Advanced Techniques in Biology & Medicine

Deschamps et al., Adv Tech Biol Med 2018, 6:1
DOI: 10.4172/2379-1764.1000255

Research Article | Open Access

Exposure Risk Assessment Follow-up in an Aluminium Salvage Plant

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Abstract

Introduction: Workers who work in salvage plant industry are at risk of exposure to aluminum (Al). The objective of this study was to conduct a longitudinal quantitative health risk and bio monitoring assessment for workers exposed to Al.

Methods: Al workers were compared to controls. A standardized medical examination and neurobehavioral tests and pulmonary assessment were achieved. The longitudinal study was based on repeated measurements (Airborne and urine Al evaluations).

Results: Clinical results showed no evident adverse effects, only mild health impairings. Modification of industrial process to reduce Al exposure leaded paradoxically to increase Al peaks in airborne and urine samples.

Conclusion: Hygienic and architectural measures taken to improve exposure and to reduce Al inhalation was a failure. Appropriate preventive measures should be carefully assessed before being applied to protect effectively exposed workers.

Keywords: Health risk; Bio monitoring; Aluminum; Workers

Introduction

Aluminum toxicity was frequent in workers exposed to this metal [1]. Health effects are well known in the aluminum industry [2,3]. Exposure to this metal is associated with large range of symptom [4,5]. Aluminum salvage production consists of many complicated operations [6]. Specialized Al salvage plants produce tons of aluminum annually.

It seems important to enhance preventive measures in the working environment of Aluminum workers with a focus on peak exposures. However, process modification should be always discussed before using, to avoid worsted situation instead of reducing toxic Al exposure.

Almost all Al workers studies are cross-sectional studies [7,8]. Most of them are conducted pragmatically aiming at the detection of significant effects and the deduction of threshold limit values [9].

The longitudinal studies focused on potential trend differences concerning health impairments between exposed and non-exposed with the target to evaluate consequences of process modification.

The purpose of this longitudinal study was to identify eventual occurrence of health effects in relationship with Al exposure variations after trying to improve Al salvage plant process.

Materials and Methods

Estimation of the exposure to Al was performed during the period 2007-2012. Investment to enhance process to increase safety and reduce occupational and environmental exposure to Al was done. A big shelter was built to confine Al dust and to avoid Al environment dispersal.

The study was in accordance with the ethical standards. All study participants should give them informed consent prior to their inclusion in the study. Hazard identification was done regarding non-carcinogenic effects of Al.

Al exposed workers and non-exposed group were examined in parallel two times over a period of 5 years (2007-2012). The groups of Al workers and assembly workers were recruited in order to try to be comparable with regard to gender, age, education, physical workload and social environment.

The non-exposed group medically checked in the same way, comprised assembly workers with no known neurotoxic exposures at work (solvents, metals, etc.).

Subjects with neurological diseases or with relevant metabolic illnesses were excluded. Only workers with at least one-year exposure to Al were included. All the data during the follow up were obtained using the same procedure and devices.

Medical visits of workers during the follow up included a standardized medical interview, the occupational history, a physical examination including neurological status and pulmonary assessment concerning the main target organs about Al intoxication.

Questions included also smoking habits. We have individualized current smokers, former smokers and non-smokers. Former smokers were those who had stopped more than 2 years before the study. Other human health diseases resulting from chronic exposure to Al were also assessed.

Neurobehavioral methods comprised the recording of a number of psychological tests aiming at the probe of different functional domains and premorbid intelligence: minimental state examination (MMSE), the clock-drawing test, sub-test of Wechsler Adult Intelligence Survey (WAIS).

The neurobehavioral methods were the same during 2007 and 2012.

Exposure assessment was done from using air-sampling data. The repeated measurements included total and Al dust in air by personal air

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Received February 02, 2018; **Accepted** February 24, 2018; **Published** February 28, 2018

Citation: Deschamps F, Salles J, Laraqui O, Manar N, Laraqui CEIH (2018) Exposure Risk Assessment Follow-up in an Aluminium Salvage Plant. Adv Tech Biol Med 6: 255. doi: 10.4172/2379-1764.1000255

sampling in the breathing zone of the workers. Moreover, stationary samples refer to fixed point on selected places. Air sampling pumps and filters were used to collect Al. After samples were analyzed by a method developed by the French National Research and Institute for occupational Health (direct current plasma-optical emission spectrometry with a spectra metrics spectra spam III B).

The internal Al load of the exposed workers was recorded (pre-shift and post-shift measurements). The Al urines values were referred to the creatinine concentrations. The evaluation was done by electro-thermal atomic absorption with a Perkin Elmer 3030/Zeeman device.

For statistical tests and correlation analysis, P levels <0.05 were considered as significant.

Results

This study supports preventive measures in the work environment with a focus on peak exposures to Al.

We identified about thirty Al workers. Around half of them were present during the studied period 2007-2012. We had no information about the reasons they had changed jobs, because of their symptoms. The statistical examination did not show any significant differences between exposed groups, non-exposed groups and exposed versus non-exposed groups, concerning age, alcohol drinking, tobacco consumption (Table 1).

The same Table gives the mean years of employment in Al factory. The Al workers had worked an average of 78 months at the date of 2007 and 111 months at the time of the last examination (2012). All groups were characterized by moderate alcohol consumption. Al workers and non-exposed show the same low level of reported symptoms with a little change in the examination course.

During 2012, Al group workers reported significantly more chronic cough symptom (Table 2). They were not previously been associated with respiratory health effects. The significant differences observed during 2007 concerning irritability was not identified during 2012.

Table 3 illustrates non-changes concerning performances in all groups during the 5 years period. The mean scores of repeated measurements show a similar level in the digit pan, MMSE and Clock drawing in all groups during the follow up.

The bio monitoring data was calculated for 5 years intervals (Table 4). The pre and post shift comparison of internal Al load across examinations reveal no remarkable difference in exposed workers. However, the bio monitoring data for Al urine during the 2007-2012 periods of Al workers differs significantly including comparison to no exposed group.

Almost all samples during the studied period were below the occupational exposure limit (OEL), for Al dust (10 mg/m^3) (Table 5). Nevertheless, the average daily mean exposure to total inhalable dust was relatively consequent during 2012 compared to 2007 data concerning stationary sampling, with an improvement about personal sampling concerning the same dates.

Discussion

This study shows that exposed workers have increased their exposure to dust including Al. It is self-evident that the attempt to reduce Al exposure is a failure. The level of Al is higher or equivalent for total and aluminum dust comparing levels at the beginning to the end of the study.

Exposure to Al were not restricted to certain tasks. It could depend also probably on weather condition and airflow patterns in the workplace. The construction of a new building to reduce contamination of the environment has conducted to confine Al dust inside and to increase Al Airborne levels for exposed workers. They are mostly contaminated by dust inhalation from extraction process. The longitudinal study contains conditions to examine the health effects induced by aluminum including neurobehavioral measures.

Various exposure effects can be detected during the follow up. The differentiation between subjects (during 2007-2012) seems to be stable across examination. This approach covering a period of 5 years reveals only few mild exposure effects.

Characteristics	2007		2012	
	Exposed Group n=30	Non-exposed Group n=60	Exposed Group n=36	Non-exposed Group n=36
Average age (years)	33.9 ± 7.38	35.8 ± 8.15	39.08 ± 9.35	39.14 ± 8.77
Months of exposure	78.1 ± 51.3	-	111 ± 77.5	-
Blue collars White collars	23 (76.7%) 7 (23.3%)	46 (76.7%) 14 (23.3%)	26 (72.2%) 10 (27.8%)	26 (72.2%) 10 (27.8%)
Smoking habits: - non smokers - former smokers - current smokers Pack years	 11 (36.7%) 4 (13.3%) 15 (50%) 15.26 ± 9.25	 22 (36.7%) 6 (10%) 32 (53.3%) 15.84 ± 9.49	 12 (33.3%) 6 (16.7%) 18 (50%) 16.61 ± 10.12	 11 (30.6%) 5 (13.9%) 20 (55.6%) 17.51 ± 8.14
Weekly alcohol consumption - none - ≤ 21 glasses ->21 glasses	15 (50%) 12 (40%) 3 (10%)	19 (31.7%) 39 (65%) 2 (3.3%)	4 (11.1%) 30 (83.3%) 2 (5.6%)	6 (16.7%) 30 (83.3%) 0 (0%)
Food induced aluminium absorption - Cola drinkers daily consumption (Coca Cola) (number of subjects) - fruit daily consumption (number of subjects)	16 (53.3%) 19 (63.3%)	23 (38.3%) 37 (61.7%)	22 (61.1%) 34 (94.4%)	21 (58.3) 30 (83.3%)
Medicines induced aluminium absorption (number of subjects)	3 (10%)	1 (1.7%)	5 (13.9%)	2 (5.6%)

No statistically significant difference between exposed and non-exposed group.

Table 1: Socioeconomic status of aluminium dust and non-dust exposed workers.

	2007		2012	
Symptoms	**Exposed group n=30**	**Non-exposed group n=60**	**Exposed group n=36**	**Non-exposed group n=36**
Neurological system				
- memory	2 (6.7%)	12 (20%)	0 (0%)	2 (5.6%)
- bad mood	3 (10%)	17 (28.3%)	3 (8.3%)	1 (2.8%)
- sleep disorders	4 (13.3%)	19 (31.7%)	3 (8.3%)	2 (5.6%)
- spoil appetite	1 (3.3%)	6 (10%)	1 (2.8%)	1 (2.8%)
- irritability*	3*(10%)	25 (41.7%)	3 (8.3%)	1 (2.8%)
- equilibrium disturbances	2 (6.7%)	1 (1.7%)	1 (2.8%)	0 (0%)
- languages troubles	0 (0%)	1(1.7%)	0 (0%)	0 (0%)
- coordination disorders	1 (3.3%)	1 (1.7%)	0 (0%)	0 (0%)
- hallucinations	0 (0%)	2 (3.3%)	0 (0%)	0 (0%)
- myoclonia	1 (3.3%)	4 (6.7%)	0 (0%)	0 (0%)
- convulsions	0 (0%)	1 (1.7%)	0 (0%)	0 (0%)
Respiratory system				
- respiratory failure	0 (0%)	3 (5%)	1 (2.8%)	0 (0%)
- chronic cough	11 (36.7%)	12 (20%)	9* (25%)	1 (2.8%)
- crepitation	0 (0%)	5 (8.3%)	0 (0%)	0 (0%)
- sibilant rales	1 (3.3%)	1 (1.7%)	1 (2.8%)	0 (0%)
Cutaneous system				
- contact dermatitis	2 (6.7%)	6 (10%)	2 (5.6%)	3 (8.3%)
- urticaria	0 (0%)	2 (3.3%)	0 (0%)	1 (2.8%)
Digestive system				
- intestinal transit disturbance	0 (0%)	5 (8.3%)	3 (8.3%)	0 (0%)
- abdominal pain	6 (20%)	5 (8.3%)	4 (11.1%)	3 (8.3%)

*P<0.05 statistically significant compared to non-exposed group of the studied year 2007 or 2012.

Table 2: Clinical symptoms of Aluminium dust-exposed and non-exposed workers.

Characteristics	**Exposed groups scoring**		**Non-exposed groups scoring**		**P**
	2007	**2012**	**2007**	**2012**	
Digit span (verbal short-term memory)	9.90 ± 0.40	9.3 ± 0.88	9.75 ± 0.21	9.17 ± 0.94	NS
Mini mental state Examination (MMSE)	26.9 ± 2.25	27.78 ± 2.08	26.87 ± 3.02	27.28 ± 1.92	NS
Clock drawing Test (CDT)	6.6 ± 0.91	6.47 ± 1.11	6.27 ± 1.25	6.33 ± 0.7	NS

NS: not statistically significant

Table 3: Psychological tests results concerning exposed and non-exposed workers.

Al according to exposed and non-exposed groups	**2007 n=30 Al concentration in urine Mean (µg/l) [range]**		**2012 n=25 Al concentration in urine Mean (µg/l) [range]**	
Exposed groups Shift beginning Shift end	11.02 ± 8.23 11.59 ± 10.09	(1.20-27.70) (2.00-31.00)	20.84 ± 27.85 20.12 ± 31.61	(10-141) (<10-168)
Non-exposed groups	4.37 ± 3.67	(0.10-17.50)	13.8 ± 13.33	(<10-68)

Table 4: Biological assessment of dust concerning exposed and non-exposed workers.

Aluminium airborne	**Concentration in air sample**		**Exposure limit ratio concentration in air sample [Threshold limit value=10 mg/ml]**	
	2007 Mean (mg/ml) [range]	**2012 Mean (mg/ml) [range]**	**2007**	**2012**
Mean total inhalable dust - Personal sampling - Stationary sampling	34.96 (0.88-196.31) 1.155 (0.66-1.68)	16.8 (1.28-29.15) 27.81 (22.12-33.5)	3.49 <0.15	1.68 2.75
Mean concentration inhalable aluminium dust - Personal sampling - Stationary sampling	2.23 (0.12-10.86) 0.175 (0.08-0.27)	1.61 (0.13-3.13) 2.38 (2.02-2.74)	0.22 <0.1	0.16 0.23

Table 5: Aluminium airborne data concerning dust exposed workers.

The number of ill workers was quite low, which might indicate a healthy worker effect. In fact, longitudinal investigation of potential Al exposure effects in old age is lacking. In the late phase of live including late working live and retirement, characterized by loss of biological compensation capacity, delayed effects of Al could be overseen.

In this study lack of loss, concerning psychological test results is not a good indicator because this carrying out is too early before retirement. This study is partly a longitudinal study, where those with occupational diseases might also, like for cross sectional study have left their job. This job transfer may have led to an underestimation of exposure response.

In return, the used spot measurements of bio monitoring variable did not differ concerning type, number, time of day and distance to neurobehavioral measurements. At the beginning of the follow up, no more workers had respiratory health problems compared to non-exposed. This result could be explained by peaks exposure to Al dust. The results obtained during 2007-2012 period are in accordance with Greaves et al.

[10] who found an association of more cough and chronic bronchitis with increasing level of current exposure to metals including Al.

In this study, we observe a connection between Al levels and cough incidence. No systematic association between exposure measures and neurobehavioral parameters of different cognitive domains was found like Bast-lettersen et al. [11] and Kiesswetter et al. [9].

The repeated measurements show no strong real differences between exposed and non-exposed across examination. Only borderline significances were found. Neurobehavioral symptoms concerning Al workers is irritability. However, it could be consider as an inconsistent result. The first conclusion could be that there is an assumption of lacking evidence that Al working is neurotoxic. Nevertheless, it seems to be relatively unlikely to find neurobehavioral signs of early aging in test performance of exposed workers [9].

The bio monitoring parameters are sensitive to exposure changes. However, Al plasma was not realized, because it shows a poor relationship to Al dust and poor temporal stability. Al urine level results reveal similarities between exposed and non-exposed supporting that the patterns might depend on laboratory methods, which are sensitive to changes in the Analytical procedure [12].

This study was characterized by long and low Al exposure. The mean exposure is significantly below the German occupational threshold limit value, which were 200 μg/Al/l urines [13].

Conclusion

Longitudinal measurements showed that peak exposures to Al could occur as a result about the failure of new preventive measure to reduce Al dust exposure. The hygienic and architectural fitting out of the factory taken, did not lead to a decrease of Al exposure.

This study showed that ever aluminum level in workplace was essentially below the threshold limit value, it is not excluded that for example, after retirement, workers still had risk of developing health impairment. Preventive measures should be carefully assessed and studied before being applied to protect workers.

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