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# The Effects of a Workplace Health Promotion Program to Decrease Cadmium Exposure Levels in Nickel-Cadmium Battery Workers

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## Abstract

**Objective.** Cadmium exposure is a common problem in the production of nickel-cadmium batteries. However, keeping the respective legislative occupational and safety policies is essential, but there are problems with compliance. We analysed the effect of strategies to increase compliance with precautions during 2013-2015 on 59 workers at a nickel-cadmium battery factory. **Material and Methods.** A health promotion program was implemented in two phases. The first phase included comprehensive education on the importance of appropriate behaviour and changes to the sanitation program. The second phase included renovation of sanitary facilities and modernization of the air exhaust ventilation. **Results.** The initial median cadmium urinary level in workers was 1.9 μg/g creatinine. After the first phase of interventions, levels dropped to 1.0 μg/g creatinine. After the second phase no significant further decrease was observed. **Conclusion.** Comprehensive education and changes in the sanitation program were able to halve cadmium levels and can be considered a useful and cost-effective preventive tool.

**Key Words:** Behaviour ▪ Cadmium ▪ Compliance ▪ Education ▪ Workplace.

## Introduction

Cadmium is a toxic heavy metal, which occurs in the environment, but it is frequently used in many industrial sectors. For example, in the production of nickel-cadmium batteries, workers are significantly exposed to cadmium dust and fumes via inhalation, but incidental ingestion from contaminated hands, food and cigarettes cannot be neglected (1). Moreover, the metal has a long biological half-life and cannot be metabolized in the human organism. So cadmium exposure, even at low levels, can lead to a wide range of adverse health effects (2). Besides, there are some other factors, i.e. sex, age, dietary intake, iron status, smoking, and length of exposure or place of residence, which can influence the total body burden (3).

To prevent negative effects on workers' health, specific occupational health and safety policies are included in the respective legislation (4). The policies are mandatory for employers and include workplace educa-


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tion and training, occupational air monitoring, and provision of adequate personal protective equipment. Despite the obligation to keep these preventive measures, there is sometimes a problem with poor compliance by employees (5).Workplace health promotion programs are quite common strategies for more precise risk reduction, using the most suitable interventions, i.e. improvement in personal hygiene or sanitation, and lead to behavioural changes (6-8).

The aim of this study was to evaluate the effects of a workplace health promotion program on exposure reduction in workers at a nickel-cadmium factory.

## Materials and Methods

This study analyses changes in urinary cadmium (U-Cd) levels in professionally exposed workers, during a workplace health promotion program that took place from February 2013 to April 2015 in a nickel-cadmium factory in the Czech Republic. The factory is situated in the centre of a village (1777 inhabitants) and operates in three shifts. Although all the manufacturing processes are fully automated, the workers may be exposed to cadmium oxide via inhalation when handling the components of nickel-cadmium batteries. In the factory, all relevant instruments for occupational safety and health related to cadmium prescribed in the legislation have been implemented, i.e. cadmium air concentrations are below the permissible exposure limit, personal protective equipment is available, and all essential technical preventive measures prescribed by law have been put into practice. Despite this, retrospective analyses of U-Cd levels, conducted by an occupational physician, showed excessive levels and this was the reason for launching this extra preventive action.

The study started in February 2013 when the initial U-Cd exposure levels in workers were analysed during their periodic medical check-up. Subsequently, in March 2013, the first phase of the workplace health promotion program began. Firstly, the safety engineer, in partnership with the occupational physician, informed workers about the increased U-Cd levels found in February and their possible future health effects. The specific preventive measures in this phase included providing specific information on the importance of personal hygiene and stopping smoking. Wet mopping between the shifts was also added. Although the workers were educated about these preventive measures from the very beginning of their recruitment, most employees neglected them. Later in 2014, the second phase of the workplace health promotion program was introduced. The interventions in this phase consisted of bathroom renovation (more showers added) and a cloakroom divided into "clean" and "dirty" parts, to avoid cross-contamination. Moreover, in 2014-2015 the modernization of the air exhaust ventilation was carried out to eliminate cadmium dust. A detailed description of the preventive measures in the health promotion program is shown in Figure 1.

Further, information on the subjects´ health history was obtained solely from medical records (in cooperation with the respective health provider). The health and safety manager from the factory provided detailed information on preventive measures.

The sample included 59 workers tested for cadmium; 36 women and 23 men, with an average age of 39.4 years. Among them, 18 workers were smokers and 12 workers lived in the same village where the factory is situated (Table 1). The workers had on average been working in the nickel-cadmium battery factory for 10 years.

Cadmium concentration is expressed as U-Cd levels. Samples were obtained from the workers at their annual preventive check-ups, in the occupational doctor´s clinic. At the beginning of the study all the

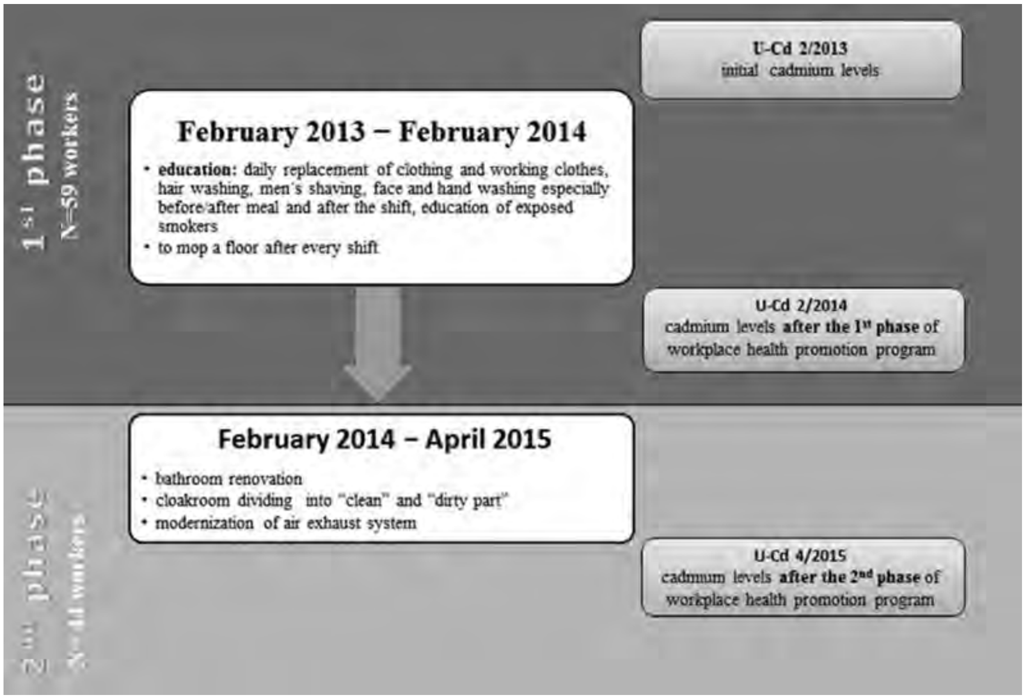


Figure 1. Scheme of Interventions Included in the Workplace Health Promotion Program and Laboratory Analyses Conducted.

Table 1. Characteristics of the Workers in the Nickel-Cadmium Factory

| Variable | Females | Males |
|---|---|---|
| Sample size (%) | 36 (61%) | 23 (39%) |
| Smokers (%) | 9(15%) | 9(15%) |
| Residence in the village with the factory | 7 (12%) | 5 (8%) |
| Average age in years ±SD (range) | 41.5±11.1 (22–61) | 36.2±11.7 (21–58) |
| Exposure duration in years ±SD (range) | 11.0±8.9 (1–34) | 7.9±4.8 (2–17) |

workers signed informed consent to confirm their participation in the study. For the laboratory cadmium testing, we collected morning urine samples. The urine samples were analysed by GT-AAS absorption atomic spectrometry with electro–thermal atomization (coefficient of variation CV: 5%; relative combined uncertainty $U_{c, rel:}$ 17%). U-Cd content was adjusted for creatinine in urine, expressed as μg/g creatinine. The chronological sequence of urine tests is as follows:

- U-Cd 2/2013 initial cadmium levels in February 2013, before the preventive interventions,
- U-Cd 2/2014 cadmium levels in February 2014, after the first phase of the workplace health promotion program,
- U-Cd 4/2015 cadmium levels in April 2015, after the second phase of the workplace health promotion program.

### *Statistical Analysis*

The differences in U-Cd levels during the workplace health promotion program were statistically analysed by the non-parametric Wilcoxon signed-rank test, and the difference in factors affecting U-Cd levels in workers were analysed by the Wilcoxon rank-sum test. A P value <0.05 was considered as the level of statistical significance. Descriptive analysis was used to calculate medians, interquartile ranges (IQR), means, standard deviations (SD), minimums and maximums. U-Cd data are demonstrated as medians. The results are graphically expressed using a box and whisker plot (median, 25th percentile is considered as lower limit, 75th percentile is considered as the upper limit).

## Results

The initial median U-Cd level observed in 59 workers was 1.9 μg/g creatinine (IQR 5.1 μg/g creatinine), 19 workers had initial U-Cd levels higher than 5 μg/g creatinine. Although median U-Cd levels in women were higher in comparison to men, the difference was not statistically significant (P=0.139). As Table 2 shows, there was no statistical difference in U-Cd levels between smokers and non-smokers (P=0.863), or between workers living in the same village as the nickel-cadmium factory and those living outside (P=0.412).

### 1st Phase of the Health Promotion Program

We analysed urine samples from 59 workers. At the beginning of the health promotion program, the initial median U- Cd level in workers was 1.9 μg/g creatinine. After the education and change of the sanitary plan, U-Cd levels dropped by about a half to 1.0 μg/g creatinine, and the difference in concentration was statistically significant (P<0.001) (Table 3 and Figure 2).

### 2nd Phase of the Health Promotion Program

Samples were taken from 44 workers. The median level of U-Cd before the improvement of technical measures was 1.1 μg/g creatinine. Subsequently, after the intervention

Table 2. The Initial U-Cd Concentration and Factors Affecting Cadmium Levels in Workers

| Variable | U-Cd [μg/g creatinine]* | | | | | | |
|---|---|---|---|---|---|---|---|
| | Median | IQR | Mean | SD | Min. | Max. | P† |
| Workers (N=59) | 1.9 | 5.1 | 4.9 | 6.8 | 0.2 | 35.6 | |
| Women (N=36) | 2.7 | 6.2 | 6.0 | 7.7 | 0.2 | 35.6 | 0.139 |
| Men (N=23) | 1.3 | 2.1 | 3.0 | 4.7 | 0.2 | 22.6 | |
| Smokers(N=18) | 1.3 | 6.3 | 5.9 | 9.0 | 0.2 | 35.6 | 0.863 |
| Non-smokers (N=41) | 2.2 | 4.5 | 4.6 | 5.9 | 0.2 | 22.6 | |
| Residence (N=12)‡ | 2.5 | 8.4 | 6.5 | 7.8 | 0.2 | 20.5 | 0.412 |
| Residence (N=47)§ | 1.7 | 4.7 | 4.7 | 6.5 | 0.2 | 35.6 | |

*Cadmium urine levels; †Wilcoxon rank-sum test; ‡In the village with the factory; §Elsewhere.

Table 3. The Effect of the 1st Phase of the Workplace Health Promotion Program on U-Cd Levels

| Variable | U-Cd [μg/g creatinine]* | | | | | | |
|---|---|---|---|---|---|---|---|
| N=59 | Median | IQR | Mean | SD | Min. | Max. | P† |
| U-Cd 2/2013 | 1.9 | 5.1 | 4.9 | 6.8 | 0.2 | 35.6 | P<0.001 |
| U-Cd 2/2014 | 1.0 | 1.7 | 2.1 | 3.0 | 0.1 | 15.0 | |

*Cadmium urine levels; †Wilcoxon signed-rank test.

Table 4. The Effect of the 2nd Phase of the Workplace Health Promotion Program on U-Cd Levels

| Variable | U-Cd [μg/g creatinine]* | | | | | | |
|---|---|---|---|---|---|---|---|
| N=44 | Median | IQR | Mean | SD | Min. | Max. | P value† |
| U-Cd 2/2014 | 1.1 | 0.5 | 2.3 | 3.4 | 0.1 | 15.0 | P=0.728 |
| U-Cd 4/2015 | 1.2 | 2.0 | 2.5 | 3.3 | 0.2 | 15.2 | |

*Cadmium urine levels; †Wilcoxon signed-rank test.

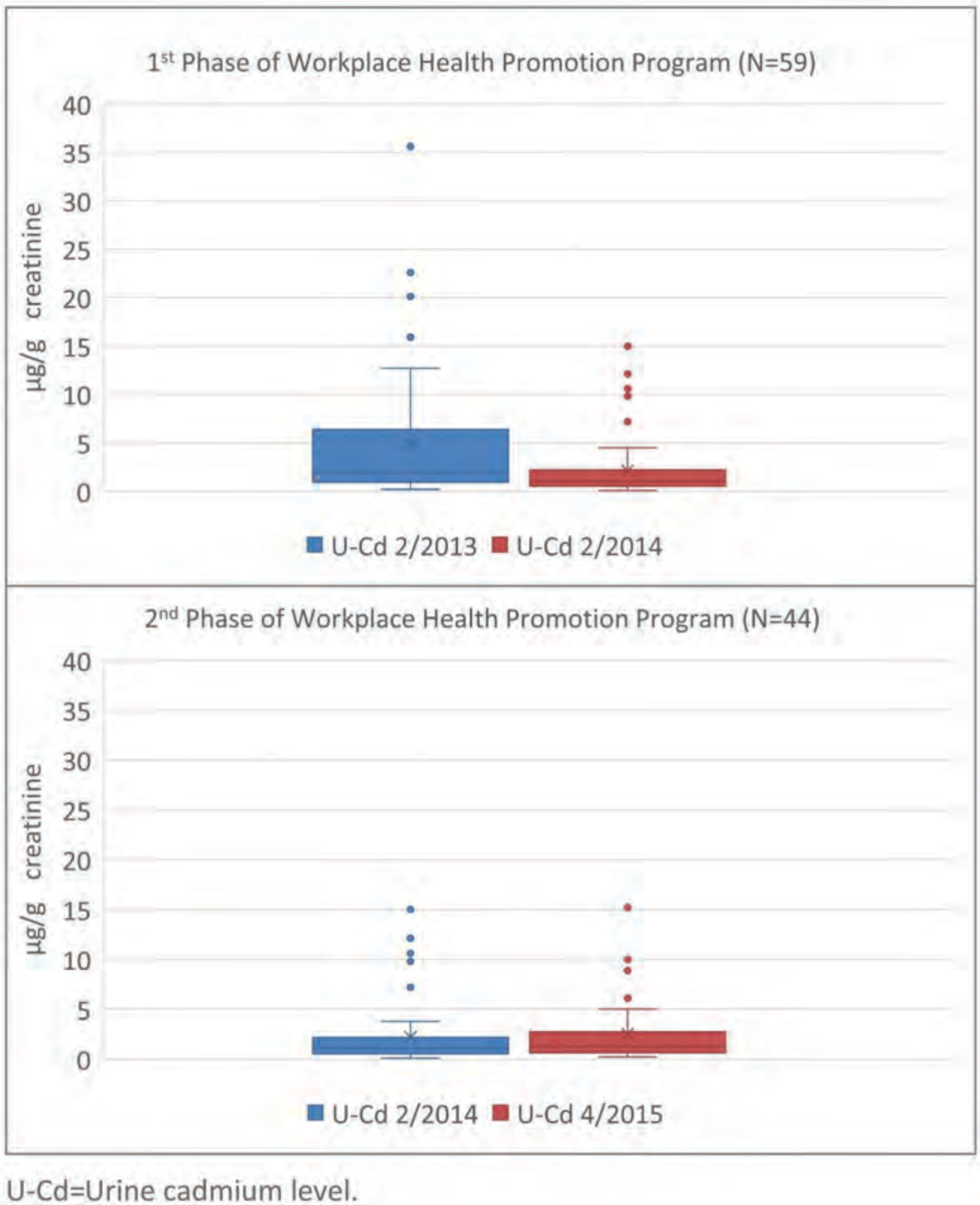


Figure 2. The urinary cadmium levels (U-Cd) after the 1st and 2nd phase of health promotion program.

(technical preventive measures), the median level of U-Cd did not change significantly (P=0.728) (Table 4, Figure 2).

## Discussion

Generally, women, smokers and the population living near factories have significantly higher cadmium levels in their blood or urine (3, 9-11). Although these studies described a strong association of these factors, our results did not confirm any significant relationship. The women in our sample had a similar job description to the men. Full automation of the manufacturing processes has led to reduction of cadmium exposure in workers, and some positions have become more favourable for women. Similarly, the exposure duration for workers was relatively long, so the variations in exposure factors may be reflected in U-Cd levels (12). The insignificant impact of smoking on cadmium levels can be explained by the strict smoking ban in the factory (13). However, there was no influence of place of residence on U-Cd levels in workers, which indicates that the measures carried out in the factory to protect the surrounding environment are effective.

The initial median cadmium level in workers was below the Czech occupational exposure limit (14), but still higher in comparison with the environmentally exposed population (15). Nevertheless, although the factory declared cadmium air concentrations below the permissible exposure limit and the presence of all statutory preventive measures, U-Cd levels in 19 workers exceeded the occupational exposure limit. So according to the previous studies, we assumed that insufficient compliance with the basic preventive measures by these workers, such as poor hygiene, could be closely associated with excessive oral exposure to chemicals (16). Therefore, apart from cadmium airborne monitoring, behavioural changes contributing to improvement in workers' personal hygiene are essential (5, 8, 17). Practicing good personal hygiene showed a significant positive effect on U- Cd levels in our sample, indeed, within a relatively short time period. Although behavioural change seems to be a rather unsophisticated preventive measure, the effect on workers´ exposure can be very significant (7). Moreover, supervision by the safety engineer significantly contributes to a notable behavioural change (18).

We supposed that the second phase of the health promotion programme could bring a further decrease in U-Cd levels. However, there was surprisingly no significant decrease in U-Cd levels. This indicates that if the compliance with the basic preventive measures is insufficient, the renovation of sanitary facilities and modernization of air exhaust ventilation would be pointless.

There were some limitations to our study. Firstly, the sample of workers exposed to cadmium was relatively small and was not divided proportionally by sex, smoking status or residence. Moreover, due to the small sample size, no statistically significant differences were found in the analysis of the influence of these factors. On the other hand, the gender distribution, proportion of smokers, and the number of exposed employees in the workplace represents a typical situation in this type of industry. Thanks to modern technologies, mechanical overload has been eliminated, and thisgenerally makes these jobs more preferable for women. Moreover, in the employment process non-smokers are preferred and strict non-smoking policies are adhered to in the workplace. Similarly, we only used cadmium urine levels for our analysis, which are considered to be a long-term exposure biomarker. Although some authors prefer blood samples to demonstrate short-term changes better (12, 19, 20), in our case urine testing was a standard part of the check-up and therefore no additional invasive procedures were needed. Finally, there was no control group from the same village where the factory is located, who would only be exposed environmentally. We assume that the limitations mentioned above did not substantially alter the measured levels and did not undermine the main contribution of the article, that is,, to demonstrate clearly the effect of comprehensive employee education in a workplace with increased risk of cadmium exposure.

## Conclusion

The study clearly indicates that, although health and safety measures are prescribed by law, there is a problem with compliance by workers in practice. The significant decrease in U-Cd levels demonstrates that education is a convincingly useful and cost-effective way to reduce occupational chemical exposure, increase workers´ compliance and save employers from the future possible compensation costs.

**What Is Already Known on this Topic:**
*Cadmium is a toxic heavy metal, exposure to which even at low levels can lead to serious adverse health effects. Legislatively based preventive measures are prescribed for workplaces, but their effectiveness can be limited by workers´ poor compliance.*

**What this Study Adds:**
*We evaluated the effect of preventive measures on cadmium levels in workers under the real conditions of a nickel-cadmium factory. After the education of workers and changes in the sanitation plan, the initial median cadmium level 1.9 μg/g creatinine dropped by about a half. Subsequently, technical preventive measures did not show any decrease in cadmium levels. The results demonstrate the importance of further education to promote workers' compliance with legislatively based preventive measures, to minimize the potential harmful effects of cadmium exposure.*

**Authors' Contributions:** Conception and design: MS and TB; Acquisition, analysis and interpretation of data: HT, LC, AŠ and MS; Drafting the article: MS and TB; Revising it critically for important intellectual content: TB and HH; Approved final version of the manuscript: MS, HT, LC, AŠ, TB and HH.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

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