# AIR QUALITY MONITORING IN QUANG NINH COAL MINE IN VIETNAM

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## Abstract

Quang Ninh is a mountainous province in the North-East of the Socialist Republic Vietnam, which has a diverse economic potentiality, many development advantages and the key territory in the strategy of the national socio-economic development. Being the biggest center of coal exploitation in Vietnam, the province possesses a coal deposit of more than 3 thousand million tones, and has gained the great profits from this mineral resource. However, the residents of this area have been facing the air environmental pollution caused by the industrial activities. This report presents some results on the ambient air quality monitoring on $NO_2$, $SO_2$, $NH_3$, CO and Suspended Particulate Matters in 27 target sampling points in Quang Ninh coal mine by diffusion passive samplers. The concentration conversion coefficients $\alpha NOx$, $\alpha SO_2$, $\alpha NH_3$ are identified by using activated method with pumping sampler in Quang Ninh province. The results have also proved that the diffusion passive samplers produced by the Institute of Environmental Technology, NCST, Vietnam could be used for air quality monitoring in exploitation in mine area and bring about similar efficiency as other methods. It has been indicated that ambient air quality of Quang Ninh coal mine are polluted by SPM, $SO_2$, $NO_2$ and CO.

***Key words***: Air quality, coal mine, passive samplers, $NO_2$, $SO_2$, $NH_3$, CO, SPM.

## Introduction

Quang Ninh province[1] is bordered in the North East by the province Kouang-Si (China), in the North and West by the provinces Lang Son, Ha Bac, Hai Hung and Hai Phong town, in the South by the Tonkin Bay, with 250 km of coastal length. Its natural area reaches 5,938 $km^2$. The climate is mild, rainy and divided into two distinct seasons: the hot season begins from April to October, the cold from November to March. The annual average temperature is $23^0$ C, that of hot season is 28 $^0$C, coal season is $16^0$C. Average of rainfall is 2,000 - 2,500mm and humidity is 83%. Quang Ninh has 2 principal tourism centers: Ha Long Bay and Tra Co. Ha Long Bay is one of World Heritages Place (by UNESCO).

The annual production of Quang Ninh ranges between 5 and 6 millions tones of coal, of which 1.5 million tones are reserved for export. The quantity of exploited coal is expected to reach 8-10 million tones. With the economic development, the Quang Ninh peoples are faced and facing to air pollutants of many kind of gases, such as CO, $CO_2$, $NO_x$, $SO_2$, $NH_3$, SPM and $CH_4$.

In order to control the quality of environmental ambient air in Quang Ninh coal mine, more than 60 target sampling points of this area were selected for air monitoring, 27 points of which were for measuring the concentrations of $NO_2$, $SO_2$, and $NH_3$ gases by diffusion passive samplers. In other points, samplers were taken by activated methods. The concentrations of CO gas and SPM were sampled by active methods, too.

The identification of concentration of those gases was carried out in Laboratory of Analytical Chemistry, IET and NCST, Vietnam.

**Methods and equipment**

- Air quality monitoring methods
- Diffusion Passive samplers of $NO_2$, $SO_2$, $NH_3$ gases made by Institute of Environmental Technology (IET), NCST.
- Activated pump samplers of CO, $CO_2$, SPM, $CH_4$ (Kimoto, Handy Sampler HS-7)
- Flow rate of air sampler, Japan
- Spectrophotometer UV-VIS, Jenway, British
- Ion Chromatography IC, Alltech, American
- Analytical balance, $10^{-5}$

**Results and discussion**

Passive sampler, prepared by Institute of Environmental Technology (IET), is based on Martin Ferm principle[2] and Yasakawa model[3]. One of the most important factors in using passive samplers is concentration conversion coefficient α of gases. Because all the diffusion passive samplers always have a constant diffusion length (L), and an area of filtration paper (A), the coefficient α depends on such climate conditions as humidity, temperature and wind speed of each area. The concentration $C_x$ of gas polluted x is identified, as follows:

$$C_x(ppb) = \alpha \frac{m}{t}$$

*where* t is the sampling time (in hour)
m is the amount of pollutant gas (in μg),
α is the concentration conversion coefficients, which is determined by both active and passive equipment (ppb.h/ μg)

The concentration conversion coefficients α of $SO_2$, $NO_2$, $NH_3$ gases depicted in table 1 were measured in Hon Gai town, Quang Ninh province, with average α $SO_2$ is 607.96 ppb.h/ μg, α $NO_2$ is 482.46ppb.h/ μg, α $NH_3$ is 1701.88 ppb.h/ μg .

Table 1. The concentration conversion coefficient α SO2, α NO2, α NH3 gases
(Duration: 10-17 March 2003 and 25 -29 March 2003)

| No | T°C | H (%) | t (hour) sampling | α $SO_2$ (ppb.h/ μg) | α $NO_2$ (ppb.h/ μg) | α $NH_3$ (ppb.h/ μg) |
|---|---|---|---|---|---|---|
| 1 | 22 | 84 | 161 | 612.40 | 601.65 | 1514.96 |
| 2 | 26 | 78 | 160 | 603.12 | 387.62 | 1754.12 |
| 3 | 25 | 75 | 160 | 605.32 | 540.78 | 1825.13 |
| 4 | 28 | 78 | 165 | 614.02 | 403.21 | 1452.32 |
| 5 | 29 | 76 | 163 | 604.98 | 479.08 | 1962.90 |
| Average | | | | 607.96 | 482.46 | 1701.88 |

Table 2 provides the results of monitoring the pollution of $NO_2$, $SO_2$, $NH_3$ gases in air environment of 27 target points in numerical order in the list of sampling points.

*The list of sampling points*

1 Deo Nai mine's office
2 Cua Ong post office
3 Ground 28 in Ha Lam mine
4 Landfill of Deo Nai mine
5 T-junction in road 18 of Cao Son mine
6 Mao Khe screening yard
7 T-junction in 18 road of Mao Khe mine
8 T-junction in 18-86 road
9 T junction of Cau Go market near Tan Lap mine
10 Six stake mine's office
11 Cao Son mine's office
12 Transportation of Six stake mine
13 Ben Bang port
14 Ha Tu Port
15 Mine chemical factory office
16 T-junction of Mong Duong -Cau Ngam
17 Ground 26 in Tan Lap mine
18 Dien Cong port
19 Nam Cau Trang selection yard
20 Screening workshop 1 in stake 6
21 Hon Gai center
22 Mao Khe mechanic cross-road
23 Mao Khe residential area
24 Pit-door 42 of Thong Nhat mine
25 Khe Ngat coal store
26 Uong Bi center
27 Giap Khau coal store

Table 2. The results of air pollution caused by $SO_2$, $NO_2$ and $NH_3$ gases in 27 target points of Quang Ninh coal mine's areas by passive samplers of Vietnam (from 10 to 29 March 2003)

| No | Time | T | RH | $NO_2$ M(µg) | $NO_2$ (ppb) | $NO_2$ C(ppb) | $SO_2$ M(µg) | $SO_2$ C(ppb) | $SO_2$ C(ppb) | $NH_3$ M(µg) | $NH_3$ C(ppb) | $NH_3$ C(ppb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (h) | ($^0$C) | (%) | | Passive | Active | | Passive | Active | | Passive | Active |
| 1 | 141 | 25 | 74 | 1.694 | 6.58 | 5.86 | 10.03 | 49.54 | 43.4 | 10.41 | 139.16 | 90.19 |
| 2 | 145 | 20 | 84 | 3.246 | 12.25 | 12.03 | 4.285 | 20.57 | 30.83 | 6.19 | 80.43 | 98.89 |
| 3 | 121 | 30 | 60 | 7.642 | 31.24 | 30.87 | 3.159 | 18.17 | 31.92 | 4.38 | 68.20 | 116.00 |
| 4 | 142 | 23 | 78 | 2.35 | 9.03 | 12.16 | 5.74 | 24.56 | 22.41 | 8.17 | 108.44 | 125.80 |
| 5 | 142 | 26 | 65 | 3.89 | 15.01 | 15.34 | 3.27 | 13.99 | 18.05 | 6.62 | 87.85 | 117.50 |
| 6 | 143 | 29 | 64 | 5.612 | 19.41 | 28.04 | 10.75 | 52.20 | 36.43 | 6.71 | 88.37 | 116.50 |
| 7 | 143 | 30 | 61 | 7.164 | 27.39 | 30.81 | 16.84 | 81.84 | 36.52 | 11.28 | 148.58 | 109.40 |
| 8 | 140 | 25 | 66 | 5.434 | 21.19 | 21.79 | 7.740 | 33.60 | 44.7 | 12.57 | 169.16 | 104.28 |
| 9 | 126 | 28 | 62 | 8.238 | 32.34 | 27.98 | 6.634 | 32.00 | 30.16 | 8.26 | 123.50 | 75.56 |
| 10 | 144 | 23 | 81 | 2.235 | 8.48 | 12.16 | 3.343 | 14.11 | 15.57 | | | |
| 11 | 142 | 27 | 61 | 1.277 | 4.91 | 5.36 | 5.703 | 24.41 | 22.73 | 12.14 | 161.06 | 110.30 |
| 12 | 144 | 23 | 83 | 1.113 | 4.22 | 5.29 | 5.236 | 22.10 | 28.87 | 7.31 | 95.66 | 97.89 |
| 13 | 142 | 23 | 83 | 7.079 | 24.66 | 21.67 | 2.738 | 13.40 | 20.89 | 3.26 | 43.24 | 97.89 |
| 14 | 141 | 24 | 81 | 7.808 | 27.39 | 34.47 | 7.758 | 33.44 | 31.25 | 6.02 | 80.41 | 132.40 |
| 15 | 141 | 25 | 72 | 4.752 | 16.67 | 21.31 | | | | 3.69 | 49.31 | 124.89 |
| 16 | 146 | 19 | 80 | 12.285 | 41.62 | 33.86 | 7.432 | 30.94 | 35.19 | 6.10 | 78.77 | 134.80 |
| 17 | 126 | 28 | 62 | 3.941 | 15.47 | 18.83 | 4.378 | 21.12 | 22.81 | 3.00 | 44.86 | 123.80 |
| 18 | 143 | 32 | 62 | 6.667 | 23.06 | 25.61 | 6.819 | 28.98 | 34.47 | 5.24 | 69.06 | 94.90 |
| 19 | 125 | 26 | 68 | 8.241 | 32.61 | 43.82 | 6.793 | 33.03 | 29.96 | 9.98 | 150.48 | 103.70 |
| 20 | 143 | 24 | 79 | 2.625 | 10.03 | 5.31 | 5.654 | 24.03 | 24.8 | 7.74 | 102.00 | 118.30 |
| 21 | 161 | 28 | 70 | 3.729 | 12.65 | 18.79 | 3.599 | 15.52 | 29.33 | 10.16 | 118.85 | 89.00 |
| 22 | 143 | 29 | 65 | 7.684 | 26.58 | 31.28 | 9.832 | 43.27 | 36.43 | 12.66 | 166.75 | 102.80 |
| 23 | 143 | 29 | 61 | 4.987 | 17.25 | 15.64 | 10.355 | 45.57 | 35.66 | 10.07 | 132.67 | 109.60 |
| 24 | 145 | 21 | 73 | 4.426 | 16.72 | 21.01 | 6.275 | 26.30 | 30.21 | 11.10 | 144.29 | 105.50 |
| 25 | 143 | 26 | 75 | 10.359 | 35.83 | 37.41 | 3.178 | 15.44 | 38.41 | 9.81 | 129.27 | 117.55 |
| 26 | 143 | 27 | 77 | 5.785 | 20.01 | 18.73 | 8.390 | 35.66 | 36.15 | 9.03 | 119.04 | 103.59 |
| 27 | 141 | 24 | 79 | | | | | | | 9.03 | 120.52 | 111.49 |
| Ave. Conc. (ppb) | | | | | **19.72** | **21.36** | | **30.15** | **30.69** | | **108.46** | **108.94** |

The air quality monitoring of $SO_2$, $NO_2$ and $NH_3$ gases were carried out from 10 March 2003 to 29 March 2003 for two times. The first time was from 10 to 17 March, and the second time was from 25 to 29 March 2003. The samples were continuously taken for 5 - 6 days all day night. The concentration of $SO_2$ was determined by Ion Chromatography (IC) and concentrations $NO_2$ and $NH_3$ were determined by Ion Chromatography and Spectrophotometer UV-VIS.

The results in table 2 show that we obtained the similar results applying either passive samplers or active samplers.

Comparison of the results provided by the two methods may give us little different results.
Figures 1, 2, 3 illustrate more clearly the similar results of two sampling methods.

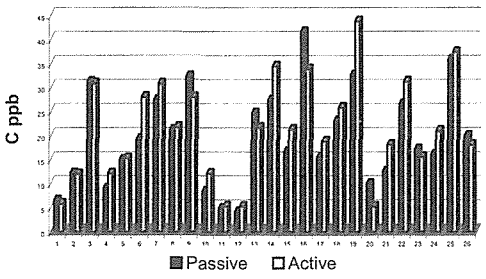


Figure 1. Monitoring results of $NO_2$ concentration in 26 points in Quang Ninh coal mine area by applying passive sampler and active sampler methods

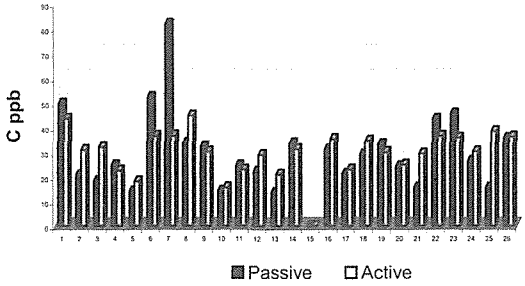


Figure 2. Monitoring results of $SO_2$ concentration in 26 points in Quang Ninh coal mine area by applying passive sampler and active sampler methods

According to the above tables and figures, the in-vessel concentrations of $SO_2$, $NH_3$, $NO_2$ in Quang Ninh are 30 ppb, 108 ppb, and 20 ppb respectively. Both passive and active sampler methods of $SO_2$ and $NH_3$ gave the coincident results in vessels. Nonetheless, 9 of 27 samplers showed apparent discrepancies in the case of $NH_3$, i.e. 24.3% of the total samplers. 13/ 27 samplers (50% of the total) resulted quite differently, of which 8 measured by passive method gave smaller results whereas 6 others gave higher results than by active methods. The lowest measured concentration is 13.40 ppb; and the highest is 81.84 ppb, taken at the T-junction of road 18, Mao Khe mine where the impacts of exploitation area and transportation are rather serious. The second highest concentration of $SO_2$ was taken in Mao Khe screening yard, the place to select and screen coal.

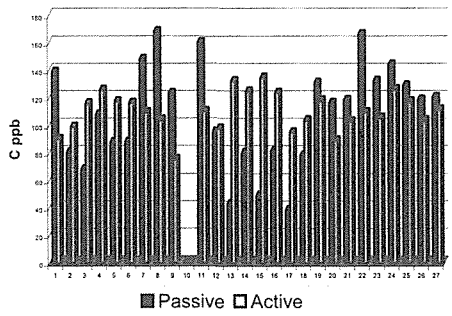


Figure 3. Monitoring results of NH3 concentration in 27 points in Quang Ninh coal mine area by applying passive sampler and active sampler methods

The sampler of $NO_2$ measured by passive method showed lower value than that by active method. The locations with highest concentration are still Mao Khe screening yard and T-junction of road 18. The high concentration of $NO_2$ was also observed in Ground 28 of Ha Lam mine (3), Ha Tu coal port (14), Mong Duong - Cau Ngam t-junction (16), South Cau Trang coal selection yard (19), and Khe Ngat store (25), Mao Khe mechanic cross-road (22). At the above-mentioned locations, the two methods showed the same fluctuation. The above - given results are quite acceptable.

The concentration conversion coefficient α is adjusted by the temperature and humidity changes in passive sampler method. The temperature during the measuring period fluctuated between 19 - 30.6$^0$C with the difference of 11$^0$C. Therefore, temperature had insignificant influence. Humidity ranged from 60% to 84%. Figures 4, 5 and 6 show the dependence of concentration of $NO_2$, $SO_2$ and $NH_3$ gases on temperature and humidity.

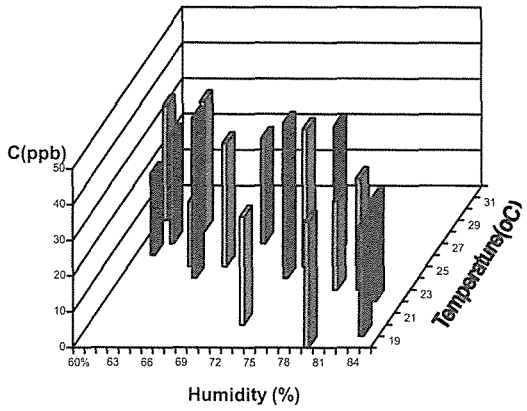


Figure 4. The distribution of $SO_2$ in 26 sampling points in Quang Ninh mine's area with Humidity and Temperature

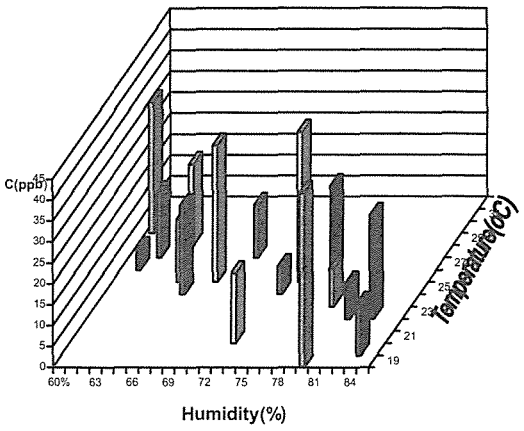


Figure 5. The distribution of $NO_2$ in 26 sampling points in Quang Ninh mine's area with Humidity and Temperature

It can be drawn from the above results (figures 4, 5 and 6) that:

- Normally, when temperature increases, humidity decreases. In Vietnam, however, humidity always remains high even if temperature increases due to the tropical monsoon climate. Nevertheless, humidity and temperature have quite little impact on passive sampler method so the concentrations of $SO_2$, $NO_2$, and $NH_3$ depend mainly on pollution levels of ambient air. This can be considered the great advantage of passive sampler method outlined in the research.

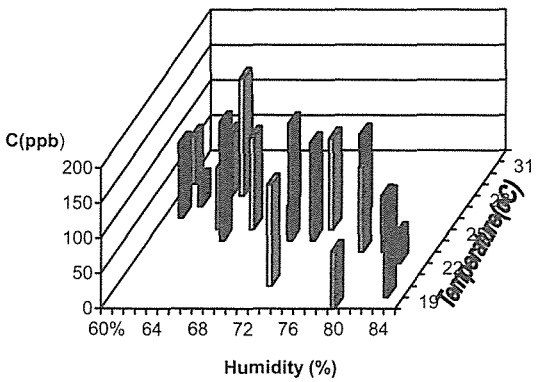


Figure 6. The distribution of $NH_3$ in 26 sampling points in Quang Ninh mine's area with Humidity and Temperature

- Coefficients α $SO_2$, α $NO_2$, α $NH_3$ during 24 hours' period by passive sampler equipment right at Quang Ninh coal exploitation area were defined and applied to calculate the pollution levels in the whole mine area.

There is also another troublesome matter involved with other pollutants such as the dust, total suspended particulate matter. According to table 3, the SPM concentrations in 26 mentioned points are 2 - 20 times higher than given in the Vietnam Standard (TCVN 5937-1995). SPM contamination is being studied by the Vietnamese concerning agencies to find out the treatment to minimize environmental pollution. The carbon dioxide contamination was also determined and their results are shown in table 3.

Table 3. Result of CO and Total Particulate Matter monitoring in Quang Ninh coal mine area (10 - 17 March 2003)

| No | CO ($mg/m^3$) | TPM ($mg/m^3$) | No | CO ($mg/m^3$) | TPM ($mg/m^3$) |
|---|---|---|---|---|---|
| 1 | 0.758 | | 15 | 1.517 | 0.35 |
| 2 | 1.57 | | 16 | 1.707 | 1.232 |
| 3 | 1.246 | 1.12 | 17 | 0.812 | 0.77 |
| 4 | 0.758 | 1.2 | 18 | 0.812 | 0.76 |
| 5 | 0.541 | 0.64 | 19 | 0.746 | 5.31 |
| 6 | 0.596 | 4.65 | 20 | 0.812 | 1.28 |
| 7 | 1.062 | 1.27 | 21 | 0.822 | 0.33 |
| 8 | 1.3 | 3.67 | 22 | 0.54 | 0.21 |
| 9 | 0.812 | 0.42 | 23 | 0.433 | 0.13 |
| 10 | 0.9 | 0.11 | 24 | 1.733 | 3.01 |
| 11 | 0.812 | 0.48 | 25 | 0.921 | 1.02 |
| 12 | 0.921 | 1.412 | 26 | 1.083 | 0.73 |
| 13 | 1.192 | 1.454 | 27 | 1.246 | 0.84 |
| 14 | 1.517 | 0.35 | | | |

Moreover, the content of $CH_4$ in the exploitation area is noticeably high, especially in the mine. There have been many explosions inside the mine, causing serious human and material losses. It is currently installed in mine regions the $CH_4$ measuring system that can notify when $CH_4$ exceeds the threshold. Due to the limited equipment, we cannot carry out the measurement of $CH_4$ parameters.

## Conclusion

1. It is essential to carry out the air quality monitoring in Quang Ninh coal mine.
2. The measured results of $SO_2$, $NO_2$ and $NH_3$ are lower than the Vietnam Ambient Air Quality Standard TCVN 5937 - 1995*
3. Passive sampler equipment produced by Institute of Chemistry, NCST are quite applicable to monitor the air pollution in coal mine areas.
4. Regarding coal exploitation regions, there need be a long-term survey plan.

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The Vietnam Ambient Air Quality Standard TCVN 5937-1995:
Standard of $NO_2$ is 0.1 $mg/m^3$ (appr. 48 ppb)
Standard of $SO_2$ is 0.3 $mg/m^3$ (appr. 105 ppb)
Standard of $NH_3$ is 0.2 $mg/m^3$ (appr. 263 ppb)
Standard of particulate matter is 0.2 $mg/m^3$