E3S Web of Conferences 1, 21001 (2013)
DOI: 10.1051/e3sconf/20130121001

Urinary Heavy Metal levels of Residents in the Vicinity of a Petrochemical Complex in Taiwan

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Abstract. A petrochemical complex located in central Taiwan is a major emission source of air pollutants locally. Among these air pollutants, it is concern that the health effects of exposure to heavy metal because of its toxicity and persistency. Therefore, we conducted a biological monitoring study to investigate the effect of heavy metal pollutants on inhabitants around this petrochemical complex. According to the distance and the wind direction from the petrochemical complex, the study area was divided into high exposure (HE) and low exposure (LE) areas, and a total of 673 study subjects who aged above 35 years old living in HE and LE areas were recruited to be collected urine sample and personal information by health screen and questionnaire administration. The concentrations of ten kinds of urinary heavy metals were analyzed by inductively coupled plasma mass spectrometry. After adjusting for age, gender, socioeconomic status, smoking, dietary habits and other potential confounders, the multiple linear regression models showed that the urinary levels of vanadium, manganese, arsenic and strontium of inhabitants in HE area were significantly higher than those of inhabitants in LE area. This study indicated the potential effects of emitted metal pollutants from a petrochemical complex on the residents nearby.

Key words: petrochemical complex, heavy metal, adult, urine

Introduction

Because of the application of a large number of chemicals and the complex manufacturing process, the impact of petrochemical industry on environmental pollution and related health effects was concerned. Previous studies showed that the correlations between petrochemical pollution exposure and increased asthma and respiratory symptoms in children and the mortalities of some cancers (Wichmann et al., 2009; Yang et al., 1997; Yang et al., 1998; Yang et al., 2000). Among these petrochemical-related air pollutants, the emissive heavy metal was one kind of important chemicals because of its toxicity in humans and persistency in environment.

Moreover, environmental monitoring found that chromium or vanadium level in air, soil or vegetable in petrochemical industrial area were higher than those in other areas (Lopez et al., 2005; Nadal et al., 2004). In addition, some metal levels in air and soil in the vicinity of coal-fired power plants were higher than those in reference areas (Agrawal et al., 2010; Jayasekher, 2009). In central Taiwan, a petrochemical complex that includes oil refineries, naphtha cracking and coal-fired power plants was considered as a locally major emission source of metal pollutants. However, few studies investigated the effects of heavy metal pollutions on the inhabitants living in the vicinity of this kind of industrial area. Therefore, this study conducted a biological monitoring study to investigate the effect of heavy metal pollutants on inhabitants around this petrochemical complex.

Materials and Methods

According to the distance and the wind direction from the petrochemical complex located in Yunlin County in Taiwan, the study area was divided into high exposure area (HE) (Mailiao, the location of this petrochemical complex, and Taisi, the downwind township of this petrochemical complex) and low exposure area (LE) (Huwei, the similar distributions of age and gender to HE areas), as shown in Figure 1. Then, all study subjects were asked to participate in health examination, questionnaire survey, and urine sample collection to be recruited in this study. After excluding the subjects who aged below 35 years old and did not live in these areas more than five years, this study totally recruited 673 study subjects, including 473 from HE and 200 from LE.

For all study subjects, 15-ml urine samples were collected into BD Vacutainer® tubes, and then stored at -80°C in a refrigerator for further analysis. Based on the possible emission heavy metals from this petrochemical complex and the toxcities and importances of these heavy metals, ten metals, including vanadium (V), chromium (Cr), manganese (Mn), nickel (Ni), copper (Cu), arsenic (As), strontium (Sr), cadmium (Cd), thallium (Tl), and lead (Pb), were detected in these urine samples. To analyze these ten metals, 1.0 mL urine samples were first diluted by 2.0 mL 2% nitric acid and filtered with a 0.45-μm filter and then analyzed by inductively coupled plasma mass spectrometry (ICP-MS) with an Agilent 7500c system (Agilent, Santa Clara, United States). To ensure the precision of the analysis, spikes were examined to make sure the measurement stability. And, Standard reference materials (SRM) for urinary metals were analyzed to assess accuracy. If the metal levels in certain urine samples were below the method detection limit (MDL), half of the MDL for the specific metal was allocated to these samples. In addition, all urine samples were conducted the creatinine analysis.

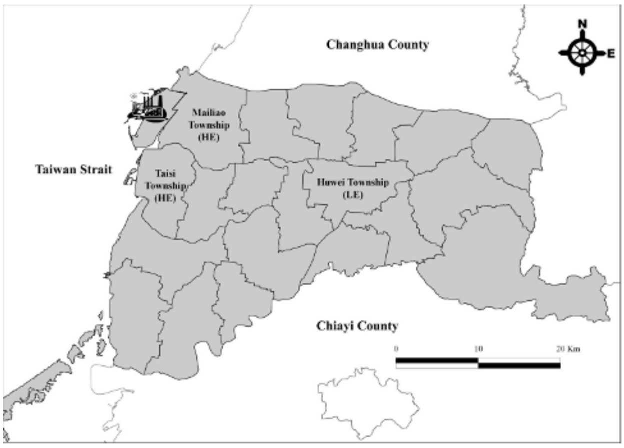

Figure 1. The location of the study petrochemical complex and the study areas in Yunlin County in Taiwan.

Results and Discussion

Table 1 showed the demographic information on study subjects in HE and LE areas. There was no difference on gender and age distributions between the study subjects in two areas, but the study subjects in LE with significantly lower educational level. For personal behavior, the frequency of betel quid chewing was significantly higher in study subjects in HE. For dietary, there was no difference on the fish consumption for last three days before conducting health examination between the study subjects in two areas, but the source of drinking water were significantly difference between study subjects in two areas. As to environmental exposure, the frequency of burning incense at home for study subjects in HE was significantly higher than those in LE, but the percentage of study subjects living close to main road was no significant difference between HE and LE.

Table 1. Characteristics of the study population in HE and LE areas (N=673).

Variables \ Area	HE (N=473)	LE (N=200)	*p* -value
Gender, N(%) [¥]			
Male	171 (36.15)	75 (37.50)	0.807
Female	302 (63.85)	125 (62.50)	
Age, N(%)			
Years [*], Mean ± SD	58.20 ± 13.00	59.16 ± 12.82	0.3778
≦ 65years old [¥]	305 (64.48)	127 (63.50)	0.8769
＞ 65years old	168 (35.52)	73 (36.50)	
Educational level, N(%) [¥]			
Below elementary school	300 (63.42)	76 (38.00)	<.0001
Above junior high school	158 (33.40)	87 (43.50)	
Above university	15 (3.17)	37 (18.50)	
Smoking, N(%) [¥]			
No	414 (87.53)	182 (91.00)	0.2455
Yes	59 (12.47)	18 (9.00)	
Alcohol drinking, N(%) [¥]			
No	412 (87.10)	180 (90.00)	0.3546
Yes	61 (12.90)	20 (10.00)	
Betel quid chewing, N(%) [¥]			
No	436 (92.18)	196 (98.00)	0.0067
Yes	37 (7.82)	4 (2.00)	
Ate fish within 3 days, N(%) [¥]			
No	373 (78.86)	157 (78.50)	0.9994
Yes	100 (21.14)	43 (21.50)	
Type of drinking water, N(%) [¥]			
Tap water	424 (89.64)	158 (79.00)	0.0004
other	49 (10.36)	42 (21.00)	
Burning incense, N(%) [¥]			
No	30 (6.34)	37 (18.50)	0.0011
Seldom	255 (53.91)	94 (47.00)	
Every day	188 (39.75)	69 (34.50)	
House near the road, N(%) [¥]			
No	187 (39.53)	83 (41.50)	0.6971
Yes	286 (60.47)	117 (58.50)	

*p-value for comparing means by Student's t-test

[¥]p-value for comparing means by Chi-square test

After adjusting potential confounders, some significant correlations between urinary metal levels and influential factors were observed, as shown in Table 2. For study areas, the urinary levels of V, Mn, As and Sr of inhabitants in HE were significantly higher than those in LE, but the reverse outcomes were shown in the urinary levels of Cu and Cd. As to demographic variables, all urinary metal levels, except for As, were higher in female when compared to male, and urinary levels of Cr, Mn, Ni, Cu, As, Cd and Pb were positively correlated with age. For personal behavior, smokers were with significantly higher urinary levels of Ni and Cd, and alcohol drinkers were with significantly higher urinary levels of V, As, Cd and Pb. In addition, the urinary Mn and Sr levels were negatively correlated with recent fish consumption.

Previous studies indicated that the main source of environmental V was from the burning of residual oil and coal and V was a good tracer for petrochemical industry (Hope, 1997), but few studies conducted biological monitoring on V exposure. The mainly metabolic pathway of V exposure is by urine excretion (ATSDR, 2011), and the present study found the higher V level in urine of residents in the vicinity of a petrochemical complex after adjusting potential confounders. Therefore, the urinary V level is regarded as an appropriate biomarker for petrochemical pollution exposure.

Strontium is one kind of air pollutants from Coal-fired power plants and human might be exposure to Sr through dietary or drinking water (ATSDR, 2011; Ondov et al., 1989). In the present study, the petrochemical complex installed three units of coal-fired power plants, and the urinary level of Sr was higher in the residents in HE when compared to those in LE after controlling the source of drinking water. For that reason, the urinary level of Sr might be a good indicator for the pollution of coal-fired power plants.

The effects of petrochemical complex on the urinary levels of Mn and As of residents nearby in this study were consistent with the results from Spain and Taiwan (Aguilera et al., 2008; Lin, 2009). After considering the effects of traffic, seafood consumption and source of drinking water, the findings of the present study provided further evidence to reveal the Mn and As pollution on the vicinities of this petrochemical complex.

Table 2. Multiple regression models of urinary metals of study subjects. (N=673)

Metal [a]	**V**		**Mn**		**Sr**		**As**		**Pb**	
Model †	**Adj-R^2**		**Adj-R^2**		**Adj-R^2**		**Adj-R^2**		**Adj-R^2**	
	0.07		0.10		0.06		0.04		0.04	
	β	*p*	Β	*p*	β	*p*	β	*p*	β	*p*
Intercept	-2.24	<.0001	-1.26	<.0001	4.75	<.0001	3.23	<.0001	-1.65	<.0001
Area (ref: LE)	0.64	<.0001	0.34	<.0001	0.15	0.0116	0.22	0.0032	0.02	0.7806
Gender (ref: male)	0.31	0.0072	0.31	<.0001	0.18	0.0019	0.19	0.1010	0.38	<.0001
Age (year)	0.00	0.8720	0.01	<.0001	-0.01	0.0418	0.01	0.0291	0.01	0.0001
Smoking (ref: no)	-0.40	0.0210	0.00	0.9636	0.04	0.6642	0.13	0.2572	0.23	0.0753
Alcohol intake (ref: no)	0.33	0.0448	0.04	0.6598	0.09	0.2761	0.30	0.0065	0.40	0.0013
Fish (ref: no)	-0.03	0.7754	-0.16	0.0196	-0.12	0.0496	0.05	0.5338	0.04	0.6125
Drinking water (ref: tap water)	-0.03	0.8423	-0.06	0.4728	-0.15	0.0376	0.02	0.8007	-0.15	0.1592

[a] Urinary metal levels were Log-transformed; Unit: μg/g-creatinine,

† Model adjusted by education levels, nut intake and living close to the road.

Table 2. (continued).

Metal [a]	**Cu**		**Cd**		**Ni**		**Cr**		**Tl**	
Model †	**Adj-R^2**		**Adj-R^2**		**Adj-R^2**		**Adj-R^2**		**Adj-R^2**	
	0.13		0.17		0.10		0.06		0.13	
	β	*p*	Β	*p*	β	*p*	β	*p*	β	*p*
Intercept	1.77	<.0001	-1.75	<.0001	-0.68	0.0175	-0.94	0.0108	-1.32	<.0001
Area (ref: LE)	-0.17	0.0001	-0.15	0.0095	0.06	0.4190	-0.11	0.2390	0.08	0.1633
Gender (ref: male)	0.12	0.0066	0.66	<.0001	0.45	<.0001	0.21	0.0272	0.29	<.0001
Age (year)	0.01	<.0001	0.01	0.0028	0.02	<.0001	0.02	<.0001	-0.01	<.0001
Smoking (ref: no)	0.10	0.1451	0.37	<.0001	0.25	0.0237	-0.15	0.2998	-0.09	0.3098
Alcohol intake (ref: no)	-0.08	0.2259	0.18	0.0390	0.00	0.9884	0.10	0.4597	-0.03	0.7070
Fish (ref: no)	0.00	0.9653	0.03	0.6565	0.01	0.8898	0.19	0.0523	-0.04	0.5443
Drinking water (ref: tap water)	0.06	0.2689	0.01	0.8709	0.04	0.6364	-0.06	0.6059	0.04	0.5390

[a] Urinary metal levels were Log-transformed; Unit: μg/g-creatinine,

† Model adjusted by education levels, nut intake and living close to the road.

Conclusion

This biological monitoring study showed the potential effects of emitted metal pollutants from a petrochemical complex, including V, Mn, As, and Sr, on the residents nearby. Furthermore, this study suggested the urinary levels of V and Sr were alternatively appropriate biomarkers for the exposure assessment on this kind of petrochemical complex.

Acknowledgements

The authors thank the financial supports providing from Environmental Protection Bureau, Yunlin County, Taiwan (Project: YLEPB-98-016 & YLEPB-99-022).

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