Risk Assessment of Lead (Pb) in Paints

Chen Chang, Zhao Qichao, Lv Xiaofei, He Shujuan

China National Center for Quality Supervision and Test of Environmental Protection Products, Shijiazhuang, China

Keywords: paints; lead; health risk assessment; target hazard quotients

Abstract: Objective To understand the level of lead (Pb) in paints by sampling from Hebei province of China, it evaluated the potential risk to children health. **Methods** 11 brands of paints including three hundred and thirty representative and typical samples were collected in Hebei province for detecting of migration of certain elements according to GB 21027-2007 and GB 6675.4-2014(neq ISO 8124-3:2010). Based on chemical environment health risk assessment referred to the U.S. environmental protection agency (EPA), the potential health risk was evaluated on the basis of target hazard quotients (THQ). **Results** The THQ values of lead were less than 1, it had small risk for children in normal using condition, however, the content of Pb was 5100mg/kg and 480mg/kg which was far exceed the maximum limit (90mg/kg) in 2 brands of samples, if it entered mouth directly, it had ten times higher health risk for potential exposure, and the THQ was greater than 1.

1. Introduction

Paints is a necessary tool for children drawing, and has advantages of bright color and good tinting strength. However, heavy metals was the raw material for the colored paints, and it will pose body harm by a little bit doses. For example, lead exposure is posed body harm (such as nerve, hematopoietic, digestive, cardiovascular and endocrine system) and has more harmful to children[1~3]. Heavy metal poisoning may occur as a result of improperly coated food containers, or the ingestion of lead-based paints. Hence, the study is sampled and detected the content of migrated lead in 3 colors (red, yellow, orange) samples of 11 brands of paints, and carried out health risk assessment on the basis of target hazard quotients (THQ) to evaluate the potential health risk of lead exposure, in order to provide scientific basis for paints safety in daily use.

2. Materials and method

2.1 Materials

a. Samples: 11 brands of paints (such as oil paint, gouache, etc.) including 330 representative and typical samples which collected in Hebei province.

b. Inspection item: Lead.

2.2 Method

2.2.1 Detection method

According to GB 21027-2007 <Request in common use of security for student’s articles>[4] and GB 6675.4-2014(neq ISO 8124-3:2010) <Safety of toys-Part 4: Migration of certain elements>[5], the study is detected content of lead by NexION^{TM} 350XInductively Coupled Plasma Mass spectrometry (ICP-Ms).

a. Condition:3 detection by KED mode with 4mL/min helium flow;

b. Tool: Nickel skimmer for NexION;

c. Procedure: take certain mass sample and remove oil in the 25 times mass of n-heptane (temp 37 Celsius degrees), and add and shake in the 25 times mass of 1.4 mol/L hydrochloric acid (HCl) to pH 1.0-1.5. The solution is vibrated 1 hour in dark place, and filtered after standing 1 hour in

  DOI: 10.25236/etmhs.2019.200

37±2 Celsius degrees, and then detected by ICP-Ms.

2.2.2 Assessment method

The study of evaluation method was based on target hazard quotients (THQ), which was a method to evaluate health risk for a kind of contaminant, if the THQ was greater than 1, the result was stated that the contaminant had potential health risk to human body.

2.2.3 Survey method

The study of survey method was based on inventory survey procedure, that was selected 3 blocks randomly, and then selected 50 family in the block, respectively. The frequency and amount of paint usage in each family were investigated.

3. Results

The study was detected 11 brands of 330 samples, and chose red, yellow and orange 3 colors of paints to detect the content of migrated lead, respectively. In the 330 samples, the lead detection rate of 3 color samples was greater than 55%, the result was shown in Table.1.

Table.1 The content of Pb in three color paints

Samples	Method detection limit (mg/kg)	Detection value (mg/kg)	Detection rate (%)
Red	0.0003	0.026-1.2	55.2 (182/330)
Yellow		0.0054-5100	58.5 (193/330)
Orange		0.016-1.0	65.2 (215/330)

In the red paints, 182 samples was detected lead, the content was 0.026-1.2 mg/kg. In the yellow paints, 193 samples was detected lead, and the content was 0.0054-5100 mg/kg. The average detection value of 2 kind gouache samples was far surpass the maximum limit (90 mg/kg), the average content of Pb was 5100 mg/kg and 480 mg/kg (56.7 and 5.3 times of maximum limit), respectively. In the orange paints, 215 samples was detected lead, and the content was 0.016-1.0 mg/kg. The lead content result of 11 brands of paints was shown in Table.2.

Table.2 Average Pb content in three color of 11 brands paints

Samples	Average Lead content (mg/kg)										
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
Red	0.45	ND	ND	1.2	1.2	0.61	ND	0.14	ND	ND	0.026
Yellow	0.59	ND	ND	5100	480	0.69	ND	0.0054	ND	ND	0.047
Orange	0.47	ND	ND	0.33	0.90	1.0	ND	0.016	ND	0.11	0.059
Remarks	ND-Not Detected; Maximum limit of migrated Pb is 90 mg/kg;										

4. Risk Assessment

In the 1980s, the U.S. environmental protection agency (EPA) proposed four steps for risk assessment of chemical environmental health, that is, hazard identification, dose-response relationship, exposure assessment and risk characterization. Among them, exposure assessment was the one of key factors for environmental health risk assessment. Exposure assessment was included that human body exposed to the concentration of pollutants in the environmental media and their behavior and characteristics, namely the exposure parameters. When concentration of pollutants was detected more accurately, the exposure parameter value was more close to the actual exposure status of the target population, and the evaluation result of exposure dose was more accurate. Above all, it brought about more accurate results of environmental health risk assessment.

4.1 Exposure Routes

Migration lead in paints was entered the human body mainly through ingestion and skin absorption, but the lead was almost impermeable by skin absorption. The one of main exposure routes was intake of food which was contacted with unwashed hand after using paints. The main risk for human body was ingestion exposure by food with paints residuals, so this study was only carried out the risk assessment by hands and ingestion exposure.

4.2 Formula derivation

Target hazard quotients (THQ) was a kind of risk assessment method for ingesting hazardous substances proposed by U.S. environmental protection agency. The formula was shown as Eq.1.

$$THQ = \frac{ADD}{RfD} \quad (1)$$

Where:

ADD is average daily exposure dose of hazardous substances, mg/(kg·d) ;

RfD is reference dose in one exposure route of hazardous substances, mg/(kg·d).

The THQ value was less than 1, it was indicated that the health risk in this way of exposure was accepTable.The average daily exposure dose was calculated by Eq.2.

$$ADD = \frac{C \times IR \times EF \times ED}{BW \times AT} \quad (2)$$

Where:

C is concentration of hazardous substances, mg/m^3;

IR is ingestion rate per unit time, m^3/d;

EF is exposure frequency, d/a;

ED is exposure duration, a;

BW is body weight, kg;

AT is average exposure time (Non-cancerogen is 30*365=10905), d.

From the point of view of the sample quality risk assessment, there was more valuable for daily limit intake of sample hazardous substances. Therefore, it was inappropriate to use existing exposure assessment model for risk assessment. It was considering whether meet the actual situation of paints user, such as students, the applicable condition and parameter did the key action for the improvement of the exposure assessment model. Daily limit intake of sample hazardous substances was instead of lifetime average exposure time AT (d), exposure frequency EF (d/a) and exposure duration ED (d/a). Hence, $\frac{EF \times ED}{AT}$ in Eq.2 was developed to average daily exposure time t(min/d), moreover, there was a situation of intake of food with paint residual by unwashed hands instead of a small probability event of paint ingestion directly by user. IR in Eq.2 was developed to probable ingestion dose M (kg/d). That is, the Eq.2 was converted to Eq.3 to calculation.

$$ADD = \frac{C \times M \times \frac{t}{1440}}{BW} \quad (3)$$

Where:

C is concentration of hazardous substances, mg/m^3;

M is probable ingestion dose, kg/d;

t is average daily exposure time, min/d;

1440 is minutes per day, min/d

BW is body weight, kg;

The study was carried out potential health risk assessment on the basis of exposure assessment mode, selecting the exposure parameter from the data in <Exposure Factor Handbook of Chinese Population (Children)>[6]. The handbook was announced recommended value of Chinese children body weight as Table.3.

Table.3 Recommended value of Chinese children body weight

Age(year)	Average body weight (kg)
6~<9	26.5
9~<12	36.8
12~<15	47.3
15~<18	54.8

4.3 Risk assessment

a. Concentration of lead in paints (C)

According to the experiment results, the study was selected sample #4 and #5 which exceed the maximum limit value to carry out health risk assessment, the concentration of lead was listed in Table.4.

Table.4 The result of concentration of lead in 2 brands of samples

Samples	Average Lead content (mg/kg)		
	Red	Yellow	Orange
#4	1.2	5100	0.33
#5	1.2	480	0.90

b. Probable ingestion dose (M)

The survey was obtained 128 family valid data to calculate frequency and amount of paint usage. It takes about 1 month to run out of 1 box paints in common. The specification of paint was 24*12mL, and calculated by 10% amount of residual paint would be ingested, the probable ingestion dose M=12*24/30*10% g/d= 0.96 g/d=0.00096 kg/d.

c. Average daily exposure time (t)

According to <Exposure Factor Handbook of Chinese Population (Children)>, the paint user was 6~18 years old children, and the average daily exposure time was as Table.5.

Table.5 Each age of Average daily exposure time

Age(year)	Average daily exposure time (min/d)
6~<9	6
9~<12	5
12~<15	6
15~<18	6

Moreover, the reference dose of lead (RfD) was 0.004 mg/(kg·d) which was consult in the data of integrated risk information system in U.S. EPA[7].

d. THQ value

In conclusion, the study was carried out health risk assessment of 2 brands of paints which the lead content was exceed maximum limit. The data was calculated by Eq.3 and the result was shown as Table.6.

Table.6 Each age of THQ values of 3 color paints

Samples THQ	Age of children	Sample #4	Sample #5
Red	6~<9	4.5×10^{-5}	4.5×10^{-5}
	9~<12	2.7×10^{-6}	2.7×10^{-6}
	12~<15	2.4×10^{-6}	2.4×10^{-6}
	15~<18	7.0×10^{-5}	7.0×10^{-5}
Yellow	6~<9	0.19	0.018
	9~<12	0.11	0.011
	12~<15	0.11	0.010
	15~<18	0.093	0.0087
Orange	6~<9	1.2×10^{-6}	2.4×10^{-6}
	9~<12	6.0×10^{-6}	1.5×10^{-6}
	12~<15	6.0×10^{-6}	1.2×10^{-6}
	15~<18	6.0×10^{-6}	1.2×10^{-5}

From Table.6, the THQ values of lead based on experiment results were less than 1, it had small risk for children and it was accepTable in normal using condition, even though the lead content was far exceed maximum limit. However, the study was calculated by 10% amount of residual paint, if it entered mouth directly, it had ten times higher health risk for potential exposure, and the THQ would be greater than 1. It had great health risk when children were accidental ingestion of paints.

4.4 Uncertainty of risk assessment

In this assessment, it had little brands of paints to divide into different categories based on its physical property or chemical composition. But also, there was only 3 color paints for detection, and it was not carried out all of samples health risk assessment. Meanwhile, the survey of exposure parameters was concentrate on one city, the generality was still to improve.

5. Conclusion

The heavy metal poisoning in people, especially children, was mainly caused by intake of food with heavy metal residuals in daily using.

1) The blood lead content of children had been reached the toxic level in some cities in China. From the data of the study, paint was a source of lead in everyday life. The students might be directly exposed to paints, which was a hidden danger for ingestion of heavy metals. Therefore, manufacturers should strictly control the content of heavy metals in raw materials.

2) Consumers should purchase from formal channels to ensure product quality, and it was provided safe and hygienic painting tools for children. People should remind the children to wash their hand in time after using paints and avoid ingesting directly.

3) The THQ of lead content in different paints was less than 1, it was indicated that the lead in common exposure did not have potential health risk to human body. But in long run, heavy metals could be highly enriched in organisms, and the harm to human body cannot be ignored.

References

[1] SHEN XM, GUO D, WU SM. China Current Situation of Lead Poisoning [J]. Journal of Clinical Pediatrics 1996(3):200-202

[2] China International Association of Litterateur and Artists. Beware of Heavy Metals in Paints [J]. Journal of Metal World.2002 (1):15

[3] CHINA CONSUMERS' ASSOCIATION. Children Painting Sticks to Heavy Metal Poisoning Guard Against -Comparison of Test Results of 19 Brands of Painting Sticks [J]. ReliabilityReports.2002 (8):32-34

[4] China Standardization Administration. GB 21027-2007<Request in common use of security for student’s articles>[S]. Standards Press of China.2007

[5] China Standardization Administration. GB 6675.4-2014(neq ISO 8124-3:2010) <Safety of toys-Part 4: Migration of certain elements>[S].Standards Press of China.2014

[6] China Ministry of Environmental Protection. <Exposure Factor Handbook of Chinese Population (Children)> [M]. China Environment Publishing Group.2016