Monitoring and evaluating the effect of the working environment factors on health of staff in the magnesite mine in Slovak Republic

ŠTEFAN RODA[1], ELEONÓRA FABIANOVÁ[2], DAGMAR GAJDOŠOVÁ[3], ONDREJ GAJDOŠ[3], PAULÍNA VIDOVÁ[3]

[1]Public institute of health, Špitálska 3, 048 01 Rožňava, Slovak Republic
[2]Public institute of health, Cesta k nemocnici 1, 975 56 Banská Bystrica, Slovak Republic
[3]Public institute of health, Ipelská 1, 042 20 Košice, Slovak Republic

(Received October 2002 Accepted December 2002)

IGCP 443

Abstract

In this large-scale study goal to contribute to the understanding of aetiology of encephaloid lung tumour affections of various underground workers, we tried to evaluate the dependency between health and working environment in magnesite mines. Mining is done in underground places with minimal weight and the important measure of an exploitation locomotive mechanization with gas-engines. The important technological changes of raw materials extraction brought also the important qualitative changes in the composition of the unhealthy factors of the working environment, where the chemical risk factors have greater importance. The working air assimilates into the mixture of various solid, liquid and fluid risk factors, which do not affect the organism separately but only with relative interactions. There originates the assumption that the workers exposure to specific mining aerosol with the non-special, toxic and late effects on human organism. The offered work has got the goal to estimate the health risk i.e. to define odds and size of eventual health changes at workers in a simulation magnesite factory in Jelšava like a result of exposure factors which are created by mining aerosol. The topic of interest was the rate of lung cancer risk from the exposure of diesel air pollutants and their selected carcinogenic elements. The exposure inhalation model was worked out for workers and total working risk was estimated in dependence on the exposure in critical professions. The results create basic document for goal-directed epidemiological study, which is the type of case control for the purpose of identification of possible working exposures in relation to lung tumour affection.

Key words: diesel exhaust, specific mining aerosol, working risk, risk assessment, lungs cancer risk, Polycyclic Aromatic Hydrocarbons (PAH)

Introduction

Magnesite is a characteristic raw material of the eastern and middle Slovakia. Its extraction and processing were developed especially in the Jelšava-Lubeník area of the Gemer region. Extraction and heat treatment of magnesite caused a large environmental charging on the surrounding countryside as well as on the health conditions of the living population, that was presented by results of several studies. The important changes in technology of raw materials extraction, which are characteristic by a trend of permanent rising of mechanization in underground workings brought with itself qualitative changes in the structure of unhealthy factors of working environs. Towards the typical underground danger factors like dust, noise, judder, micro-climate, CO, NO_X and mental ballast (so-called mining stress) there access still more unhealthy chemical pollutants. Working air turns out to the mixture of various hard, liquid and gaseous elements, which are inaffective to the organism separately but only after relative interactions. There originates the risk of exposure of workers to special mining aerosol (Fig. 1) with non-specified, toxic and retarded effects on human organism. Listed facts request a new access to interpretation of work risk in relation to health.

The goal of the study

The continuation of the research on the epidemiological study - "Monitoring of the health state of population in the polluted area of Jelšava - Lubeník, years 1991 - 1994" was motivated by the decree of government of Slovak Republic. It had to apply the results of the retrospective and prospective parts of the study in evaluation of the possible negative effects of the living and working environs on the health of workers extracting and processing magnesite as well as to objectivize the incidence of professional illnesses. The study had to evaluate the health safety level of work, concerning results presented epidemiological study and to accentuate the request of complex appraisal of the working environs quality and progress of the health state especially from the reasons the correctly directed strategy of prevention.

The conclusions of the present study give the evaluation of risks on existing workings, the qualitative and quantitative of physical-chemical parameters of working environs, biological monitoring with particular analysis of the health state of workers. Just the results of health state analysis and biological screening offers us information about malignance of harmful substances with possible toxic and retarded effects on human organism.

The realized epidemiological study concludes, that the boom in the magnesite industry and increase of production in 1989 required targeted objectivization of the relation between the working environs and health because the results obtained during the 1991-1994period were affected by the trend of economic markers.

The project schedule

Phase 1

The estimation of the working conditions and working environment, characterizing the relation between environment and health with evaluation of the past situation:

- compilation of entries about exposure as well as other epidemiological entries about underground workers from history
- creating a database of compiled entries
- quality evaluation of compiled entries

Phase 2

2.1 To prepare a complex research programme of magnesite mines problematics in model the area of Jelšava - Lubeník, Slovak Republic, focussed on:

- Estimation of the health risk, i.e. to identify probability and intensity of possible health changes, which can appear in the case of workers as a result of the working environments factors like exposure with dust and chemical harmful substances, alternatively mining aerosol (Fig. 1).

2.2 To solve underground places work problems:

a/ the identification of risk size

- to identify the qualitative contents of mining aerosol in underground workings
- to realize the objectivization of the working environs factors with using of the most modern available investigative system

b/ the estimation of the dose and reaction relation

- to interpolate the results of experimental studies on magnesite factories conditions

c/ the estimation of exposure

- to evaluate qualitative and quantitative conditions of exposure

d/ the characteristic of risk

- to evaluate indirect consequences in files of monitored workers
- to realize the analysis of the workers health state in relation to harmful factors of working environments

Phase 3

- to prepare the database of records for epidemiological study of the type "case control" for the identification of possible working exposures causing the lung tumour diseases
- to apply the results of foreign studies about these problems

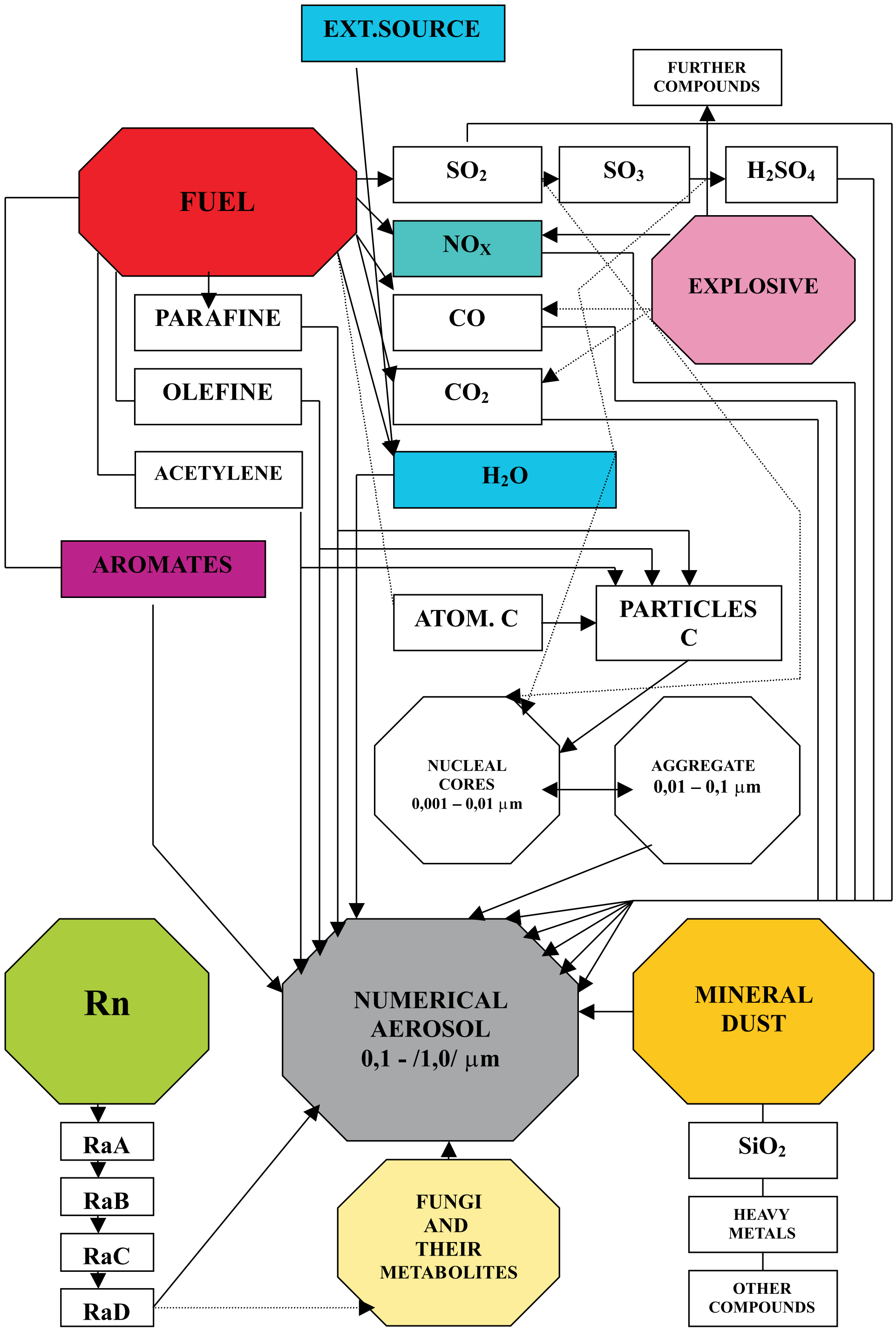

Fig. 1. Model of mining aerosol

Results

Phase 1

1.1 Characteristic of model factory in Jelšava

The factory SMZ Jelšava is situated in the Muraň valley (south of central Slovakia). It is oriented on magnesite exploitation, its concentration and heat treatment. The factory is a permanent source of air pollution to the living and working environments by magnesite dust ($MgCO_3$ and MgO). The factory consists of 3 plants: one for mining, one for sintering, and assistant plants.

The mining plant executes the perforating and exploitation of magnesite in underground workings in sectors Miková and Dúbrava. The extraction is realized by chamber and bossed mining with mining mechanization. 232-468 workers work underground in the SMZ Jelšava factory.

1/ Input data collecting

* List of underground workers, exposure, age, previous work place, profession, working activity description (time frame of work), professions according to method of mining, map documentation of individual horizons and working sectors, ventilation

2/ Unit database creating

* A database with the results obtained on harmful factors of the working environments monitoring was prepared by the software EPIINFO for the SMZ Jelšava, Slovmag Lubeník, Magnatech Hačava and Slovmag Lovinobaňa factories.

3/ Quality assurance of accumulated data

* To increase the validity of results there were used, apart from the results of the foundation The public institute of health (with branches in Košice, Rožňava, Rimavská Sobota, Banská Bystrica), also the results of the monitoring being realized by non-public health organizations,-Mining institute of the Slovak Academy of Sciences (SAV) Košice, SAV Geotechnics institute Košice and Scientific college of the university UPJS Košice.

The health risk estimation is a process used to determine probability and amount of health changes, which are found, when affecting people, to be a result of exposure to harmful factors of the living and working environments.

The risk estimation method is an effective instrument in obtaining information for decisions in the inspection process and risk control. The risk estimation is principally a sequential process and it implies 4 main steps:

- risk identification
- exposure estimation
- dose and effect appraisal
- risk characteristic

The risk identification consists on the detection of what may cause damage in real situations, about probability estimation if these effects and impacts are really able to occur in existing environments affecting a special population group and with what consequent after-effects. The main goal is to obtain the above mentioned informations to find out how to keep under the risk limit, to eliminate risk or how to compare one risk with other risks.

The goal:

- Health risk estimation i.e. specification of probability and amount of possible health changes, which can be detected affecting workers as a result of exposure in the working environments factors with focus on single ingredients of mining aerosol (Fig. 1) which cause the tumour lungs morbidity.

Pollution sources:

- Pollution sources are evaluated by authority using the analysis of qualitative structure of the working environments as well as technological process in collaboration with factory management.

Harmful factors in working environs:

- For exposure evaluation there were assigned the most significant harmful factors NO_X, PAH, mixture - diesel air pollutants. The informations about toxicity were acquired from professional literature.

The working hypothesis definition for the evaluation of exposure and risk characteristics:

1/ The health risk identification concerning the health damage is realized by the work of single professions in underground exploitation of magnesite i.e.

- to obtain the information about physical and chemical composition of the mining aerosol
- to obtain the information about amount of exposure of workers in each single professions
- to obtain the information about occupational composition, exposure duration of workers as well as about their working activity
- to obtain the information about the whole loading of workers by danger factors including out-of-service activity (Fig. 2), too
- to obtain the information about possible behaviour factors which influence the harmful effects of mining aerosol

2/ The health risk resulting from the excessive exploitage of mining mechanization i.e. diesel air pollutants effect

- to obtain the information about carcinogenic factors of mining aerosol
- to obtain the information about mutagenic behaviour of working environments
- to obtain the information about PAH occurrence during practicing of typical professions in underground
- to try to evaluate the health risk of carcinogenic harmful components

3/ Probable growth of lung tumours morbidity of workers in underground workings being exposed to selected harmful factors - i.e. risk estimation using values of UR given by US EPA and WHO.

Without prejudice the evaluation of the endurance factors in the workbench was needed to work out the model of creation and composition of mining aerosol (Fig. 1). From the model the results show that mining aerosol is a mixture of organic, mineral and biological components originating during underground mining in combination with the elements of the natural rock background. The classic model of mining aerosol is affected in a big measure by the work of internal combustion engines in underground spaces what multiplies the incidence of a variety of carcinogenic compounds in the working air like components of diesel air pollutants. The appearance of carcinogenic materials in underground spaces was elaborated according to the foundation IARC Lyon (Figs. 3 and 4).

The estimation of total exposure and risk characteristic

For evaluation of the long-term exposure for individual workers *the temporal balancing averages of exposure* (CVP) are calculated

- Calculation of temporal balancing average CVP of exposure:

$$CVP = \frac{\sum_{i=1}^{n} c_i}{n} \quad \text{where}$$

ci - average annual exposure
n - number of years in all monitored time period

- Average of yearly exposures for exposed profession profiles according to time period are listed in table.

- Average annual exposures of background according to time period are listed in the table

The results of the estimation of the exposure measure for every working profile permitted to characterize the exposure CVP for every particular worker in the underground.

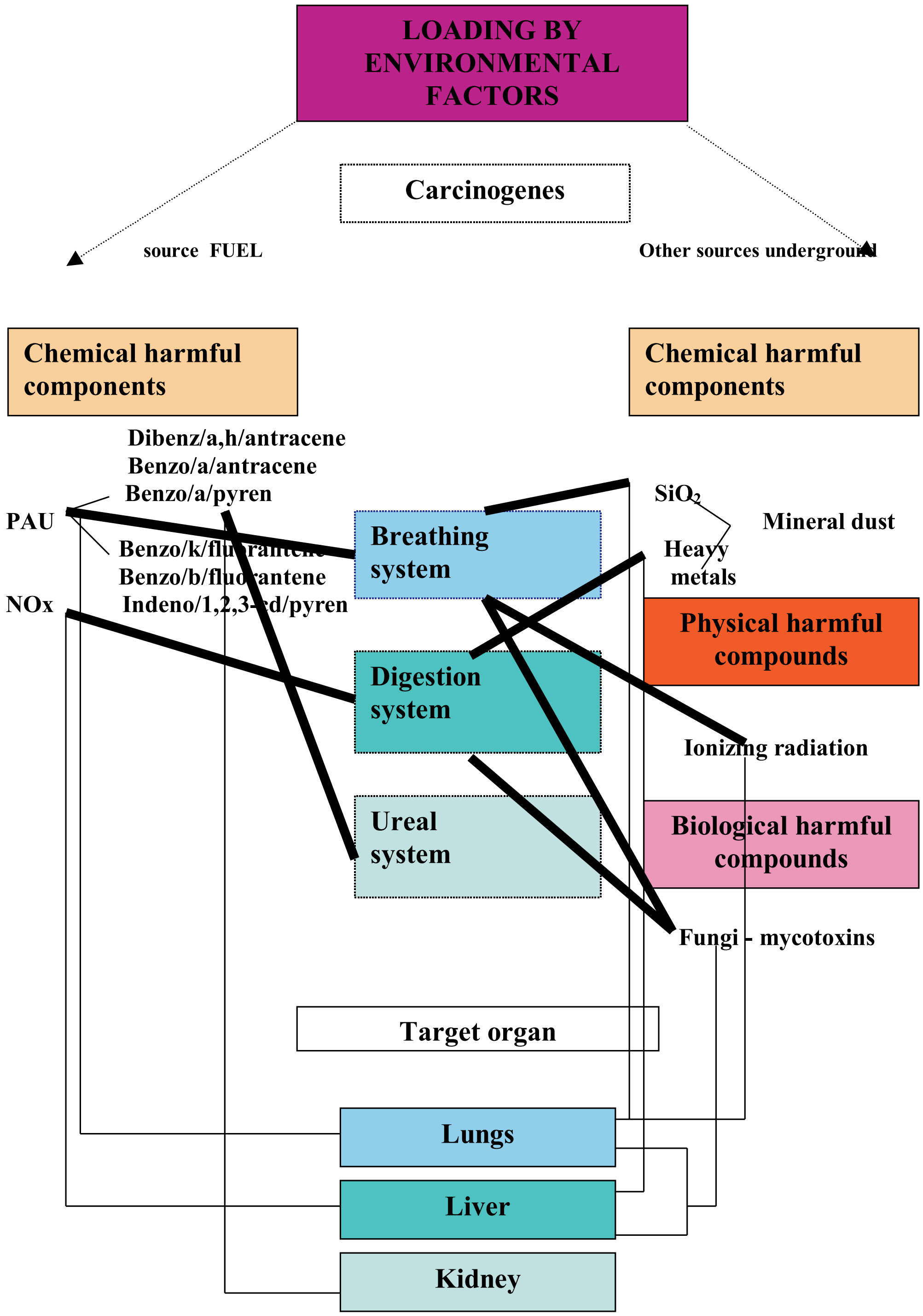
LOADING BY ENVIRONMENTAL FACTORS
Carcinogenes
source FUEL
Other sources underground
Chemical harmful components
Chemical harmful components
Dibenz/a,h/antracene
Benzo/a/antracene
Benzo/a/pyren
PAU
Benzo/k/fluorantene
Benzo/b/fluorantene
Indeno/1,2,3-cd/pyren
NOx
SiO_2
Mineral dust
Heavy metals
Breathing system
Digestion system
Ureal system
Physical harmful compounds
Ionizing radiation
Biological harmful compounds
Fungi - mycotoxins
Target organ
Lungs
Liver
Kidney

Fig. 2.

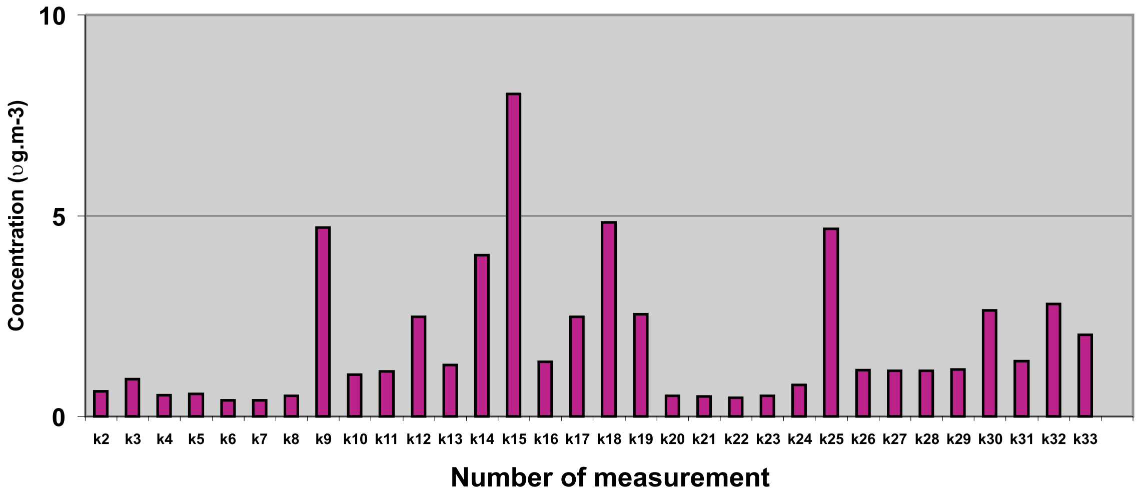

Fig. 3. Concentration of carcinogenic compounds PAH (according to IARC)

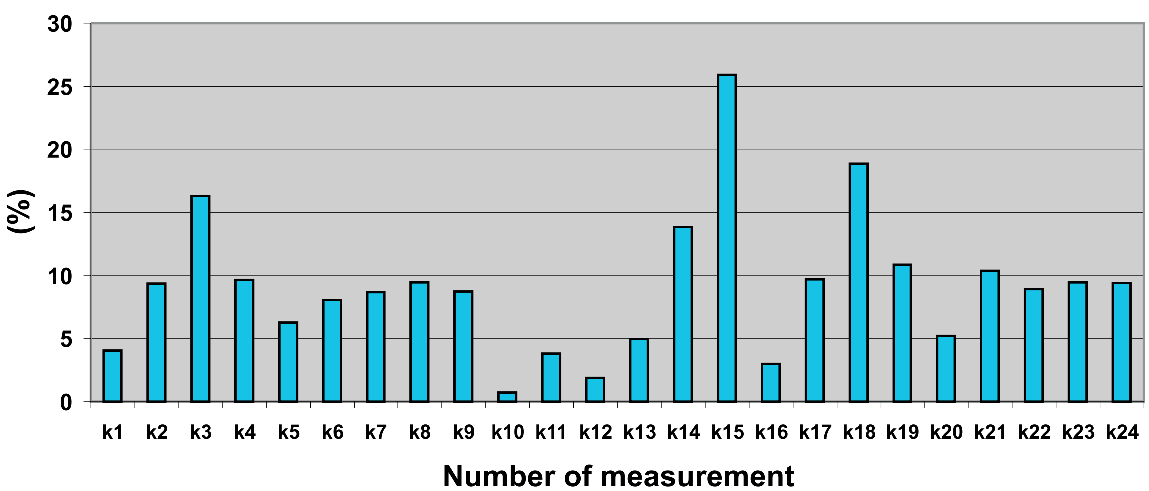

Fig. 4. Ratio of concentration of carcinogenic compounds PAH (according to IARC) to overall concentration of compounds PAH.

The exposure inhalation model was calculated for workers as follows:

Living period	Daily exposure
Adolescence - till 18 years	24 hours concentration of background (ZP) from that 12 hours in external environment and 12 hours in internal one
Active working age -18 till 55	8 hours working exposure 6 hours exposure background - external environment and 10 hours internal environment
Pensioner - above 55	12 hours exposure background - external environment and 12 hours internal environment

The exposure inhalation model

The length of annual working exposure - 8 x 250 = (0.34 x 0,7)

The length of extra-work exposure - 16 x 115= (0.66 x 0.3)

The expected average lifetime - 70 years

The risk characteristic

The topic of interest was the estimation of lung cancer risk from diesel air pollutants exposure and their selected carcinogenic elements (benzo/and/pyren, dibenzo/a,h/antracen).

- The of cancer lungs) expected incidence of lung cancer in connection either with lifetime or working exposure was calculated:

CR = UR . IE . CVPE where

CR - total risk (expected incidence

UR - risk unit (increase of cancer risk in consequence of unit concentration of carcinogenic exposure)

IE - exposure index (ratio between real exposure and average supposed life expectancy)

CVPE - temporary-valuable exposure average

- The values of the risk unit were taken from literature:

Substance	Target apparatus (tumour)	Risk unit
Diesel air pollutants	lungs	UR (according to WHO) - $1.6 .10^{-5}$-$7,1.10^{-5}$ $\mu g.m^{-3}$
Benzo/and/pyren	lungs	UR = $8.7 .10^{-2}$ $\mu g.m^{-3}$

The total expected risk was evaluated like the examples with inputting only of exposure from the working activity, with evaluation of extra-work exposure and under various assumptions for the profession of mining railless mechanization (MRM)

The examples of risk estimation of harmful substances in relation to lung cancer:

Example Nr.1 - The risk estimation of lung cancer from the diesel air pollutants exposure.

UR (according to WHO) - $1.6 .10^{-5}$ - $7.1 . 10^{-5}$ $\mu g.m^{-3}$

- For calculating we input the minimal and maximal values of UR interval

1/ Name of profession: Tenter of MRM - container feeder on bossed mining

2/ Assumption: let the diesel air pollutants concentration equal the concentration of organic elements of mining aerosol.

3/

TIME PERIODS DIVISION (YEARS) ACCORDING TO DEVELOPMENT TREND OF EXTRACTION TECHNOLOGY IN RELATION TO EXPECTED CONCENTRATIONS OF HARMFUL SUBSTANCES IN UNDERGROUND (diesel air pollutants)			
till 1981	1982 - 1990	1991 - 1994	since 1995
1.0 mg.m^{-3}	2.7 mg.m^{-3}	2.7 mg.m^{-3}	2.8 mg.m^{-3}

External environment: 30-160 μg.m^{-3} (average 100 μg.m^{-3})

Internal environment: 10-30 μg.m^{-3} (average 20 μg.m^{-3})

4/ Assumption: a miner works in underground since 18 years old and uninterruptedly he performs work in listed professions for 20 years i.e. till his age of 38 years.

From the total time duration of one day (24 hours - 100%) he keeps himself 25 % of the time in external environments, 41 % of time in internal environments and job time presents 34 %.

From the total number of days (365) in one year (100 %) 70 % are of working days (250) and 115 are free days - not working days (30 %).

5/ The average yearly concentrations in dependency from exposure:

- 1962 - 1979 : 40 μg.m-3
- 1980 - 1981 : 1,000 μg.m-3
- 1982 - 1994 : 2,700 μg.m-3
- 1995 - 2000 : 2,800 μg.m-3

6/ The calculating temporal balancing average CVP of exposure for period 1962 - 2000.

CVP = 345 μg.m-3

7/ The calculating IE - exposure index:

Assumption - we predict average age of living 70 years

IE = 0,54

8/ The calculating of total risk:

CR minimal = UR minimal. IE. CVP = 3 . 10^{-3}

CR maximal = UR maximal. IE. CVP = 13.2 . 10^{-3}

Example of the total working risk calculation:

CVP = 602 μg.m^{-3}

IE = 0.29

CR minimal = UR minimal. IE. CVP = 2.8. 10^{-3}

CR maximal = UR maximal. IE. CVP = 12.4. 10^{-3}

Total work risk in dependence of exposure:

Risk exposure (years)	**UR (μg.m^{-3})**	**CVP exposure (μg.m^{-3})**	**Exposure index**	ňTotal **risk**
5	1.6 .10^{-5}	690	0.07	0.8 . 10^{-3}
5	7.1 . 10^{-5}	690	0.07	3.4 . 10^{-3}
10	1.6 .10^{-5}	678	0.14	1.5 . 10^{-3}
10	7.1 . 10^{-5}	678	0.14	6.7 . 10^{-3}
15	1.6 .10^{-5}	674	0.21	2.3 . 10^{-3}
15	7.1. 10^{-5}	674	0.21	10.0 . 10^{-3}
20	1.6 .10^{-5}	602	0.29	2.8 . 10^{-3}
20	7.1. 10^{-5}	602	0.29	12.4 . 10^{-3}
25	1.6 .10^{-5}	532	0.36	3.1 . 10^{-3}
25	7.1 . 10^{-5}	532	0.36	13.6 . 10^{-3}
30	1.6 .10^{-5}	486	0.43	3.3 . 10^{-3}
30	7.1 . 10^{-5}	486	0.43	14.8 . 10^{-3}

Example Nr.2 - The risk estimation of lungs cancer from benzoe/and/pyren exposure

Assumption: From literary evidences (US EPA) the resuls that had the most serious compounds from the viewpoint of lung cancer are benzoe/and/pyren and dibenzo/a,h/anthracene. The realized measurements indicate that the average value (maximal because we take into account in the case of non-detectable values the minimal measurable value ND) of concentrations BaP = 0.03971 µg.m^{-3} and DBahA = 1.031 µg.m^{-3}. The average concentration value of all carcinogenic PAH = 1.792 µg.m-3. It is calculated, and taken into account these average values, the risk of tumour morbidity from exposure.

For UR BaP we calculate with concentration of the most dangerous PAH elements (a sum of BaP and DBahA).

The average value of concentration:1.07051 µg.m^{-3}.

Total working risk in dependence of exposure:

Risk exposure (years)	UR (µg.m^{-3})	CVP exposure (µg.m^{-3})	Exposure index	Total risk
5	$8.7 . 10^{-2}$	0.2548	0.07	$1.5 . 10^{-3}$
10	$8.7 . 10^{-2}$	0.2548	0.14	$3.1 . 10^{-3}$
15	$8.7 . 10^{-2}$	0.2548	0.21	$4.6 . 10^{-3}$
20	$8.7 . 10^{-2}$	0.2548	0.29	$6.4 . 10^{-3}$
25	$8.7 . 10^{-2}$	0.2548	0.36	$7.9 . 10^{-3}$
30	$8.7 . 10^{-2}$	0.2548	0.43	$9.5 . 10^{-3}$

The discussion of phase 1 and phase 2 solution:

- One of the most questionable points during the analysis of the quantitative markers was the fact that continual measurements of selected markers did not exist and many times there were used only estimations and it could increase the inaccuracy of exposure estimation and risk characterisation. There were applied the measurement results being realized by various worker teams and also in some cases they were received by different methods. Non-comparable results were excluded from the measurement statistics. Realized measurements on the state of the working environments in time dependency despite the listed facts that introduce the background material for significant evaluation of the underground work risk.

- From reason of rapidly alternating conditions in the working environments (the technique of extraction, dimension of space, ventilation quality, etc.) we excluded the ultra values of measurements and as meaningful we took the average values.

- In case of the evaluation of the carcinogenic effects of diesel air pollutants components we took into account the literature data, which often varied in the evaluation of their effects. We selected the opinions adopted by US EPA and the carcinogenic influence on people we determined according to IARC Lyon - Overall Evaluations of Carcinogenicity to Humans.

- We presented several examples of the risk estimation of lung tumour morbidity from the diesel air pollutants exposure as a whole and individual carcinogenic PAH elements. Theoretical calculations come out from various hypothesis of access to the evaluation of relation exposure - risk of Ca lungs. In most cases we focussed on working with the risk estimation without evaluating the effects of external and internal environments in home locality.

- The risk of lung cancer from exposure varies around the interval of one case on 10^{-3}-10^{-5} workers taking into account the use of UR for diesel air pollutants and Benzo/and/pyren. Concerning the trend of increasing diesel motor

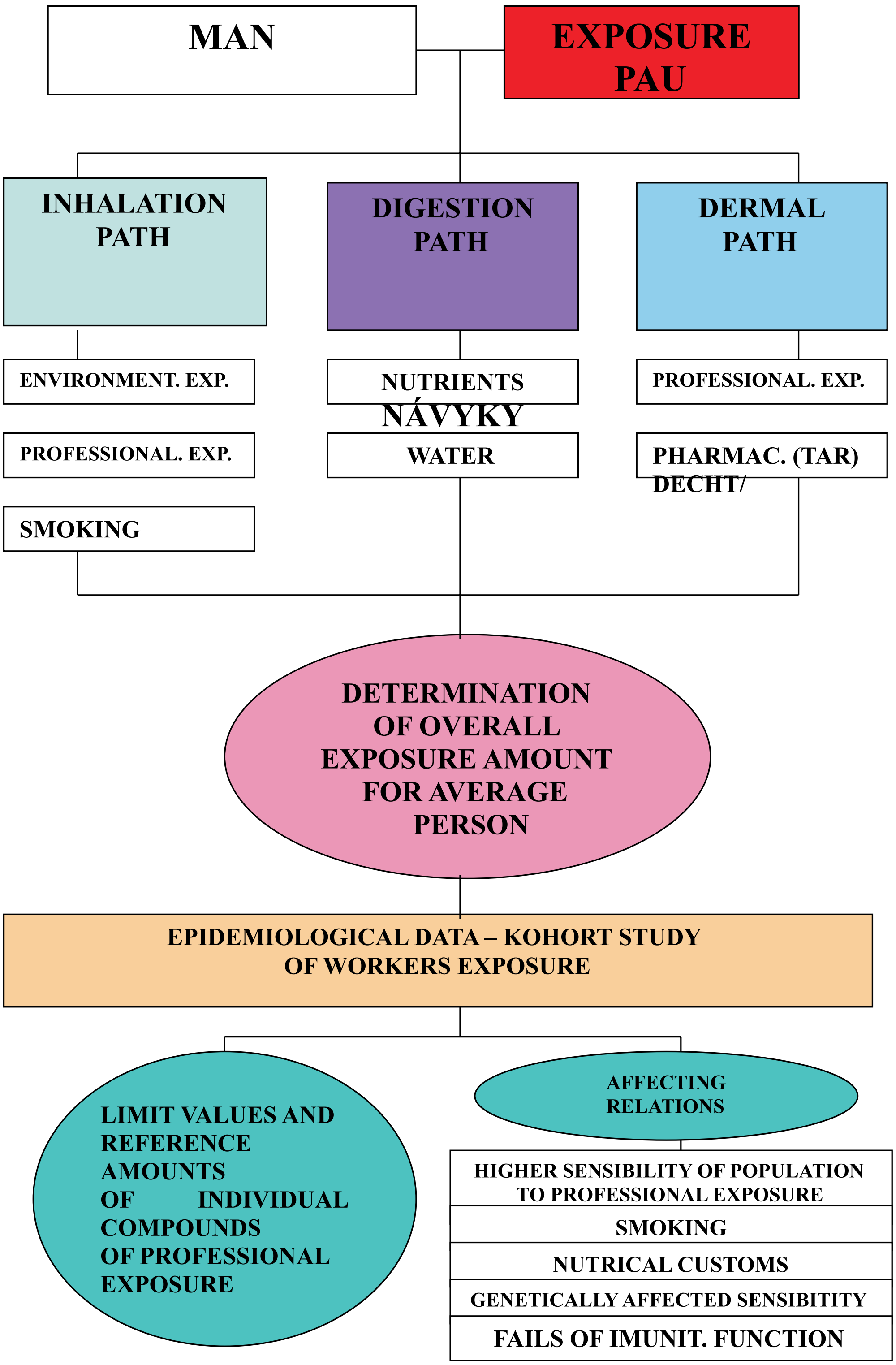

Fig. 5. Estimation of exposition and consideration of exposure vs. impact

usage in the underground it can be predicted in the future an accelerated tendency of lung cancer incidence from the diesel air pollutants exposure.

From discussion about received results it results that in continuity there is need to solve:

- The quantitative evaluation of size of the dust elements $PM_{2,5}$ and PM_{10} as well as the total distribution the number of dust particles.
- The targeted genotoxic investigation is modelled according to relation exposure vs. profession.
- It is probable that it is needed to make longer modelling measurement of PAH concentration because of low measured values as well as to precise the time demand of sampling for mutagenity of air determination.
- It will be needed to think how to evaluate the additive effects of proved or suspicious cancerogenis from the viewpoint of exposure of workers as well as about the methods of sampling.
- It will be necessary to take a standpoint to other cancerogenis causing the lung cancer risk.

PHASE 3

During solution of phase 3 of the project, it is needed to prepare individual findings to the data infobases for targeted epidemiological studies of the type case control. It will be purposed for identification of the possible working exposure, focussed on lung tumour morbidity.

We are expecting that the solution of phase 3 of the project will gives us the valid answer to the real relation of the exposure vs. predicted incidence of lung cancer. As it results from Fig. 5 it will be necessary to obtain the records for evaluation of the dependencies, preferably smoking and eating habits.

Conclusion

This targeted study offered comprehensive information about quality and quantity of harmful factors in the working air of underground workings during exploitation of magnesite rock. It was made an inhalation exposure model. The global working exposure to carcinogenic factors of mining aerosol was estimated being conditional for lung cancer origin. The differences in predicted risk, listed in individual examples of risk characteristic accentuated the significance of the used premises. The correctness of a working hypothesis from methodical point of view apparently will be possible to confirm after phase 3 of the project will be realized in the next time period. Within the frame of continuity of the project solution the interest will be extended to workers from superficial workings and acquired results will contribute to generalization of discussed topics for magnesite mines conditions in Slovakia.

References

Bobro M.1992. Geology-Ecology: The evaluation of heavy elements appearance in aerosol of mining workings SMZ Jelšava, Košice

Department of Physical and analytical chemistry PF UPJS 1993. The analysis of polycyclic aromatic hydrocarbons in mining aerosol, Košice

Geotechnics institute SAV 1993: The analysis of harmful elements CO and NOx in shot raw material in SMZ Jelšava, Košice.

Geotechnics institute SAV 1997. The analysis of measure products of Rn in mine Miková and Dúbrava SMZ inc. Jelšava, Košice

Geotechnics institute SAV 1998. The monitoring of the contents of heavy metals in mining aerosols of factory SMZ inc. Jelšava, Košice

Phare II EC/HEA - 18/CZ 1999. Program Teplica II, Publications sanitation 13. Retrieval: Magnesite dust - health effects, Banská Bystrica 2000

Phare project EC/91/HEA/18. The year-book1995. The study of the environmental pollution effect on population health in the area Nováky, Bojnice

Retrieval: Diesel air pollutants - Pah - risk assessment. The public institute of health Rožňava 2000

Retrieval: Pah - health effects, Banská Bystrica 2000

Safe S.H. 1998. Hazard and risk assessment of chemical mixtures using the toxic equivalency factor approach. Environ Health Perspect 106, S4, the U.S.A.

The mining institute of SAV 1990. The measurement of harmful compounds in aerosol of working environments in factory SMZ Jelšava, Košice.

The public institute of health Košice, The public institute of health Ro•òava1995. The monitoring of population health state in polluted area Jelšava-Lubeník in years 1991-1994, The final report.

U.S.EPA 1987. Risk Assessment Guidelines of 1986, Washington

Warshawsky D. 1999: Polycyclic Aromatic Hydrocarbons in Carcinogenesis, Enviromental Health Perspectives N4, the U.S.A.