

Current status of exposure to total suspended particles (TSP), total chromium, and chromium (VI) in cement plant in South of Vietnam

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ABSTRACT

Total suspended particulate (TSP), total chromium (T-Cr), and chromium VI (Cr^{6+}) at three cement factories in the southern region of Vietnam were determined in this study. A 488 samples were taken independently from work locations and personal areas in dry and rainy seasons. Evaluate the results obtained based on the average value and standard error of samples in the work area. The concentration of T-Cr and Cr^{6+} are not affected by weather conditions, but TSP differs between the two seasons. There are 117 samples (accounting for 48%) in the rainy season and 124 samples (accounting for 51%) in the dry season of [TSP] exceeding the limit of QCVN 02:2019/BYT (National Technical Regulation on Dust - Permissible Exposure Limit Value of Dust at the Workplace, $\leq 4 \text{ mg.m}^{-3}$), mainly concentrated in raw materials, clinker, and cement areas. There are 13 samples of [T-Cr] exceeding the limit of QCVN 03:2019/BYT (National Technical Regulation on Permissible Exposure Limit Value of 50 chemicals at the Workplace, $\leq 0.5 \text{ mg.m}^{-3}$), of which 84.6% are in the dry season. There are 105 samples of [Cr^{6+}] exceeding the QCVN 03:2019/BYT (National Technical Regulation on Permissible Exposure Limit Value of 50 chemicals at the Workplace, $\leq 0.05 \text{ mg.m}^{-3}$), accounting for 21.5% of the total number of samples collected and 82.8% of the total number of samples exceeding the limit in the cement area. Based on the analysis of variance (ANOVA), there is a positive correlation between TSP concentration and the concentrations of T-Cr and Cr^{6+} with coefficients of 0.92 and 0.89, respectively. Workers exposed to TSP and Cr^{6+} in high dust increase the risk of occupational diseases. Managers need to monitor chromium and metabolite concentrations in biological samples to have appropriate interventions.

Key words: Portland cement, cement dust, Chromium (VI), exposure assessment

INTRODUCTION

Portland cement is a gray powdery binder made from mineral dust, when mixed with water, it forms a jelly mass¹. In Nigeria, construction site workers are exposed to heavy metal cement in the dry process. The first step is quarrying the raw materials containing limestone, clay, and other materials. The stone will be crushed into small sizes about 6 inches, 3 inches or smaller. Next, the raw materials will be delivered to the pyro-processing system. Pyroprocess is removing water from the raw meal by calcining limestone, and mixing components for forming, cooling, and storing clinker¹.

The main emissions from cement manufacturing are particulate matter from the material preparing stage, and hazardous gas from the kiln and transportation such as NO_x , SO_2 , ...The chemical composition of cement includes Silica (10.1%), Calcium (38.32%), Oxygen (36.14%), Aluminum (1.68%), Magnesium (0.3%), Iron (1.09%), Sulfur (1.73%), Carbon (10.64%), and Chromium (0.008%) [18]. The plants of cement manufacturing are prepared with

dust control equipment so all the dust can be captured by them. Cement kiln dust (CKD) is lost about 4 % after the cement processing. In detail, the quarrying and crushing steps emit about 1 kg of particulate matter, the pyro process step emits 39 kg of cement kiln dust. Various industry sources emit particulate matter and particulate-bound metals¹. The sources of particulate matter emission in cement plants are raw materials preparation, delivery, clinker grinding and storage, cement loading, packing, and transportation². Cement dust was one of the main reasons for respiratory diseases, impaired lung function, and respiratory dysfunction in workers through assessment of maximum vital capacity index (FVC) and maximum expiratory volume during the first second (FVC1), excluding the weight, age, and smoking factor^{1,3,4}. There 210 people (50 workers, 60 residents, and 100 controls) aged 18-60 years participated in research about liver function and serum components⁵. They conclude that exposure to cement dust affects liver function and hematological changes in workers and residents near cement factories. The statistics on

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tooth wear index (TW), gingival recession (GR), and pocket depth (PD) in the cement plant industry show a significant impact on the oral health of workers. Heavy metal components in cement dust will enter the worker's body, forcing anemia, lessened red blood cell count (RBC), PCV, expanded white blood cells (WBC) and HBG indexes, MCV, MCH, MCHC, lymphocytes due to the influence of exposure time.

Portland cement dust particles have a small aerodynamic diameter. More than 90% of the dust volume has an aerodynamic diameter of $\leq 10\mu\text{m}$. The cement dust particle composition includes silicon (20.4%), and heavy metals (cadmium, arsenic, chromium, lead, nickel, zinc, manganese, and cobalt)^{2,6-8}. Cement production workers with low dust during long-term work show clinical symptoms that have been recorded by studies over the years: chronic cough, chest tightness, impaired respiratory function, and irritation. According to research by Chiou-Jong Chen et al. (2008) on chromium in urine related to the skin. The average rate of workers exposed to cement with skin diseases and urinary chromium concentration $\geq 25\mu\text{g/L}$ is 17.2% with a confidence interval of 95%⁹. Chromium (VI) induces oxidative stress by generating reactive oxygen species (ROS) that damage cellular components such as lipids, proteins, and DNA. This oxidative damage can lead to cellular dysfunction and apoptosis. Chromium (VI) can penetrate cell membranes and interact with DNA directly, causing mutations, chromosomal aberrations, and DNA strand breaks. This genotoxicity is a significant factor in carcinogenesis. Once in the bloodstream, chromium (VI) is reduced to chromium (III), which can bind to macromolecules and proteins, disrupting their functions and leading to systemic toxicity affecting various organs, including the liver and kidneys. The International Agency for Research on Cancer (IARC) has classified chromium (VI) as a Group 1 carcinogen, indicating sufficient evidence of its carcinogenicity in humans. Chronic exposure can lead to lung cancer, as demonstrated in various occupational studies. Chromium (VI) is also a well-known cause of allergic contact dermatitis. Skin exposure to chromium can cause eczema, ulcerations, and allergic reactions, as observed in workers handling cement. Inhalation of chromium (VI) particles can cause respiratory tract irritation, leading to chronic bronchitis, decreased lung function, and an increased risk of lung infections. Long-term exposure has been linked to chronic obstructive pulmonary disease (COPD). In Nigeria, construction site workers are exposed to heavy metals from cement dust, which damages their DNA and increases cancer risk through the indicators

8-OHdG, Malondialdehyde (MDA) in plasma. There are also records of higher heavy metals Cr and Cu in the plasma of these workers than in the control group¹⁰. According to a report on the health status of workers exposed to cement in Taiwan, dermatitis, skin allergies, and eczema are related to chromium concentration in urine. Urinary Chromium concentration depends on the use of labor protection and personal hygiene of workers during and after work⁹. Cement dust impairs workers' respiratory function^{11,12}, causing cancer was monitored at a cement factory in Korea¹³, heavy metals (Cd, Cr, Ni) found in biological samples of cement production workers, the results were different from control samples¹⁴. Because of the health risk of cement dust or the trace metal in cement, some studies are measuring the concentration of TSP or metal in cement plants for further suitable strategy. Average dust concentrations in the crane, packing, and grinding areas at the cement factory in Tanzania are 38.64, 21.3, and 13.48 mg.m^{-3} ¹⁵. Other studies also determined the concentration of heavy metals such as As, Cd, Pb, and Cr in cement dust in Nigeria¹⁶. In Indonesian cement plants, the highest level of TSP is about 18.48 -133.24 $\mu\text{g.m}^{-3}$ which is not allowed by Canadian National Ambient Air Quality Objectives⁸. The concentration of trace metal found in a cement plant from Ghana consisted of Ni, Zn, As, and Cr of 44.38 mg.kg^{-1} , 25.65 mg.kg^{-1} , 2.87 mg.kg^{-1} , 15.26 mg.kg^{-1} , respectively¹⁷. The non-carcinogenic hazard was minor though the threat of cancer existed liable, with ingestion orientation posing the most elevated level of risk for both grown-ups and kids in the space¹⁷.

The research of Tinh Thai, in the cement plants of Ho Chi Minh City, illustrated the concentration of [TSP] = 0.06 - 38.24 mg.m^{-3} , [PM1] = 0.00 - 0.06 mg.m^{-3} , and [PM10] = 0.04 - 26.85 mg.m^{-3} (i.e. particulate matter (PM)) exceeds the allowable limit for the 8h shift. They also found the silica in the respirable dust (about 20.4%)⁷. In 2019, Vietnam's cement industry was the third rank in the world with a production output of 99 million tons. Total revenue of the cement industry reached 119 trillion VND, contributing 1.9% to the country's total GDP. It is predicted that by 2030, the total capacity will increase by 9.73 million tons/year, nearly 9% compared to 2019. Portland cement dust has a TWA value of 4 mg.m^{-3} specified by QCVN 02:2019/BYT. The concentrations of T-Cr and Cr^{6+} according to QCVN 03:2019/BYT are 0.5 mg.m^{-3} , and 0.05 mg.m^{-3} , respectively.

While these studies provide valuable insights into the health impacts of cement dust, they often focus on

specific health outcomes without a comprehensive assessment of the mechanisms of chromium exposure. Additionally, there is limited research on hazardous substances in cement factories in Vietnam, despite the country being the third-largest cement producer globally. This study offers information on the levels of dust and chromium exposure at a cement plant in Vietnam, serving as a step toward assessing risks to workers' and residents' health. Additionally, it is a primary step in implementing environmental management plans to address health risks and improve safety measures.

MATERIALS AND METHODS

Location of research

Research locations are conducted at Portland cement factories in suburban areas of Ho Chi Minh City (NM1), Southeast region (NM2), and Southwest region (NM3), in the period from 2022 to 2023. The location of sampling areas included the office area, maintenance department, materials and spare parts warehouse, quality control department, raw material areas, clinker areas, and cement areas.

Working area and working conditions

Based on the factory job description, production departments are divided into the following working areas: raw material production area, cement clinker area, cement production area, maintenance area, warehouse, and management office. The jobs in each area and working conditions are described in Table 1.

Determine sample size

Calculate sample size according to the formula:

$$n \geq Z_{1-\alpha/2}^2 \frac{p(1-p)}{d^2} \quad (1)$$

Where p estimated rate, $Z_{1-\alpha/2}^2$ is desired confidence level 95% ($Z=1.96$), d : margin error can be calculated as the desired deviation of 5%, and n : calculated sample size. The sample size was calculated by:

$$n \geq Z_{1-\alpha/2}^2 \frac{p(1-p)}{d^2} = 219 \quad (2)$$

The research identified and took 244 samples from 3 cement factories. The distribution of samples at factories and production areas is shown specifically in Table 2. Samples are taken repeatedly in the dry and rainy seasons, each factory takes samples every 2 to 4 weeks.

Sampling method

TSP and T-Cr samples were taken during the 8-hour morning shift. Individual samples were randomly selected from working workers and sampled at work positions and in the breathing zone. The sampling volume is 35 - 245 liters, so the mass of dust collected on the filter paper is ≤ 2 mg. Samples are collected on 37mm diameter PVC filter papers with a pore size of $5\mu\text{m}$ (Zefon, USA), connected to SIBATA sampling pumps, models MP-Σ300NII and MP-Σ500 (SIBATA, Japan), with flow rates set from 1 to 3 liters per minute. The sampling pump is calibrated before sampling, the pump's sampling volume error is $\leq 5\%$, and no pump stops during the sampling process. The sample was sealed in a plastic bag and transported to the environmental laboratory of the Branch of the National Institute Of Occupational Safety and Health in Southern Vietnam (SNIOSH) for analysis.

Analytical method

The filter paper was weighed before and after sampling using a GH-202 DNA analysis balance (AND, Japan) with a sensitivity of 0.01 mg. The detection limit of the method is 0.03 mg/m^3 . Each factory is provided with two field control dust samples.

Analysis of T-Cr in the air by microwave destruction (CEM type MARS 6, USA) with HNO_3 (Merck, USA), products were analyzed by atomic absorption spectrometry Perkin Elmer P900T (Germany) with flame technique, hollow Chromium HCl-Catode lamp at wavelength 357.9nm, Chromium standard 1000ppm (Merck, USA). The detection limit of the method is 0.025 mg/m^3 . Sample collection efficiency reaches 98.9%.

Analyze Chromium (VI) in air by sample destruction with 0.5N H_2SO_4 and developing color with diphenyl carbazide reagent (Merck). The sample was then colorimetrically measured at 540nm wavelength on a Perkin Lambda25 device using a 5cm cuvette, the reference standard was by dissolving 3.735g K_2CrO_4 (Merck) in 1000mL of deionized distilled water. The limit of the detection method reaches $1.1 \mu\text{g/m}^3$, and the sampling efficiency reaches 99.4%.

Evaluate results and statistical analysis

Statistical analysis of mean value, variance, and standard error of data. Proportionality test, comparing two or more groups of data using a t-test, with a significance level of 0.05. Compare and evaluate correlation using Pearson's r analysis. Data analysis and processing were performed on R software version 4.3.2.

Table 1: List of surveyed areas and job categories

Area	Working conditions	Plant
Raw materials	Job description: The worker operates excavators, and loaders for extracting limestone, and clay at the quarry; drives dump trucks to transport materials from the quarry to the crushing station; operates limestone and clay crushing machines, coordinates dump trucks to unload materials into the hopper; operates material spreading machines in the warehouse and performs equipment maintenance. Working conditions: Exposure to outdoor weather conditions; dust from quarrying and material spreading processes; noise from vehicle engines and crushing machines. Personal protective equipment: Workers are provided with N95 masks, helmets, and protective footwear.	NM3
Clinker	Job description: Supplementing raw materials, operating a raw material grinder, coal mill, pelletizing machine, clinker rotary kiln, electrostatic precipitator dust filtration system, conveyor system, and equipment maintenance. Working conditions: Exposure to high temperatures in the clinker rotary kiln area; noise from crushers, rotary kilns; dust from crushers, clinker silos. Personal protective equipment: The workers use N95 masks, earplugs, goggles, helmets, and safety shoes	NM3
Cement	Job description: Workers operate cement grinding machines, cement bagging machines, feed bags into machines, load cement bags onto trucks, operate weighing stations, cement dispatch stations, conveyor systems, electrostatic precipitator dust filtration systems, clean work areas, and perform equipment maintenance. Working conditions: Exposure to noise from grinding machines, bagging machines; dust from bagging machines, and dispatch areas. Personal protective equipment: The workers are provided with N99 masks, fabric gloves, earplugs, goggles, helmets, and safety shoes.	NM1, NM2, NM3
Maintenance	Job description: Repairing forklifts, dump trucks, loaders, machinery within the factory, electrical systems, and electrical equipment in the production line. Working conditions: Exposure to outdoor weather conditions; noise from welding, and cutting processes; exposure to dust while repairing equipment in the production line. Personal protective equipment: Workers are equipped with fabric gloves, earplugs, goggles, helmets, and safety shoes.	NM1, NM2, NM3
Warehouse	Job description: Employees work in finished goods warehouses, coal warehouses, raw material warehouses, and supply warehouses. Forklift drivers arrange cement pallets, use material spreading machines, run dump trucks for material transportation, and clean warehouses and work areas. Working conditions: Spacious warehouse space, well-ventilated, with wall-mounted fans for air circulation. Personal protective equipment: Workers are provided with goggles, helmets, and safety shoes.	NM1, NM2, NM3
Office	Job description: Including business, human resources, medical, and quality assurance departments. Working conditions: Office employees work in air-conditioned environments and occasionally go down to the production area to collect samples.	NM1, NM2, NM3

RESULTS AND DISCUSSIONS

The P-value results in Table 3 show that the TSP concentration in working areas was significant with $P - a$ value < 0.05 . The difference between the two seasons is based on the reduced dust dispersion at outdoor work locations during the rainy season. Monitoring results of T-Cr and Cr^{6+} concentrations according to seasons were not significant due to the P -value > 0.05 . Therefore, we could conclude that the seasons did not affect the monitoring results of T-Cr and Cr^{6+} .

From Figure 1, the average TSP monitoring results at cement factories all exceed the QCVN 02:2019/BYT, as samples exceed the limit up to 11 times. In maintenance areas, offices, quality management, and warehouses, the concentration of TSP in the air between the two seasons has an insignificant. It could be explained that these areas are mainly indoors, with surrounding walls. The production areas for cement, clinker, and raw materials tend in the dry season to have a higher average concentration of TSP in the rainy season due to the open area, which made it eas-

Table 2: Distribution of quantity and sample rate at 3 cement factories

AREA	NM2, (N=41)	NM1, (N=43)	NM3, (N=160)
MAINTENANCE	4 (9.8%)	4 (9.3%)	21 (13.1%)
CLINKER	5 (12.2%)	7 (16.3%)	51 (31.9%)
WAREHOUSE	3 (7.3%)	-	5 (3.1%)
OFFICE	4 (9.8%)	4 (9.3%)	4 (2.5%)
QAQC	5 (12.2%)	5 (11.6%)	10 (6.3%)
CEMENT	20 (48.8%)	23 (53.5%)	48 (30.0%)
RAW MATERIAL	-	-	21 (13.1%)

Table 3: TSP concentration, T-Cr, and Cr⁶⁺ in dry and rainy seasons

Characteristic	RAINY, N = 244 ¹	SUNNY, N = 244 ¹	P-value ²
TSP	11 (13)	13 (15)	0.032
T-Cr	0.12 (0.16)	0.15 (0.18)	0.058
Cr ⁶⁺	0.019 (0.027)	0.023 (0.031)	0.14

¹ Mean (SD)

² Welch Two Sample t-test

ier for dust to spread around. Additionally, higher air humidity during the rainy season causes dust to settle deposition faster. Particularly in the raw material area, the average TSP concentration in the dry season (21.9 mg.m^{-3}) was nearly twice that of the rainy season (11.2 mg.m^{-3}) because of mining activities and raw material transportation, the reduction of material thresher and wet material.

In the dry season, there were 124 samples exceeding the limit of QCVN 02:2019/BYT, accounting for 51%, with an average of $13.4 \pm 15.0 \text{ mg.m}^{-3}$. The highest average TSP concentration in the dry season was 27.4 mg.m^{-3} at the NM1 factory, exceeding the limit of QCVN 02:2019/BYT by 6.9 times. In the rainy season, the TSP concentration exceeds the standard 6.3 times, which was 25.1 mg.m^{-3} at the NM2 factory. The average TSP concentration in the clinker area exceeded the limit at the NM1 plant in both dry and rainy seasons, higher 3 times (12.0 mg.m^{-3}) and 2.25 times (9.0 mg.m^{-3}) than the value of QCVN 02:2019/BYT, respectively. In the raw material warehouse area of the NM2 factory and the maintenance area of the NM3 factory, there was only one sample of TSP exceeding the limit in both the dry and rainy seasons. TSP concentrations in office areas, quality management, material warehouses, and auxiliary materials warehouses were all acceptable.

In raw material, clinker, and cement areas, there were mining activities, operating wheel loaders, crushing,

rolling pellets, loading cement bags on trucks in the cement export area, and packing cement bags, which emitted dust into the air environment. Besides, the technical requirements of cement have a fineness of $\leq 10 \mu\text{m}$ over 90%⁷, so the finished cement has a small particle size that is easy to disperse into dust particles. As show in Figure 2, the results of monitoring T-Cr in two seasons have 13 samples exceeding the limit, the factory in NM3 accounts for 11 samples, and the NM2 had 2 samples. T-Cr monitoring results in two seasons had 13 samples unacceptable to QCVN 03:2019/BYT. The NM3 and NM2 plants contributed 11 and 2 samples, respectively. The average concentration of unacceptable 2 samples in the dry season was $0.652 \pm 0.002 \text{ mg.m}^{-3}$. Also, in the dry season, there were 11 samples exceeding the limit ($0.6 \pm 0.128 \text{ mg.m}^{-3}$), accounting for 84.6% of the total unacceptable number. The samples exceeding the limit are mainly in the clinker area: 9 samples at the conveyor position, clinker transport, the bottom of the Clinker Silo and cement, and 4 samples at the bagging and loading positions on the truck. TSP monitoring results in working areas in the cement factory are also shown in Figure 2. There are 117 TSP monitoring locations exceeding the limit, accounting for 48% of the total samples taken in the rainy season. TSP concentration ranges from 0.3 to 43.3 mg.m^{-3} . And 124 samples exceeded the limit, accounting for 51%, with

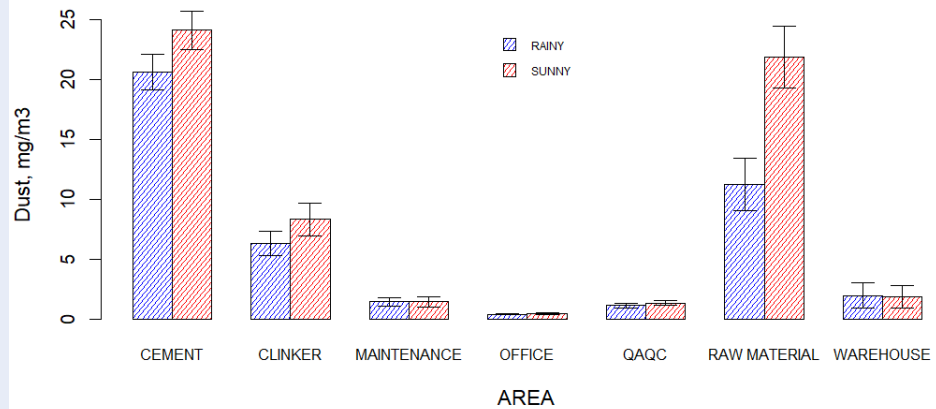


Figure 1: TSP concentration in a variety of areas at cement factories in wheater conditions

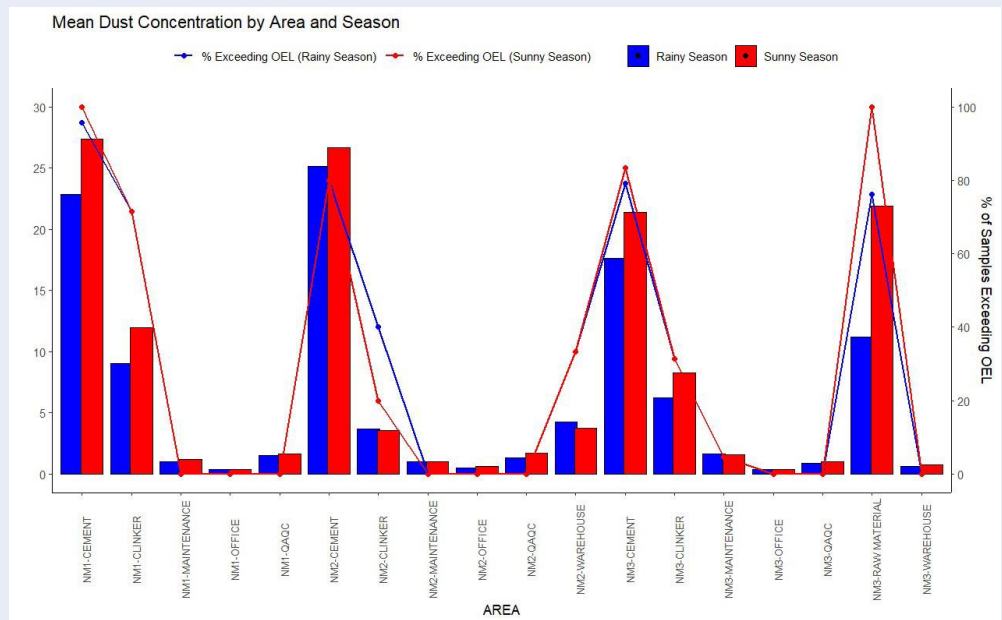


Figure 2: Mean dust concentration by areas and seasons

a median of 4.79 mg.m^{-3} in the dry season. TSP samples exceeded the limit mainly in the raw material, clinker, and cement areas.

In 2020, a cement grinding plant in Southern Vietnam conducted a study that revealed TSP concentration levels that exceeded the allowable limit QCVN 02:2019/BYT. The TSP concentration levels were found to be above the limit in the following areas: raw material storage and processing area (18.22 mg.m^{-3}), under the feed tank connected to the conveyor belt (25.62 mg.m^{-3}) before grinding, during cement grinding (5.63 mg.m^{-3}), at the packaging machine (5.34 mg.m^{-3}), on the truck during transportation (11.55 mg.m^{-3}), and during the transport of cement to the barge loading system (13.4 mg.m^{-3})⁷.

Figure 3 shows that Cr^{6+} concentration was correlated with TSP and T-Cr. However, in the raw material area of the NM3 factory, TSP exceeded the permissible limit in 88% of the samples. The correlation coefficient between TSP and T-Cr was 0.92,

and between Cr^{6+} concentration and T-Cr was 0.98. The correlation coefficient between TSP and Cr^{6+} was 0.89, showing that the substances were strongly and linearly correlated. This result was due to T-Cr and Cr^{6+} existing in particulate form in the air and sampled on filter paper. The correlation of TSP – Cr^{6+} was smaller than the TSP – T-Cr. In the raw material area, the concentration TSP was $21.9 \pm 11.7 \text{ mg.m}^{-3}$ (21 samples), and the values exceeded the limit. Moreover, the average T-Cr concentration was $0.068 \pm 0.064 \text{ mg.m}^{-3}$ but the average Cr^{6+} concentration in this area was only $0.002 \pm 0.002 \text{ mg.m}^{-3}$. High temperatures during the clinker kiln process (up to $1250 - 1450^\circ\text{C}$) may convert Cr^{3+} into Cr^{6+} , increasing its concentration in the cement dust produced after the process. According to the report of Gbadom et al. (2007), the heavy metal content is in the air around the crusher area at the plant. Southwest Nigeria has an average T-Cr concentration of $2.38 \pm 4.42 \text{ mg.m}^{-3}$, about four times higher than this study¹⁶. Announced Cr^{6+} concentration at the cement factory in Negeri Sembilan, Malaysia had an average value of $1.53 \pm 2.47 \text{ mg.m}^{-3}$, nearly ten times higher than the Cr^{6+} concentration in this work¹¹. The difference in Cr^{6+} in the air of the work area is affluence in the Chromium of the composition material in Nigeria. The reason for the differences between T-Cr and Cr^{6+} in the air of these studies was based on production technologies, raw material composition, and mixing ratio.

As shown in Figure 4, compared to T-Cr, 105 samples of Cr^{6+} exceeded the limit, accounting for 21.5%, and the NM3 factory had samples that exceeded the limit nearly 3 times. The concentration of Cr^{6+} exceeding the limit was only found in the cement and clinker area, but the cement areas accounted for 82.8% of the total number of samples. In the clinker area of the NM3, Cr^{6+} samples are higher than the remaining areas. The concentration of Cr^{6+} was high in working areas with high TSP, exceeding the limit of the cement and clinker area (Figure 3). The raw material area at the NM3 factory has high TSP but high concentration. Chromium (VI) levels at working positions all meet the limit. At a cement factory in Negeri Sembilan, Malaysia, and near Banjaran Titiwangsa, Cr^{6+} has a geometric mean and standard deviation of $1.53 \pm 2.47 \text{ mg.m}^{-3}$ ¹¹. This result is nearly 10 times higher than this study's Cr^{6+} . The average dust exposure concentration at a cement factory was 21.82 mg.m^{-3} , nearly 2 times higher than the average level of the study. Regarding research limitations, we have not conducted respiratory dust sampling. The reason is due to limited time to conduct research. Field sample collection and sampling equipment do not meet the

accuracy of the data. Therefore, research has not been able to evaluate the Cr concentration in respiratory dust, leading to the current situation of Cr exposure in respiratory dust for workers not being studied. Some other components in cement dust as Silica dust and heavy metals (e.g. Pb, As, and Cd) are not analyzed. The harmful effects of these types of pollutants are also worrying. In addition, another limitation is that the study only stopped at assessing exposure through inhalation and did not assess exposure through the skin and gastrointestinal tract. Some of the above shortcomings are the basis for further research to be expanded and conducted to make comprehensive conclusions about the impacts on workers in Portland cement factories. From there, propose appropriate management and handling solutions, ensuring the rights and safety of workers.

CONCLUSION

The analysis for TSP revealed that there was a significant difference between the two seasons. The average TSP concentration in all three seasonal cement plants exceeded the allowable limit of QCVN 02:2019/BYT. In the rainy season, the unaccepted samples were 117 samples. In the dry season, there were 124 samples, approximately 49% of the total samples. The chromium concentrations were monitored in 13 samples, and of these, 105 were above the permissible limit for Chromium(VI) QCVN 03:2019/BYT. Workers who were dealing with high dust levels were protected with N99 masks. The managers should make sure that the staff complies with individual labor protection equipment. It was necessary to periodically test workers for occupational diseases and monitor the intake and accumulation of Chromium in bio-samples to take precautionary measures and provide timely medical care.

COMPETING INTERESTS

All authors declared that there is no conflict of interest in this study.

AUTHORS' CONTRIBUTIONS

Formal analysis, Huynh Duc Thang; Writing - original draft, Nguyen Thi Minh Hoa; Methodology, Le Truong An; Writing - review & editing, Huynh Duc Thang.

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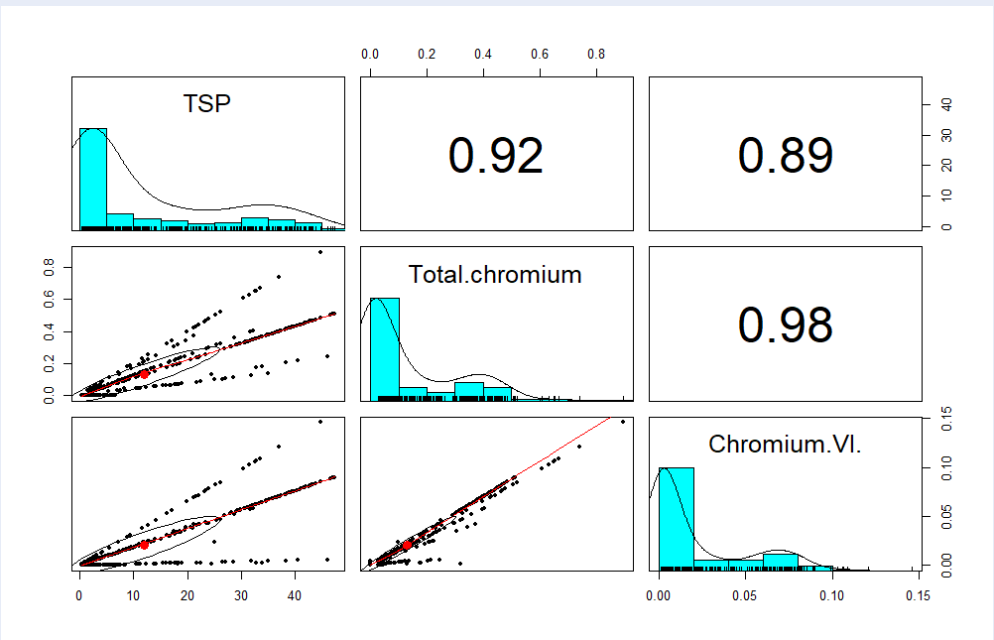


Figure 3: The correlation between TSP, T-Cr, and Cr⁶⁺

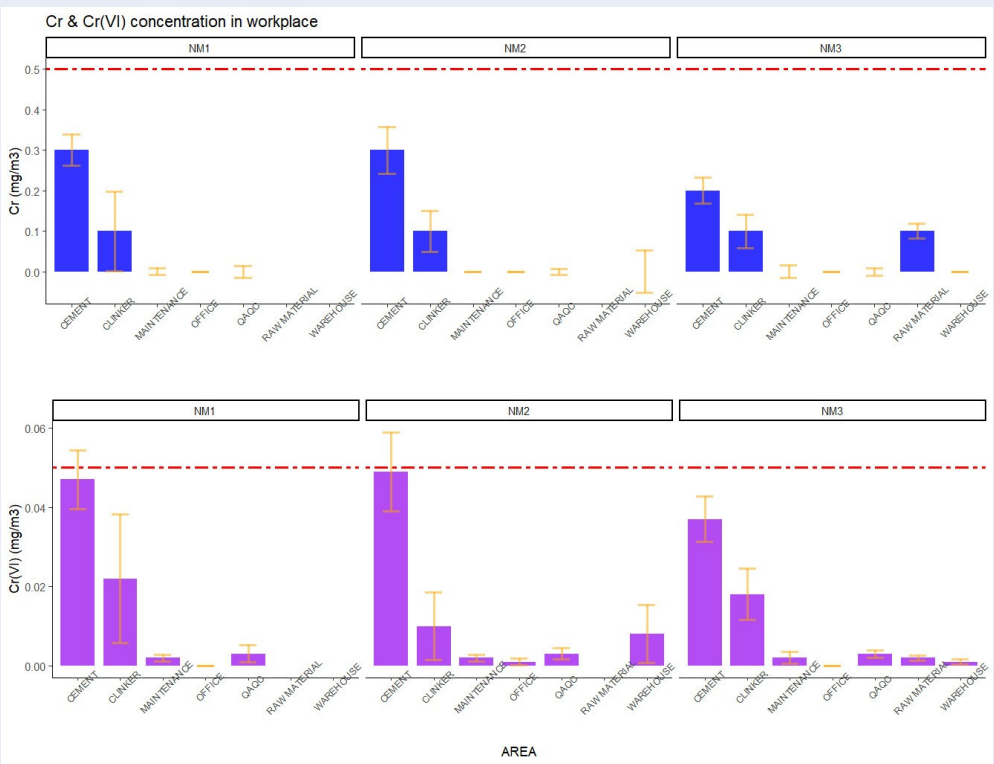


Figure 4: The T-Cr and Cr⁶⁺ concentration of at cement plants

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Thực trạng phơi nhiễm tổng bụi lơ lửng (TSP), crom tổng và crom (VI) tại nhà máy xi măng phía Nam Việt Nam

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TÓM TẮT

Nghiên cứu này đã xác định nồng độ tổng bụi lơ lửng (TSP), crom tổng (T-Cr), và crom VI (Cr6+) tại ba nhà máy xi măng ở Phía Nam Việt Nam. Tổng cộng 488 mẫu đã được lấy mẫu độc lập từ các vị trí làm việc và khu vực cá nhân vào mùa khô và mùa mưa. Đánh giá kết quả dựa trên giá trị trung bình và sai số chuẩn của các mẫu trong khu vực làm việc. Nồng độ của T-Cr và Cr6+ không bị ảnh hưởng bởi điều kiện thời tiết, nhưng TSP khác biệt giữa hai mùa. Có tổng cộng 117 mẫu (chiếm 48%) trong mùa mưa và 124 mẫu (chiếm 51%) trong mùa khô vượt quá giới hạn của QCVN 02:2019/BYT (Quy chuẩn kỹ thuật quốc gia về bụi - Giá trị cho phép tiếp xúc về bụi tại nơi làm việc, $\leq 4 \text{ mg.m}^{-3}$), chủ yếu tập trung ở các khu vực vật liệu nguyên liệu, clinker và xi măng. Tổng cộng có 13 mẫu [T-Cr] vượt quá giới hạn của QCVN 03:2019/BYT (Quy chuẩn kỹ thuật quốc gia về giá trị cho phép tiếp xúc 50 chất hóa học tại nơi làm việc, $\leq 0.5 \text{ mg.m}^{-3}$), trong đó 84.6% là vào mùa khô. Có tổng cộng 105 mẫu [Cr6+] vượt quá giới hạn của QCVN 03:2019/BYT (Quy chuẩn kỹ thuật quốc gia về giá trị cho phép tiếp xúc 50 chất hóa học tại nơi làm việc, $\leq 0.5 \text{ mg.m}^{-3}$), chiếm 21.5% tổng số mẫu thu thập và 82.8% tổng số mẫu vượt quá giới hạn tại khu vực xi măng. Dựa trên phân tích phương sai (ANOVA), có mối tương quan tích cực giữa nồng độ TSP và nồng độ T-Cr và Cr6+ với hệ số lần lượt là 0.92 và 0.89. Các công nhân tiếp xúc với TSP và Cr6+ trong môi trường bụi cao có nguy cơ mắc bệnh nghề nghiệp tăng lên. Các nhà quản lý cần theo dõi nồng độ crom và các chất chuyển hóa trong mẫu sinh học để có các biện pháp can thiệp phù hợp.

Từ khoá: Xi măng Portland, bụi xi măng, Crom (VI), đánh giá tiếp xúc

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