# Can occupational exposure to elementary mercury increase the risk of suicide?

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**Abstract:** An increased mortality rate due to suicides among miners of the Idrija Mercury Mine was observed. The objective of this study was to evaluate the impact of long-term past occupational exposure to elemental mercury vapour ($Hg^0$) on the emotional states of ex-mercury miners. Mercury miners were intermittently exposed to $Hg^0$ for 7-31 years. The miners' mean exposure cycle urine mercury (U-Hg) level ranged from 20 to 120 mg/L. The results of the Emotional States Questionnaire (ESQ) showed that mercury miners tend to be more depressive, more rigid in expressing their emotions, and are likely to have a more negative self-concept than the controls. The results of the present study suggest that the interaction of long-term increased occupational exposure to Hg° and continuous "moderate" alcohol consumption could be associated with the increased risk of suicide among miners of the Idrija Mercury Mine.

**Keywords:** Elemental mercury, Occupational exposure, Emotional state

## INTRODUCTION

The central nervous system is the critical organ for Hg° vapor exposure (WHO, 1991). Post mortem studies (KOSTA ET AL., 1975; BYRNE ET AL., 1995; FALNOGA ET AL., 2000) have shown that the accumulation of mercury in the brains of ex-mercury miners was very high even several years after exposure. Strong mercury accumulation and retention was found, particularly in the hippocampus, cerebral cortex, nucleus dentatus, pituitary, and also in the pineal gland. An increased mortality rate due to suicides among miners of the Idrija Mercury Mine was observed.

The purpose of the present study is to evaluate the impact of long-term occupational exposure to $Hg^0$ on the personality traits reported by ex-miners in the Eysenck Personality Questionnaire (LOJK, 1981) and the Emotional States Questionnaire (LAMOVEC, 1988) in the period after exposure.

## SUBJECTS AND METHODS

120 males were examined in the study. After the selection procedure, the study population comprised 53 ex-mercury miners previously exposed to $Hg^0$ and 53 age matched workers from mercury free works in the control group. The miners were employed in the Idrija Mercury Mine for a period ranging from 7 to 31 years. They were intermittently exposed to Hg° in intervals – cycles. The interval between the last exposure and the present evaluation of miners varied from 8 to 336 months. The final selection of the study population was based on medical examinations and some biological analyses performed at the time of the survey.

*Medical and psychological examinations.* All participants gave informed consent before being included in the study. The medical examination included the determination of general clinical status of examinees' medical history and lifestyle habits (smoking, alcohol consumption). All participants completed Eysenck Personality Questionnaire (LOJK, 1981) and the Emotional States Questionnaire (LAMOVEC, 1988). The metric characteristics of ESQ suggest that the questionnaire is appropriate for further analysis. Measures of internal reliability, such as the Cronbach alpha coefficient (VOGT, 1993) and the Guttman split-half coefficient, show the consistency or stability of a measure of the test from one use to another. Both are relatively high (ranging from 0.65 to 0.89). Since reliability is associated with accuracy of the test, ESQ may be ranked among those psychometric tests with higher reliability.

*Assessment of exposure.* On the basis of exposure records, the following environmental indices of $Hg^0$ occupational exposure were determined: years of exposure, cycles of exposure, average time-weighted (ATW) air $Hg^0$ concentration (expressed in mg $Hg^0/m^3$ air). The U-Hg concentrations determined during occupational biological monitoring of each exposed miner were used to calculate the following biological indices of occupational exposure: geometric mean of cycles U-Hg level, geometric mean of cycles peak U-Hg level, cumulative U-Hg level (the sum of all cycles U-Hg levels), U-Hg level at the last exposure (in μgHg/L). U-Hg levels were determined by cold vapor atomic absorption spectrophotometry (CVAAS).

*Data Analyses.* For all computations we used the SPSS for windows (Standard version, sep. 2001). To find possible explanations of associations between the target variables (personality traits) and biological indicators of occupational $Hg^0$ exposure in combination with co-variables, we used machine learning methods; more specifically we used model trees (QUINLAN, 1992), which are a generalization of regression trees.

## RESULTS AND DISCUSSION

The observed groups did not differ in mean age, body mass index (BMI), dental amalgam score and cigarette consumption. The mean consumption of alcohol tended to be higher in miners (35 versus 22 ml/day). The number of alcohol consumers with over 20 ml/day was higher in miners (28 % versus 19 %). The miners' cycles of $Hg^0$ exposure varied between 13 to 119 cycles, at air $Hg^0$ concentration ranging from 0.14 to 0.45 mg/m$^3$. The miners' mean exposure cycles U-Hg level ranged from 20-120 µg/L.

A comparison of the group of miners and the control group in EPQ revealed a lower mean score of extraversion in the group of miners (p = 0.017). The average score on a lie scale was also lower in the group of miners (p = 0.003). Table 1 presents the ESQ results. The average scores for depression and negative self-concept were significantly higher (p<0.01) in miners than in controls. The indifference average score also tended to be higher in miners (p=0.025) in comparison to the controls.

**Table 1.** Average scores on the Emotional State Questionnaire (ESQ) of observed groups.

| ESQ | Miners (n = 53) Mean | SD | Controls (n = 53) Mean | SD | p-value |
|---|---|---|---|---|---|
| depression | 20.33 | 5.07 | 17.73 | 3.61 | 0.009 |
| contentment | 30.52 | 4.97 | 31.05 | 6.06 | 0.667 |
| aggressions | 17.17 | 4.20 | 15.95 | 2.71 | 0.122 |
| indifference | 9.74 | 2.73 | 8.51 | 2.11 | 0.025 |
| positive self-concept | 15.52 | 3.16 | 16.51 | 2.91 | 0.143 |
| negative self-concept | 8.98 | 2.51 | 7.68 | 1.71 | 0.008 |

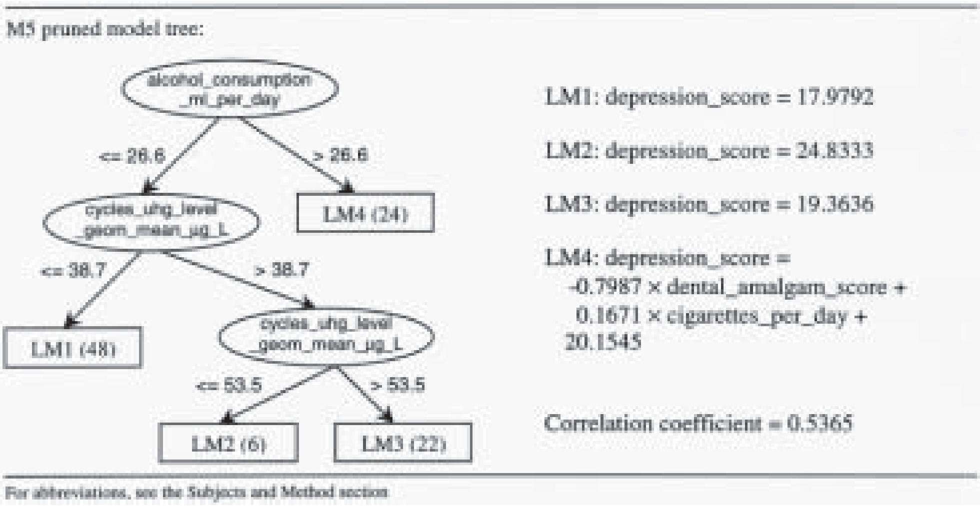
For abbreviations see Subjects and Method section.

The model tree predicting the depression score presented in Table 2 contains four leaves, of which three contain constant predictions and one contains linear model. It is evident from the LM1 model, which was based on a larger number of subjects (39 controls and 9 miners), that low alcohol consumption (<26.6 ml/day) at a lower level of occupational exposure (mean cycle U-Hg <38.7 µg/L) did not increase the depression score. Models LM2 and LM3 relate to an increased depression score in 28 miners at a higher level of exposure (male cycles U-Hg >38.7 µg/L). A higher consumption of alcohol (per se) (>26.6 ml/day) tends to increase the depression score in 14 miners and 10 controls.

From the model tree we can see that permanent increased alcohol consumption per se (> 26 ml/day) increases depression in both miners and controls, which is also known from other studies (SCHUCKIT, 1986; LEIBENLUFT ET AL., 1993). Lower permanent alcohol consumption (< 26 ml/day) associated with long-term higher occupational $Hg^0$ exposure (cycles U-Hg level > 38 µg/L) seems to increase the miners' depression score. The model tree also shows that the internal doses received during occupational exposure, expressed by the geometrical mean U-Hg level (> 32 mg/L) and U-Hg at last exposure, appear to be the factor most strongly associated with miners' negative self-concept.

The model tree predicting the negative self-concept score (not presented here) contains

**Table 2.** Model tree (with 4 linear models) constructed by M5', describing the depression score and its correlation coefficient. The number of subjects in each leaf is given in parenthesis.




two leaves with one linear model each (LM1 and LM2). Model LM1 represents the controls (N=53) with a relatively lower score. Age and alcohol consumption partly increased their negative self-concept score. LM2, which represents the ex-miners (N=47, only miners with "last exposure" U-Hg >10 µg/L), relates the negative self-concept score to mean cycles of U-Hg level (>32.5 µg/L) and U-Hg level at last exposure. In these cases as well, the mean cycles peak U-Hg level did not increase the observed score.

Alternations of emotional state, mood and some unspecific symptoms were most frequently observed at U-Hg levels ranging between 30-100 µg/L (GERSTNER AND HUFF, 1977; CAMERINO ET AL., 1981; PIIKIVI ET AL., 1984: PIIKIVI AND HÄNNINEN, 1989), while in some studies they were also observed at lower levels of occupational exposure at U-Hg mean levels ranging from 30 to 40 µg/L (SOLEO ET AL., 1990; ECHEVERIA ET AL., 1995). In the study of SOLEO ET AL. (1990) and ECHEVERRIA ET AL. (1995), the personalities of exposed workers was found to be considerably changed at lower levels of occupational exposure, whereas certain mood measures were associated with Hg exposure. The measurements of neuropsychological effects in workers previously exposed to $Hg^0$ were applied only in the study of LETZ ET AL. (2000), but no residual mood changes with depression have been observed.

Theoretically, consideration should be given to the potential impacts of mercury on the metabolism of neurotransmitters (MOTTET ET AL., 1997)) and the impacts of increased accumulation of mercury in the pineal gland itself (KOSTA ET AL. 1975; FALNOGA ET AL. 2000), which might also influence the synthesis of melatonin and, indirectly, the balance of serotonin (KASPER ET AL., 1996), which in the opinion of certain researchers (HEERINGEN, 2001), influence the occurrence of depression and low self-concept.

Despite the above-mentioned theoretical outline, our results suggest that emotional rigidity, depression, negative self-concept, and partly also introversion, which characterise the personalities of miners, may be associated with long-term moderate occupational exposure to $Hg^0$. We presume that the mutual interaction of long-term increased exposure to $Hg^0$ and long-term "moderate" alcohol consumption has had a decisive influence on the development of depression in the miners observed.

This depressive mood itself could, as a result, increase the risk of suicide among miners of the Idrija Mercury Mine. Other studies (KOBAL, GRUM, 2003) also indicate that a low or negative self-concept could be a significant factor for suicidalness. However, the increased mortality due to suicides among miners of the Idrija Mercury Mine in the last 40 years (standardized mortality rate 123.95 %, confidence interval 88-168; unpublished data) cannot completely confirm the relation between occupational exposure to $Hg^0$ and depression as one of the potential causes of suicidal behavior. This is primarily because the results of the epidemiological study on the mortality of miners in four mercury mines (BOFFETA ET AL., 1998) are not consistent, probably due to errors in the classification of the cause of death in some countries, or due to variations in psychosocial or genetic risk factors (MARUŠIČ & FARMER, 2001).

## CONCLUSIONS

Despite the limitations, long-term intermittent moderate exposure to $Hg^0$ in interaction with alcohol remains a plausible explanation for depression, disposition to emotional rigidity, and negative self-concept established by the present study in mercury miners in the period after exposure. This study thus further supports efforts to reduce the occupational exposure levels of $Hg^0$, to the lowest observed adverse effect level (WHO, 1991) capable of preventing the late effects of $Hg^0$ exposure.

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