hypotonic type VVD	20	21.6	23	25	24	25	25	26	31.6
Chronic bronchitis and pharyngitis	33	34	34	9	15	20	8	9	10.5
Chronic gastritis	7	8	8.5	8.5	9	8.5	8	8.7	10.5
Dermatitis	10	10	11	10	12	9	10	10	10
Chronic cholecystitis	30	32	33	10	10	10.9	19	21	36.8

An occasional contact to powders results only in a slight acceleration of vegetovascular dystonia and rhinitis (Table 2). Within the control group, the examinations of peptic ulcer are within the measurement accuracy of the comorbidity, since the peptic ulcer is one of diseases of different population groups.

Table 2: Morbidity rates of laboratory employees, who are in an occasional contact to occupational hazards compared to the control group (in %)

Disease	2nd group			Control group		
	1	2	3	1	2	3
Hypertensive disease	8.1	8.1	8.1	7.4	7.5	7.5
Hypertensive type VVD	8.3	8.3	8.9	2.9	3.1	3.1
Hypotonic type VVD	6.7	7.1	7,1	4.5	4.5	4.5
Chronic bronchitis and pharyngitis	4.5	4.5	4.5	3.3	3.4	3.4
Gastric ulcer	3.3	3.3	3.3	1.8	2.1	2.2
Vertebral osteochondrosis	11.2	11.2	11.2	9.1	9.1	9.1
Atrophic rhinitis	8.3	8.3	8.5	6.8	6.8	6.8
Chronic cholecystitis	10	10	10	9.9	9.9	9.9

Morbidity rates are calculated as a number of diseased people / (number of people in the group of interest × duration of the period under review). In the light of a number of research laboratories employees who were addicted to vegetovascular dystonia and respiratory tract diseases, the exposure to disease amounted to about 30 %.

To a certain extent, the high exposure rate conflicted with the labor safety practice at the research center, where there was a salaried medical worker responsible for preventive care, preliminary and regular medical examinations of employees which are occupied in physically demanding jobs and hazardous and (or) harmful factors. In the course of observation and survey, the employees of laboratories who were in a direct contact to hazardous nanopowders, have been found to be fully equipped with personal protective means (masks, gloves, clothes, shoes, ventilation systems) providing for the properties of nanomaterials used. They are acutely aware of potential risks and realize of possible adverse health effects. However, the following has been discovered:

- Regular failure to comply with labor safety regulations: the employees frequently did their works without gloves and masks, particularly when they happened to leave the laboratory during business hours.
- None of precaution measures in contacting to other center employees have been used in most cases (for example, shift of clothes, shoes).
- Heads of laboratories took a relaxed look at such violations, giving just comments with no consequences.
- Students who undertake their internship in the laboratory behave concerning their personal safety in the same manner as the investigators.

This also holds true for the employees of Center administrative services who freely move through laboratories in order to solve any given business issues without appropriate protection means.

Regarding the formal training to safety procedures and control of labor safety precautions, all the employees are of the same mind that such regulations are required, but they are too stringent and often interrupt the course of scientific research.

DISCUSSION

The result of employees' examination showed some variations in their health confirming the assumption about the predominant effect on respiratory, bronchopulmonary and cardiovascular systems of the person who was in a direct contact to nanopowders mixtures in the climate of a research laboratory. However, following the examination results, it was made clear that the progress of pathological conditions found in employees of scientific and research laboratories have been affected not only by working environment harmful factors, but also their behavior when operating with nanopowders.

Without any doubt, the presence of a formal labor safety system in the research and scientific center creates prerequisites for staff safety; the traditional systems based on formal regulations and procedures, however, appear to be low efficient regarding the study staff. It is related at least to two reasons. First, the most laboratory employees are known to strive to direct their activity on their own, at the same time, however, the freedom and independence are not an absolute dominant idea towards the high scientific productivity (Antsiferova & Esaulova, 2013). Second, the health risks are often determined by the fact that the employees:

- underestimate the importance of labor safety requirements; the result is that minor infractions without consequences lead to more serious breaches with time and health effects not only for themselves, but also for the others;
- adjust to danger – without any real risk, when no accidents happen for a long time, the employee becomes less careful, conceiving that protection systems would provide his safety anyway;
- overestimate the labor safety level – the employees believe that the administration makes every effort for their safety, considering that they are fully protected against different hazards;
- nominally treat the safety rules learning, assuming that the most of them would hardly be useful in the future.

In that context, adverse health consequences become unlikely only when the employee takes his behavior-based safety as natural and the only possible. This issue requires an integrated approach that includes, first, special medical measures in regard of certain groups of employees differentiated by

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occupational morbidity risks and, second, development of the labor safety culture to generate a long-term base for rational and responsible attitude to health and safety of both employees themselves and their heads.

Risk groups and labor safety regulations

The above-mentioned results of the medical examination demonstrated a high (30 %) occupational morbidity risk of laboratory employees for vegetovascular dystonia, chronic rhinitis, pharyngitis and bronchitis; a relation between the prevalence rate and activity time in the research center has been set. Moreover, since the picture of potential health and safety risks is still incomplete, there is a fact to be taken into account that, in the climate of scientific laboratories, the risks may take place both due to specific conditions in the course of several laboratory works, and at the short-time exposure of metal nanopowders and their compounds enhancing the liability to the above diseases or intensifying the chronic symptoms.

It seems that the reduction of morbidity risks among the laboratory employees may be promoted with preventive measures which comply with a certain group of employees depending on the risk increase condition: chronic disease, age and activity time (Table 3).

Table 3: Occupational morbidity risk matrix in operation with nanomaterials and preventive measures for risk reduction

Health risk level	Criterion	Risk group	Measures for disease probability reduction
High	Chronic disease	Employees with a chronic hypertensive disease	Weekly blood pressure and cardiac rhythm monitoring. Mandatory emergency care drugs prescribed by a doctor
		Employees with hypertensive-type VVD	
		Employees with hypotonic-type VVD	
		Employees with chronic bronchitis and pharyngitis	Visual and medical control of health conditions. Temporary suspension with overt symptoms; temporary move to other activities excepting direct contact with hazards – with light symptoms
		Employees with atrophic rhinitis	
Moderate	Age	Aged employees	General health monitoring for all risk-related diseases in the course of the regular health survey
	Laboratory work experience	Employees with over 3 years' experience	
Low		New employees	General health monitoring in the first year of employment
		Student-apprentices	General health monitoring during the whole practice period
		All salaried employees declared as healthy	Annual health survey
Comment: Since the study has not found any effect of nanopowders mixtures on the progress of spinal osteochondrosis, gastric ulcer and chronic cholecystitis, the risk groups for those diseases are useless to separate			

The employees assigned to the risk groups by chronic diseases require the persistent health control, the accessibility of emergency medical care in event of a sharp pressure increase or heart rhythm disorder. Rhinitis and pharyngitis are capable to amplify the negative impact of nanoparticles due to those easier ingress on mucous coats and further unobstructed movement through the other body systems of not only those with chronic diseases, but also healthy employees. Thus, if the employee has even light respiratory symptoms, the best measure is to temporarily shift him/her to an activity, which excepts any contacts with nanopowders. There, the employee may do paperwork, work with literature, write articles etc.

Other risk groups included: aged employees, since the liability to diseases increases with age; employees with over 3 years' experience, since they have a poor dose-effect relationship prognosis; as well as newly employed and student-apprentices because their individual response to the materials used in the laboratory may be still unknown, what increases the probability of the morbidity risk.

The laboratory employees without any chronic diseases belong to the group of low morbidity risk, special measures are not required, except the regular, in general, annual health survey.

It is worth mentioning that all above measure require the individual and collective protection regulations be implemented inviolately when operating with nanomaterials.

Labor safety culture

At the moment, the key attention is paid to the preventive practice aimed at the labor safety culture, where the safety is one of the key organization values, and the behavior of employees is being forwarded by a mutual belief in the safety importance and the realization that every member intentionally supports respective regulations (Guldenmund, 2010). As a matter of fact, it is the safety culture which is the critical factor of how efficient the formal security systems are applied.

The concept of labor safety culture is construed as employees' common ground, beliefs, perception and interpretation of safety rules and regulations that determine their behavior and reactions with respect to risks and risk management systems (Hale, 2000; Richter & Koch, 2004). When focusing on informal aspects of the labor safety, it is getting evident that complex and technically reliable labor safety systems become efficient only when the employees deliberately assume personal responsibility for themselves and others. The propagation depth of safety culture greatly depends on coherence and insistency of the administration on the labor safety issues, daily attention of managers to the safety matters of subordinates, provision with true and complete information about possible risks, feedback etc.

Safety culture development assumes the availability of well-defined principles and regulations of organization in the field of labor safety, open communications and staff involvement into the investigation and solution of security issues. In this case, knowledge, experience and activity of employees become a factor of the early detection of labor safety hazards, promote in the enhancement of the labor safety system, as well as the distribution of positive experience in the field of labor safety. In that context, based on the best practice of study staff safety management (5; 9; 10; 17; 19; 26), the following measures may be suggested.

Safety risk management model in the scientific center

The behavioral motivation of laboratory employees when operating with nanomaterials is achieved through a reliable risk management system, which considers the specific nature of laboratory research. The paper (Groso et. al., 2010) thoroughly describes a risk management model as a decision tree for the selection of organizational and personal safety measures based on the differentiation of laboratories with respect to the ambient conditions, where any research is executed (open or closed system), size and properties of nanoparticles surface; on this basis, the hazard class is determined for a certain laboratory and single processes (production, usage) when operating with different nanomaterials and their states. The authors believe that such an approach may provide the labor and environment safety even in case of new products, without limiting the search for innovations. The implementation of this model into research laboratories could help not only to enhance the awareness of employees on possible health risks, but also create a framework for the self-regulation of personal and collective labor safety when operating with understudied nanomaterials and those unclassified by hazard criterion.

System of internal and external labor safety control

Mutual obligations of the administration and employees on the safety issues are met, if the managers discuss the performance or violations committed by employees on a regular basis, and take appropriate measures (Burns, Mearns, & McGeorge, 2006). However, in the current practice when the labor safety measures are neglected, an unfailing implementation of personal and collective protection regulations may be provided only by a firm control. An external control on behalf of the head of a research laboratory or project is to be complemented with internal control measures by involving the investigators themselves into the current assessment labor safety regulations performance. These regulations include the compulsory use of personal protection equipment when operating with nanomaterials; hand washing before meat, smoking or leaving the working place; prohibition against food stuffs or drinks in the working areas; change of clothes to prevent an unintentional transfer of nanomaterials on clothes and skin into other scientific center departments and home etc. (19). The social control and censure are often being taken by breakers as fair, since they come from the colleagues equal in status and position. Simple visualization tools also facilitate it – placard, graphic tablet etc. to clearly demonstrate all violation cases and dynamic pattern of employees' behavior. Systematic violations certainly shall result in material adverse effects – administrative measures, temporary suspension of the project work etc.

Safe behavior models

The safety culture starts (and ends) from the attitude and behavior of research team heads in terms of the labor safety (O'Toole, 2002). It is the laboratory or project head who becomes a role model for the rest people due to his/her academic standing. New employees immediately accept «bad» behavioral models, and the neglect on safety issues is inherited by the new generations of investigators and students-apprentices. The development of labor safety culture in the scientific and research laboratories may be facilitated by *Peer Mentoring*, where pairs of young employees interact with each other, one of them has already a brief experience in the scientific center, and the other is a student-apprentice, university graduate or trainee, who is just getting started. It disciplines the mentor himself and prevents the propagation of the undesirable "don't care" practice for the labor safety.

Change in the approach to the labor safety learning

Generally, the labor safety learning is too formalized, since it is executed by OSH department specialists according to the standardized programs. Then, the purpose of a training is not to learn rules and pass the examination, but the fact is that the employees shall act properly under the environment-related circumstances. The problem is that the labor safety officers are not professional trainers and cannot use active learning methods. Trainings, demonstrations, cases etc. make it possible to combine the regulations with a real practice, serving to comprehend and master safe behavior models of employees. These methods can be also useful for the induction training of labor safety regulations for new employees and students-apprentices.

Involvement of laboratory employees into the labor safety practice improvement

A variety of studies in the field of management proves that the involvement of employees could affect the reduction of incidents and accidents, since the managers provide the subordinates to participate in accident reduction activities and often delegate fully the safety concern to their employees (27). The above results indicate that the involvement of laboratory employees into the labor safety issue solution is one of the most effective measures for a quicker and deeper implementation of safety culture in the research centers. The most important here are the following measures.

- During the regular panel meetings of the scientific and research groups, the attention shall be paid to the safety issues to facilitate the generation of a positive safety culture in certain laboratories (24).
- Since the safety regulations usually appear to be the general-purpose instructions, which may be fairly efficient for a single type of scientific and research laboratories, but not quite useful for the others (24), internal expertise mechanisms are to be created to specify labor safety regulations and measures depending on the profile of a certain laboratory. The best solution is to create a virtual community of experts (Resnick, 2006), where the scientific center employees may discuss problems, accumulate information, share their expertise, suggest solutions and get competent advice etc.

- The aggregation of investigators into a temporary or permanent working group with a temporary participation to execute the internal control of labor safety regulations performance will promote initiatives for improvement of labor safety organization, active sharing of experiences, distribution of best practices from the leading research centers etc.
- The participation of laboratory employees in the generation of a knowledge base for nanopowders with a human risk assessment will greatly support both the development of a labor safety system in the research center, and the wide distribution of such experiences among the nanomaterial investigators throughout the world. Particularly, in the paper (Balas et. al., 2010) an assumption was made towards the staff of scientific magazines to make a statutory requirement that the authors of articles about the properties of nanomaterials shall provide information about the safety regulations and protection equipment observed during the investigations, thus, promoting a faster development and implementation of the most effective regulations in research teams.

SUMMARY

The investigation of how ultrafine and metal nanopowders and oxides (Fe, Ti, Mo, Co), aerosols of metal nanopowders (Fe, Co) and their mixtures affected health of employees of scientific and research laboratories, being permanently exposed to nanoparticles, proved that the simultaneous use of several metals may be accompanied by a synergitic increase in their toxicity which primarily affects the respiratory system and development of vegetovascular dystonia. A relation between the disease incidence and duration of employment in the scientific and research center is established. Based on this data, the groups of employees are separated and classified by morbidity risk level depending on the chronic disease, age and duration of employment. The developed risk matrix is capable of not only identifying staff groups by the sensitivity of nanopowders adverse effects, but also selecting individual-oriented preventive measures for the reduction of laboratory staff morbidity. The investigation findings may be used to forecast health risks when operating with specified materials, in order to develop the techniques of primary and secondary preventative treatment of their adverse impact.

Based on the results of the study of additional factors of high risk for the health of laboratory staff, it was found that, in the presence of formal labor safety systems in research centers, the measures employed cannot always provide adequate standards of behavior for employees when operating with nanomaterials. The main conclusion is that the core reason for the unfavorable dynamics of staff morbidity is the absence of a labor safety culture, which is the determining factor in how effectively OSH systems are used. Based on the best practices for safety management of employees of research laboratories and taking into account the specific conditions of the research center, measures are proposed for the preventive assessment and prevention of health risks, strengthening the performance of employees with regard to safety regulations, the formation of safe behavior models, changes in teaching methods and the involvement of laboratory staff in activities to improve labor safety practices. Despite the variety of the above measures, they share a common principle - active assistance of the researchers themselves in solving the problems of individual and collective labor protection, contributing to the formation of safe labor models, based on self-control and high responsibility for the personal safety and security of others. The approaches considered are based on the application of simple methods that can be adapted and used in the practice of labor protection in scientific centers, taking into account the profile and specific nature of research activities.

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