A retrospective analysis of urinary 1-hydroxypyrene in casing welders and tappers in a chrome smelter

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ABSTRACT

Background: Coal tar-derived substances consist of numerous polycyclic aromatic hydrocarbons (PAHs), several of which are known carcinogens. Different processes used during steel making influence PAH release into the work environment. Furthermore, employees' jobs and personal hygiene practices may influence personal PAH exposure.
Objective: This study sought to investigate urinary 1-hydroxypyrene corrected for creatinine (1-OHP-Cr) levels in casing welders and tappers exposed to coal tar pitch volatiles (CTPVs) in a chrome smelter, and to determine personal hygiene practices.
Methods: In this cross-sectional study, urinary 1-OHP-Cr bio-monitoring data collected from 2000 to 2010 was obtained from a chrome smelter. A structured questionnaire was used to assess the smoking habits, personal hygiene practices, use of personal protective equipment (PPE), and workplace conditions of casing welders and tappers.
Results: Bio-monitoring information was provided for five casing welders and 26 tappers. Urinary 1-OHP-Cr was significantly higher in casing welders than in tappers (6.2±3.1 and 2.2±2.3 µmol/mol creat, respectively; $p=0.00$). The 1-OHP-Cr levels in workers in the ferrochrome and technochrome plants were similar (3.9±2.9 and 2.5±2.7 µmol/mol creat, respectively). Cigarette smoking did not influence urinary 1-OHP-Cr levels ($p=0.80$). Most employees reported adherence to good hygiene practices.
Conclusion: In the smelter, urinary 1-OHP-Cr levels were influenced by job category rather than the section of the plant in which the employees worked. Personal hygiene practices may contribute to differences in urinary 1-OHP-Cr levels amongst workers.

Keywords: 1-hydroxypyrene-createnine, coal tar pitch volatiles, polycyclic aromatic hydrocarbons, benzo(a)pyrene

INTRODUCTION

Coal tars are by-products of the destructive distillation (carbonisation) of coal to produce coke and/or gas. In the steel industry, coal tar pitch is an integral component of electrodes used in metallurgical furnaces. During heating of the electrodes, coal tar pitch volatiles (CTPVs) are released into the workroom air. The composition and properties of the released CPTVs depend primarily on the temperature of carbonisation and, to a lesser extent, on the nature of the coal used as feedstock.[1] Coal tar pitch is made up of several compounds which include polycyclic aromatic hydrocarbons (PAHs), some of which are carcinogenic. They are released when coal tar pitch is heated, and the PAH content of coal tar pitch increases with increasing carbonisation temperature.[1]

PAHs contain rings with six carbon atoms. As the number of rings increases, volatility decreases at ambient workplace temperatures. Pyrene is a PAH with four rings and exists in vapour form in workroom air; it is always present in a relatively high proportion in any PAH mixture. It is not carcinogenic and is predominantly metabolised to 1-hydroxypyrene (1-OHP) which is excreted in the urine. Other PAHs, containing five or more rings, are usually in the solid (particulate) state and are more likely to be carcinogenic.[2-4] Exposure to PAHs derived from coal tar pitch is associated with increased cardiovascular disease mortality in asphalt workers, and increased cancer risk in aluminium smelter and coke oven workers.[3] Much uncertainty remains, however, in terms of the exposure-response relationships and specific role(s) of individual PAHs.[5,6] Long-term exposure to PAHs might cause bladder and colon cancer, and benzo(a)pyrene (BaP), considered the most carcinogenic PAH, has been shown to cause skin, lung, colon and bladder cancers in humans and animals.[2,3,7-10] In most instances, BaP is present at much lower concentrations than pyrene, and none of its metabolites is suitable for biological monitoring.[11,12]
Occupational and environmental exposures to PAHs occur as composite combinations. Benzene soluble materials (BSM) and BaP are used as measures of the PAH composite in air, and show the highest exposure-response relationship with occupational diseases associated with CPTV exposure.[5,6]
Possible routes of exposure for coal tar pitch include inhalation, skin absorption and ingestion. Inhalation and dermal exposure are the most common types of occupational exposure, as PAHs are easily inhaled and absorbed through the skin.[1] Cigarette smoking is also a source of PAH exposure. However, if occupational exposure is very high, the contribution of cigarette smoking to total PAH exposure is negligible.[1-3]

Short-term exposure to BaP can cause skin rash or eye irritation with redness and/or a burning sensation.[9] Exposure to sunlight and BaP together can aggravate these effects. If BaP is present on the skin when sunlight or ultraviolet light exposure occurs, the risk of skin cancer increases. Repeated exposure to substances containing BaP may cause the skin to thicken and darken, and pimples to appear.[1,9] Long-term skin changes include loss of colour and reddish areas, thinning of the skin, and warts. Bronchitis may also result from repeated exposure to mixtures containing BaP.[5,13]

Urinary 1-OHP-Cr, the primary metabolite of pyrene, is usually present in significant amounts of about 1-10% in most PAH mixtures.[1] Creatinine-adjusted excretion rate of 1-OHP is used in the bio-monitoring of exposure to CTPVs as it allows for better determination of the toxicokinetic parameters of 1-OHP urinary excretion.[6-8,11] It is used to assess occupational exposures to pyrene, and is an indirect biomarker for all PAHs and a good indicator for cancer risk.[10] Testing for 1-OHP-Cr in urine is simple and easy. The use of this biomarker is based on the linear relationships between pyrene exposure and total PAHs, and pyrene dose and 1-OHP urinary excretion.[7,9,14] Most approaches for the biological monitoring of CTPVs rely on the measurement of 1-OHP-Cr in urine. It is assumed that urinary creatinine excretion is constant across and within individuals, such that changes in the ratio will reflect changes in biomarker excretion, making 1-OHP-Cr an appropriate biomarker.[15]

In a chrome smelter, casing welders and tappers are exposed to higher concentrations of CTPVs than other workers, and hence undergo biological monitoring for CTPVs. These workers use Söderberg electrodes which are self-baking electrode systems made from a carbon-based paste, consisting of two components: a binder, consisting mostly of coal tar pitch, and a solid filler made of coke or calcined anthracite.[16] Casing welders are responsible for precision welding to ensure that electrode columns are stable while in operation. They lay out, fit and fabricate metal components of bridge parts and pressure vessels. Tappers perform quality inspections of the electrode casings and preparation of casing and belly bands prior to installation of electrode columns, and align casings with electrode columns.

The aim of this study was to compare 1-OHP-Cr levels in casing welders and tappers working in the ferrochrome and technochrome sections of a chrome smelter, and to describe personal hygiene and smoking practices of these workers.

METHODS

This was a cross-sectional study. The study population consisted of 14 casing welders and 15 tappers working at the furnaces in a chrome smelter in South Africa from 2000 to 2010.

A sample of 31 routine biological monitoring samples from tappers and casing welders tested for CPTV metabolites from 2000 to 2010 was provided by the company. Routine biological monitoring of 1-OHP-Cr is done before the start of the first shift and at the end of the fourth shift to gauge the effectiveness of control measures and the potential for dermal exposure. Personal samples involve the drawing of air samples from the breathing zone of the worker over a period representative of an eight-hour shift. This allows compliance with an 8-hour time-weighted average (TWA) occupational exposure limit (OEL). Full-shift sampling is defined as a minimum of the total time of the work shift less one hour (e.g. seven hours of an eight-hour work shift or nine hours of a 10-hour work shift). The data were anonymised to safeguard the confidentiality of the workers.1-OHP-Cr was measured using the NIOSH 5515 method.[17]

A work process questionnaire was developed to assess the work hygiene practices of casing welders and tappers. The questionnaire was in English, and the language used was appropriate for the study population. The questionnaire included questions relating to the use, cleanliness and frequency of use of PPE, e.g. overalls, welding suits, gloves, masks and canisters.

Before the questionnaires were distributed amongst the study participants, the plant management and employees were briefed on the purpose of the research. Each question on the questionnaire was discussed and explained in detail so that the prospective participants knew what was expected of them. The casing welders and tappers were assured that all data collected would remain anonymous. After informed consent was obtained, participants were asked to complete and return the questionnaires.

EpiData version 3.1 was used to develop the questionnaire and to capture the responses. For statistical analyses, STATA version 12 was used. The results are presented as means and standard deviations, and frequencies and percentages. Student's t-test was used to test for differences in 1-OHP-Cr between casing welders and tappers, and the chi-square and Fisher's exact tests were used to determine differences in personal hygiene practices and working conditions between groups.

The study was approved by the Ethics Committee of the Faculty of Health Sciences, University of Pretoria (S135/2011). Permission to conduct the study was obtained from management of the chrome smelter.

RESULTS

Thirty-one biological monitoring data records, for males only, were obtained for the study. Table 1 shows the comparison of 1-OHP-Cr levels according to plant sections, job categories and smoking status. Urinary 1-OHP-Cr levels were significantly higher in casing welders compared to tappers, and there were no differences between the ferrochrome and technochrome plant workers, or between smokers and non-smokers.

Of the 45 questionnaires distributed, 29 (14 from casing welders and 15 from tappers) were returned (64.4% response rate). Questions relating to the overalls included those with reference to contamination of the arms, back, chest and lower limbs. Table 2 shows the percentage contamination of PPE amongst casing welders and tappers. Most of the overalls, suits, gloves and masks of the casing welders and tappers were contaminated, and there were no statistical differences in the contaminations.

The frequency of washing overalls was similar for casing welders and tappers, with most (approximately 60%) reporting that they washed their overalls daily (Table 3). There was a significant difference in the frequency of washing suits with most casing welders (57.1%) reporting that they washed their suits weekly, and most tappers (66.7%) reporting daily washing. A few workers reported that they never washed their overalls (24.1%) or suits (13.8%).

All casing welders and tappers reported that they always washed their hands before eating. Most welders and tappers (71.5% and 66.7%, respectively) always washed their hands before using the toilet (Table 4); about 20% never washed their hands before using the toilet. Of the five casing welders and six tappers who smoked, 60.0 and 66.7%, respectively, always washed their hands before smoking.

There was a significant difference in the reporting of exposures to fumes moving in the direction of workers (Table 4). More casing welders than tappers reported that fumes moved in their direction, sometimes or always.

Table 1. Comparison of mean 1-OHP-Cr levels according to plant section, job category and smoking status (N=31)

		1-OHP-Cr (µmol/mol creat)		
Variable	**n**	**Mean**	**SD**	**p-value**
Plant section				
Ferrochrome	8	3.9	2.9	0.20
Technochrome	23	2.5	2.7	
Job category				
Casing welder	5	6.2	3.1	0.00
Tapper	26	2.2	2.3	
Smoking status				
Non-smoker	17	2.9	3.0	0.80
Smoker	11	3.2	2.8	

DISCUSSION

The current regulatory limit, the Occupational Exposure Limit (OEL), to CTPVs is 0.14 mg/m^3 as stipulated in the Regulations for Hazardous Chemical Substances from the Occupational Health and Safety Act and Regulations, Act 85 of 1993.[18] There is no set limit for 1-OHP-Cr for biological monitoring although, in the United Kingdom, the Health and Safety Laboratory (HSL) has set a Health Guidance Value (HGV) of 4.0 µmol/mol creat.[19] HGVs are set at levels at which there is no scientific evidence for injury to health.[19,20] Values that frequently exceed the HGV indicate that the exposure is not adequately controlled and might result in adverse health effects.[19,20] In our study, there was no statistical difference in urinary excretion of 1-OHP-Cr between workers in the ferrochrome and technochrome plants, indicating that exposures to CTPVs were similar in the two plants; and smoking did not contribute significantly to urinary 1-OHP-Cr.

The 1-OHP-Cr levels were below 4.0 µmol/mol creat for all groups except casing welders who had a mean level of 6.2 µmol/mol creat. This finding is in agreement with Barbeau D *et al*. who also reported higher BaP levels in a group of workers responsible for furnace maintenance.[21,22] Possible reasons for the significantly higher urinary 1-OHP-Cr differences measured for casing welders may be due to contamination of PPE, wash frequency of overalls and welding suits, and working conditions.[23] The impact of behavioural and personal hygiene practices to lower exposure must therefore not be underestimated.[24]

We did not observe significant differences in self-reported contamination of PPE, and wash frequency of overalls and welding suits between casing welders and tappers. Hence, differences in hygiene practices do not appear to explain the higher urinary 1-OHP-Cr levels in casing welders. However, working conditions may have contributed towards the increased levels as three times more casing welders than tappers reported that fumes always moved in their direction while working.

Future studies need to be conducted to observe work practices, behaviour and personal hygiene practices to identify best practices for lowering personal exposures. The Australian Institute of Occupational Hygienists (AIOH) has a position paper that provides guidelines for controlling exposure to

PAHs. It is recommended that, in areas where CPTVs are generated, there should be efficient ventilation or source containment. If that cannot be achieved, employee enclosures should be considered where ventilation systems are installed.[25]

Limitations

We were unable to differentiate between environmental and occupational PAH exposures. Therefore, in our interpretation of the findings, we assumed that levels of 1-OHP-Cr concentrations were associated with occupational exposures. The data used is from a 10-year period and there may have been variations in the exposures over time. Due to the small study population, we were unable to determine changes in 1-OHP-Cr over time and assumed that the levels reported were representative of the study period. In addition, our study focused on casing welders and tappers, and excluded other employees who might have had chronic low exposures to CPTVs. We therefore recommend that the study be repeated with a larger sample, covering more job categories.

The 31 CPTV biological monitoring samples that were provided by the company might not have been representative of the samples taken from tappers and casing welders in the study period. It would have been preferable to have randomly selected the samples, or to have analysed all the data available from the company.

The questionnaire response rate was relatively low at 64.4%, which might have influenced the results. The results might not be representative of the population exposed to CTPVs. There may have been biases associated with self-administered questionnaires, including response and recall bias. Response bias is an individual's tendency to respond in a certain way, regardless of the actual evidence they are assessing. Respondents might have chosen to answer questions in a manner that put them in a better position, especially with regard to personal

Table 2. Summary of the condition of PPE of casing welders and tappers (N = 29)

PPE	Region	Casing welders Clean		Contaminated		Tappers Clean		Contaminated		p-value
		n	%	n	%	n	%	n	%	
Overalls	Arms	2	14.3	12	85.7	2	13.3	13	86.7	0.94
	Back	2	14.3	12	85.7	2	13.3	13	86.7	0.94
	Chest	3	21.4	11	78.6	3	20.0	12	80.0	0.92
	Lower limbs	3	21.4	11	78.6	4	26.7	11	73.3	0.74
Welding or tapping suits	Arms	4	28.6	10	71.4	4	26.7	11	73.3	0.91
	Back	4	28.6	10	71.4	5	33.3	10	66.7	0.78
	Chest	4	28.6	10	71.4	4	26.7	11	73.3	0.91
	Lower limbs	3	21.4	11	78.6	3	20.0	12	80.0	0.92
Gloves	Left digits	3	21.4	11	78.6	2	13.3	13	86.7	0.56
	Left palm	1	7.1	13	92.9	4	26.7	11	73.3	0.16
	Left dorsal	2	14.3	12	85.7	3	20.0	12	80.0	0.68
	Right digits	3	21.4	11	78.6	3	20.0	12	80.0	0.92
	Right palm	1	7.1	13	92.9	3	20.0	12	80.0	0.35
	Right dorsal	3	21.4	11	78.6	3	20.0	12	80.0	0.92
Mask	Front	2	14.3	12	85.7	2	13.3	13	86.7	0.94
	Back	11	78.6	3	21.4	12	80.0	3	20.0	0.92

Table 3. Frequency of washing of PPE amongst casing welders and tappers (N = 29)

PPE	Casing welders Never		Daily		Weekly		Tappers Never		Daily		Weekly		p-value
	n	%	n	%	n	%	n	%	n	%	n	%	
Overalls	3	21.4	9	64.3	2	14.3	4	26.7	9	60.0	2	13.3	0.94
Welding / Tapping suits	2	14.3	4	28.6	8	57.1	2	13.3	10	66.7	3	20.0	0.09

Table 4. Personal hygiene practices and exposure to fumes for casing welders and tappers (N = 29)

		Casing welders Never		Sometimes		Always		Tappers Never		Sometimes		Always		p-value
		n	%	n	%	n	%	n	%	n	%	n	%	
Wash hands	Before eating	0	-	0	-	14	100.0	0	-	0	-	15	100.0	0.99
	Before smoking	0	-	2	40.0	3	60.0	0	-	2	33.3	4	66.7	0.99
	Before using toilet	3	21.4	1	7.1	10	71.5	3	20.0	2	13.3	10	66.7	0.86
Direction of fumes	Towards workers	1	7.1	7	50.0	6	42.9	8	53.3	7	46.7	0	-	0.00
	Away from workers	1	7.1	12	85.8	1	7.1	6	40.0	7	46.7	2	13.3	0.07

hygiene. Recall bias might apply, considering that some questions were based on past events, such as those relating to the directions of fumes. Each working day is different and it might be challenging to recall a general trend of working conditions.

Recommendations

In order to reduce PAH exposures, especially among casing welders, showering facilities should be made available at the workplace to enable employees to wash before leaving the plant. This will also reduce photo-sensitisation and potential skin inflammation from UV exposure. We also recommend that work suits and PPE should not be washed at the work place, to prevent contamination of domestic laundry. Work suits, overalls and gloves should be washed frequently, e.g. once a week, and should be replaced when they show signs of wear. Disposable face masks should be discarded after each shift, as one working shift is sufficient to contaminate a face mask.[25]

Regular education and training to increase employees' awareness of the different routes of exposure and the associated health risks may help employees to approach their work with a better understanding of the risks involved. Work hazards should be thoroughly explained to employees and any myths/misconceptions nullified. Both the employer and employees need to take responsibility to mitigate excessive exposure to CPTVs and to adhere to the current regulations and guidelines.

CONCLUSION

The findings from this research indicate that the levels of urinary 1-OHP-Cr for employees are significantly influenced by the job category, but that plant section and smoking of cigarettes do not play a role. The importance of implementing proper engineering and administrative controls before reverting to PPE is highlighted.

DECLARATION

The authors, individually and collectively, and the steel manufacturing company, have no conflicts of interest or financial disclosures.

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LESSONS LEARNED

1. Use of PPE by casing welders should be adhered to and monitored in order to keep 1-OHP-Cr in line with the United Kingdom Health and Safety Laboratory Health Guidance Values
2. Regular biological monitoring for CTPVs should continue in the chrome smelter

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