Investigation on lead pollution and occupational health status of workers in lead-zinc smelting enterprises

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Abstract. Objective to explore lead pollution and its health impact on workers in a lead zinc smelter. Methods By convenient sampling method, 142 workers exposed to lead in the smelting workshop of a lead zinc smelter in Inner Mongolia were chosen as test group, 88 administrative and logistic personnel without occupational lead exposure as control group. Occupational health field survey, detection and evaluation of lead smoke and lead dust in the air of workplace were conducted, and occupational health examination was carried out for the two groups of people. Results From 2015 to 2017, the TWA level of lead and lead dust decreased year by year. The detection rates of blood lead, blood routine abnormality, urine routine abnormality, liver function abnormality, electrocardiogram abnormality and blood pressure abnormality in exposed workers were higher than those in control group (P<0.05). Conclusion The level of blood lead is closely related to the level of lead in the workplace. Blood lead is a reliable indicator for lead exposure bio-monitoring and lead poisoning assessment. Reasonable and effective engineering protection measures can effectively inhibit lead hazards in workplace.

1. Introduction

Lead is an important industrial material. Metal lead, lead alloys and its compounds are widely used in batteries, cable sheath, machinery manufacturing, ray protection and other industries. In China, about 80% of lead was applied to battery production. Lead and zinc smelting enterprises are in the upstream of industrial chain, lead pollution in the field is particularly prominent. There are a number of occupational health risks in lead and zinc smelting enterprises with its rapid development, workers' health may be get damaged by occupational lead exposure. In order to understand the health effects of lead and zinc smelting process on workers, and provide theoretical support and scientific basis for the prevention and control of lead hazards in the future, we investigated the level of lead contamination and the health impact on workers in a lead zinc smelter in Inner Mongolia in 2015 - 2017.
2. Objects and Methods

2.1. Objects
Convenient sampling method was adopted. For objects selection. We selected 142 workers in smelting workshop of a lead and zinc smelter in Inner Mongolia during 2015-2017 as test group, 88 administrative and logistical personnel as control group. Average age of test group was 31.6±8.3, average seniority was 6.6±2.7 years; average age of control group was 31.4±6.2. The survey was examined and approved by the Medical Ethics Committee of Shandong Institute of Occupational Health and Occupational Disease Prevention and Control. All the subjects had informed consent.

2.2. Field Survey
The process flow of lead and zinc smelting, main engineering protection measures, overall layout, individual protection status and occupational health management, etc.

2.3. Occupational Health Testing and Evaluation
Field sampling and testing were based on “Specifications of air sampling for hazardous substances monitoring in the workplace” (GBZ159-2004) and “Methods for determination of lead and its compounds in the air of workplace” (GBZ/T 160.10-2004). Evaluation of the results was based on “Occupational exposure limits for hazardous agents in the workplace Part1: Chemical hazardous agents” (GBZ 2.1-2007).

2.4. Occupational Health Examination
We carry out occupational health examination according to the requirements of “Technical specification for occupational health surveillance” (GBZ 188-2014), inspection items included symptom inquiries, internal medicine routine, nervous system routine, blood routine, urine routine, electrocardiogram, liver function and blood lead, etc. Blood lead levels were measured by Graphite Furnace Atomic Absorption Spectrometry (GFAAS), evaluation criterion was “diagnosis of occupational chronic lead poisoning” (GBZ 37-2015).

2.5. Statistical Analysis
All analyses were performed using SPSS version 17.0 statistical package. The measurement data and numeration data were statistically analyzed with Factor analysis of variance and $\chi^2$ test respectively. Test level $\alpha$ was 0.05.

3. Survey Results

3.1. Occupational Health Survey
The lead and zinc smelter was completed in 2015, annual production of electrolytic lead was $1.0 \times 10^4$ tons, the by-products were silver ingot, zinc dust, copper matte, sulfuric acid, etc. The main flow of lead and zinc smelting was as follows: raw material $\rightarrow$ batching system $\rightarrow$ bottom blowing furnace smelting $\rightarrow$ reducing furnace smelting $\rightarrow$ melting of fuming furnace $\rightarrow$ coarse lead. The smelter carried out on-site rectify and reform to protect workers' health.

3.2. Workplace Inspection
In this study, we used time weighted average concentration (TWA) for respond objectively and accurately to the level of occupational lead exposure. Detection result showed that concentration range and the mean value of lead fume and dust were decreasing year by year, the qualified rates of samples promoted from 43.75% to 78.12% during 2015-2017 (shown in table 1), which showed the rectification measures adopted in the workplace have achieved results.
### Table 1. Statistics of time weighted average concentration of lead dust and lead fume

| Year | Lead dust (mg/m³) | Lead fume (mg/m³) |
|------|-------------------|-------------------|
|      | Number of samples | Qualified rate (%)| Mean value | Sample concentration range | Mean value | Sample concentration range |
| 2015 | 32                | 43.75             | 0.07       | 0.04-0.09                  | 0.08       | 0.03-0.12                  |
| 2016 | 33                | 63.64             | 0.05       | 0.03-0.07                  | 0.05       | 0.03-0.06                  |
| 2017 | 32                | 78.12             | 0.04       | 0.02-0.06                  | 0.02       | 0.01-0.04                  |

3.3. Occupational Health Surveillance

We compared the results of occupational health examination between test group and control group in 2015-2017. In test group, 71 cases of blood lead exceeded the standard, among which 19 cases reached the level of mild lead poisoning, the exceeding rate was 16.67%; the highest concentration of blood lead was 8.72 mol/L, which was 4.59 times of the national blood lead concentration (1.9 mol/L). In control group, 7 cases of blood lead exceeded the standard, none reached the level of lead poisoning, and the exceeding rate was 2.65%, the highest concentration of blood lead 2.37 μmol/l, which was 1.25 times of the national blood lead concentration. The examination results showed that a variety of indicators in test group were generally higher than those in control group, the differences were statistically significant (P<0.05), the examination results were shown in table 2.

### Table 2. Results of occupational health examination in test and control group (case / %)

| Groups               | Blood lead excess | Blood routine abnormalities | Urine routine abnormalities | Electrocardiogram abnormalities | Liver function abnormalities | Blood pressure abnormalities |
|----------------------|-------------------|-----------------------------|----------------------------|---------------------------------|-------------------------------|------------------------------|
| Test group (426 persons) | 71/16.67          | 75/17.61                    | 102/23.94                  | 58/13.62                        | 63/14.79                     | 46/10.80                    |
| Control group (264 persons) | 7/2.65           | 12/4.55                     | 23/8.71                    | 25/9.47                         | 15/5.68                      | 18/6.82                     |
| \( \chi^2 \) value | 74.543            | 8.866                       | 5.262                      | 4.427                           | 2.543                        | 0.374                       |
| \( P \) value       | <0.01             | <0.01                       | <0.05                      | <0.05                           | <0.05                        | <0.05                       |

We made statistics on occupational health examination results of lead-related posts. Statistical results showed that excess rate of blood lead had reduced from 26.76% to 7.75% science 2015, which showed a significant downward trend, the differences of excess rate of blood lead in each year were statistically significant (\( \chi^2 = 18.334, P < 0.01 \)). The abnormal rates of blood routine and electrocardiogram also showed a downward trend. The abnormal rates of blood pressure, liver function and urine routine were reduced too, but the decrease was not obvious.
Table 3. Statistics of abnormal results of occupational health examination for personnel in test group (case / %)

| Year | Blood lead excess (case / %) | Blood routine abnormalities (case / %) | Urine routine abnormalities (case / %) | Electrocardiogram abnormalities (case / %) | Liver function abnormalities (case / %) | Blood pressure abnormalities (case / %) |
|------|-----------------------------|--------------------------------------|--------------------------------------|------------------------------------------|----------------------------------------|--------------------------------------|
| 2015 | 38/26.7/6                   | 30/21.13                             | 38/26.76                             | 23/16.20                                 | 25/17.61                               | 18/12.68                             |
|      | (142 persons)               |                                      |                                      |                                          |                                        |                                      |
| 2016 | 22/15.4/9                   | 26/18.31                             | 30/21.13                             | 19/13.38                                 | 18/12.68                               | 13/9.15                              |
|      | (142 persons)               |                                      |                                      |                                          |                                        |                                      |
| 2017 | 11/7.75                     | 19/13.38                             | 34/23.94                             | 16/11.27                                 | 20/14.08                               | 15/10.56                             |
|      | (142 persons)               |                                      |                                      |                                          |                                        |                                      |
| Total| 71/16.6/7                   | 75/17.61                             | 102/23.94                            | 58/13.62                                 | 63/14.79                               | 46/10.80                             |
|      | (426 persons)               |                                      |                                      |                                          |                                        |                                      |

\(\chi^2\) value: 18.334, 6.652, 8.648, 27.455, 22.394, 11.362

P value: <0.01, <0.05, <0.05, <0.01, <0.01, <0.01

We made statistics on blood lead detection of lead-related posts. The results showed a trend of decreasing year by year. The concentration distribution of blood lead in lead-related posts was statistically significant (P<0.01), shown in table 4.

Table 4. Statistics of blood lead concentration distribution in occupational health examination of test group (case / %)

| Year       | Blood lead concentration distribution (case / %) |
|------------|-----------------------------------------------|
|            | <1.9\(\mu\)mol/l | 1.9->2.9\(\mu\)mol/l | ≥2.9\(\mu\)mol/l |
| 2015 (142 persons) | 104/73.24 | 26/18.31 | 12/8.45 |
| 2016 (142 persons) | 120/84.51 | 17/11.97 | 5/3.52 |
| 2017 (142 persons) | 131/92.25 | 9/6.34 | 2/1.41 |
| Total (426 persons) | 355/83.33 | 52/12.21 | 19/4.46 |

\(\chi^2\) value: 13.863, 3.294, 2.848

P value: <0.01, <0.01, <0.01

4. Discussion

The detection results revealed that the hazards of lead fume and dust in workplaces were effectively controlled, the qualified rate of TWA samples was increased from 43.75% of year 2015 to 78.12% of year 2017, which indicated the reasonable engineering protection measures could effectively inhibited the concentration (intensity) of occupational hazard factors in workplace, and favorable results can be achieved by comprehensive treatment measure such as local exhaust devices installation [1-3].

Lead dust and lead fume produced in the production process mainly entered human body through the respiratory tract. Research results showed that abnormality rates of blood routine, urine routine, blood lead in test group were obviously higher than those in control group. The abnormal rate of ECG, blood pressure and liver function was over 1 times higher than those of the control group, which was similar
to the research findings of Chen Xue-Qin [4-5]. It can be seen that long-term occupational exposure to lead will seriously damage the health of workers, lead to internal peroxidation, destroy the balance of oxidation and antioxidant system, cause the health damage to multiple organs and systems, and ultimately damage the human liver, kidney, and brain tissue [6-8].

The results of our survey also showed the blood lead level of workers decreased with the decrease of TWA concentration, both presented positive correlation, which was consistent with correlative research conclusions [9-10]. It also explained the reliability and practicability of blood lead as a bio-monitoring index for lead exposure and of evaluation index [11-12] for lead poisoning.

The monitoring data showed that the qualification rate of TWA sample was significantly increased after on-site rectification, the lead hazards in workplace had been effectively controlled. But there were still new excessive lead cases every year, which indicated the damage of lead to human body was an accumulative process, it may still cause damage to workers' health [13-14] even if the concentration of lead dust (fume) in the workplace was under control. In addition, some research results indicated that occupational lead exposure was positively correlated with seniority, that was, the incidence of occupational lead poisoning increased with the increase of seniority [15-16].

The impact of lead hazards on human health was a gradual accumulation, long-term damage process, but also related to other occupational hazards factors of the synergistic or antagonistic effects, which mean a variety of elementary research data was needed to support the study of lead hazards. But at present, there was a general lack of long-term and continuous research data, which may affect the accuracy of subsequent research results.

The key factor for reducing the harm of occupational lead exposure was to improve the operation conditions and reduce lead concentrations. Therefore, employers must carry out the main responsibility of occupational disease prevention, enhance the source control, set up detoxification ventilation facilities, strengthen occupational health management, implement monitoring and occupational health care for lead-related workers, and protect workers' occupational health effectively.

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