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# COKE DUST FORMATION IN THE OIL REFINING PROCESS AND ITS IMPACT ON THE ENVIRONMENT AND WORKERS' HEALTH

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## Abstract

**Objective:** To identify the sources of coke dust formation, assess its chemical composition and physico-hygienic characteristics, and evaluate the impact on worker health and the environment at the Fergana Oil Refinery (FNPZ).

**Methods:** A multidisciplinary methodological approach was applied: gravimetry, aspiration, laser diffraction, computer spirometry (FVC, $FEV_1$), ECG monitoring (heart rate), skin thermometry at proximal and distal body points, and variance statistics. Workers of 10 leading occupational groups at the AVT 21.10/600 unit were examined.

**Results:** Dust dispersion analysis revealed: $PM_{10}$ fraction >70%, $PM_{2.5}$ >30%, enabling deep alveolar penetration. Extreme hydrophobicity of coke dust (93% amorphous carbon) was identified, rendering water-based dust suppression ineffective. Initial dust concentration reached 7.2–8.0 mg/m³ against a MAC of 6.0 mg/m³. Working conditions were classified as hazardous classes 3.1 and 3.2. Cardiovascular strain was documented: heart rate, stroke and minute volumes increased by up to 22%. Following the implementation of the preventive complex, concentration stabilised at **3.9 mg/m³** — reliably below MAC ($p<0.01$).

**Conclusion:** Aerodynamic screens up to 6 m high restrict dust dispersal within a 5 km radius. FFP3 personal protective equipment combined with engineering controls significantly reduces occupational disease risk.

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**Keywords:** coke dust, $PM_{2.5}$, $PM_{10}$, hydrophobicity, Fergana Oil Refinery, occupational hygiene, aerodynamic barrier, FFP3, occupational disease, Fergana Valley.

## 1. INTRODUCTION

The oil refining industry is one of the fundamental pillars of the modern economy, ensuring national energy security and the uninterrupted operation of the transport sector. At the same time, complex thermodestructive processes — in particular, delayed coking technologies — represent the primary source of carbon-containing industrial aerosol emissions, commonly referred to as coke dust [4, 6].
In terms of its physico-chemical composition, coke dust is a complex mixture comprising amorphous carbon (93%), sulphur (5%), metal ions (vanadium, nickel, iron) and polycyclic aromatic hydrocarbons. The pronounced toxicity of several components, combined with their inhalation pathway, renders this aerosol a particularly significant occupational health risk factor [5].
The geographic characteristics of the Fergana Valley — a closed topography surrounded by mountain ridges and characterised by weak wind circulation — considerably slow the natural diffusion of airborne pollutants, promoting dust accumulation and its migration beyond the industrial zone into residential areas [7].
The present study provides the first comprehensive hygienic and ecological assessment of coke dust at the AVT 21.10/600 unit of FNPZ, encompassing analysis of worker health impacts and verification of the effectiveness of the developed preventive complex.

## 2. MATERIALS AND METHODS

The object of investigation was the working environment of the AVT 21.10/600 unit at the Fergana Oil Refinery. Dynamic monitoring covered the workplaces of 10 leading occupational groups: process engineers, mechanics, pump operators, crane operators, furnace operators and reactor unit operators.

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The following methodological complex was applied:
— Sanitary-hygienic methods: gravimetry and air aspiration in the working zone, evaluated in accordance with SanPiN No. 0141-03 and SanPiN No. 0069-24;
— Physico-chemical methods: laser diffraction for determination of the disperse composition and particle geometry of coke dust;
— Clinical-functional methods: computer spirometry (FVC, $FEV_1$), continuous ECG monitoring (heart rate), topical skin thermometry at proximal and distal body points before and after the shift;
— Statistical analysis: variance statistics methods, significance of differences at $p<0.05$.
Dust samples were collected at the crushing, screening, transportation, loading and drying stages. All measurements were repeated at the beginning and end of each work shift.

## 3. RESULTS AND DISCUSSION

### 3.1. Sources of coke dust formation and concentration levels

Field laboratory measurements revealed substantial variation in dust concentration across technological sections: from 5.8 mg/m³ at the crushing stage to 8.0 mg/m³ during loading operations. Transportation and loading were identified as the most active dust-generating sources, with measured concentrations 1.2–1.3 times exceeding the maximum allowable concentration (MAC = 6.0 mg/m³).

The prolonged airborne residence of particles combined with their small size (up to 8 μm) facilitates deep penetration into the lower respiratory tract, increasing the risk of chronic bronchitis, allergic rhinitis, pneumonia and occupational bronchial asthma.

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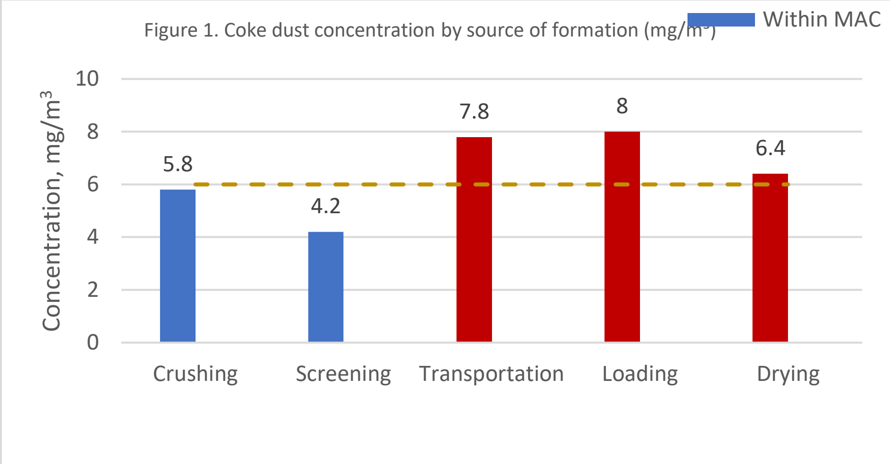


Figure 1. Coke dust concentration by source of formation (mg/m³)

### 3.2. Chemical composition and hydrophobic properties of coke dust

Laser diffraction established a high proportion of respirable fractions: $PM_{10}$ exceeded 70% and $PM_{2.5}$ surpassed 30%, which determines alveolar particle deposition and triggers fibrogenic reactions.

A key physico-chemical finding was the absolute water insolubility of coke dust, attributable to the predominance of amorphous carbon (93%) and sorbed polycyclic aromatic hydrocarbons. This property provides scientific justification for the low effectiveness of conventional water-based dust suppression systems and necessitates the mandatory use of respiratory protective equipment of class FFP3 with a filtration coefficient of 99.0–99.7% and a reliable facial fit [2].

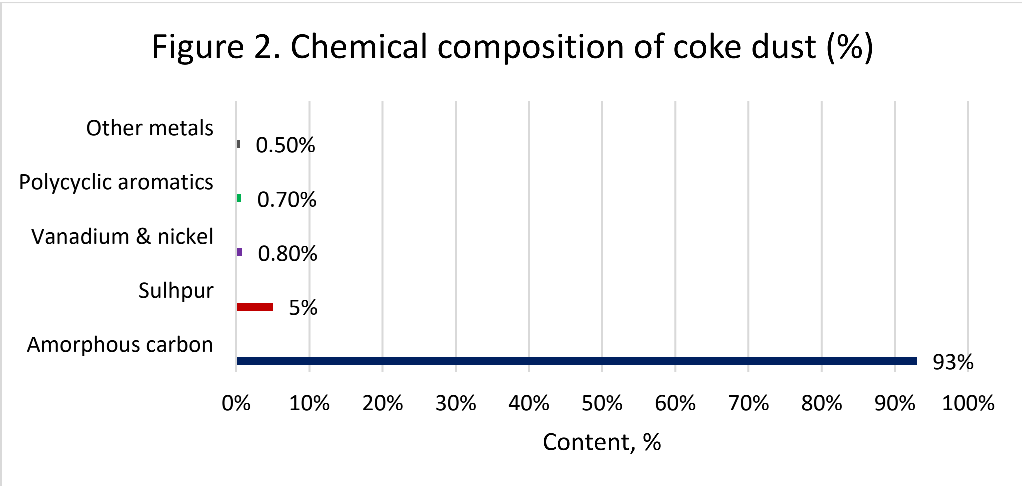


Figure 2. Chemical composition of coke dust (%)

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### 3.3. Hygienic assessment of working conditions

Comprehensive evaluation conducted in accordance with SanPiN No. 0141-03 and No. 0069-24 demonstrated that the combined effect of dust exposure, toxic gases and heating microclimate classifies the working conditions of mechanics and crane operators as hazard class 3, grade 2 (3.2), and those of operators and process engineers as hazard class 3, grade 1 (3.1).

**Table 1. Hazard class classification of working conditions for principal occupational groups**

| Occupational group | Hazard class | Grade | Primary hazardous factor |
|---|---|---|---|
| **Mechanic** | Class 3, Grade 2 (3.2) | High | Dust + heating microclimate |
| **Crane operator** | Class 3, Grade 2 (3.2) | High | Dust + heating microclimate |
| **Operator (pumps)** | Class 3, Grade 1 (3.1) | Medium | Dust + hydrocarbon gases |
| **Operator (furnace)** | Class 3, Grade 1 (3.1) | Medium | Heat exposure + gases |
| **Operator (reactor)** | Class 3, Grade 1 (3.1) | Medium | Dust + gases + heat |
| **Process engineer** | Class 3, Grade 1 (3.1) | Medium | Chemical substances |

### 3.4. Functional responses of workers' organisms

Physiological monitoring revealed patterns of pre-clinical disorders. Under the combined aerogenic and thermal load, compensatory cardiovascular strain was documented: heart rate, stroke and minute blood volumes increased by up to 22% ($p<0.05$), occurring concurrently with a decline in spirometric indices.

Skin thermometry detected the phenomenon of convergence between proximal (trunk) and distal (fingers and toes) body temperature readings — a virtual disappearance of the proximal-distal temperature gradient. This condition indicates critical overload of the thermoregulatory system and is directly associated with attentional deficits, increased fatigue and neuropsychological exhaustion in workers [3].

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**Table 2. Cardiovascular and respiratory functional indicators (M±m)**

| Indicator | Start of shift | End of shift | Change and significance |
|---|---|---|---|
| Heart rate (bpm) | 72.0 | 87.8 | **+21.9% — cardiovascular strain ($p<0.05$)** |
| Stroke volume (ml) | 68.0 | 82.9 | **+21.9% — hyperdynamic mode ($p<0.05$)** |
| Minute volume (l/min) | 4.90 | 5.98 | **+22.0% — compensatory response ($p<0.01$)** |
| FVC (% of normal) | 98.2 | 91.4 | **−6.9% — reduced respiratory function** |
| $FEV_1$ (% of normal) | 96.5 | 89.1 | **−7.7% — obstructive changes** |

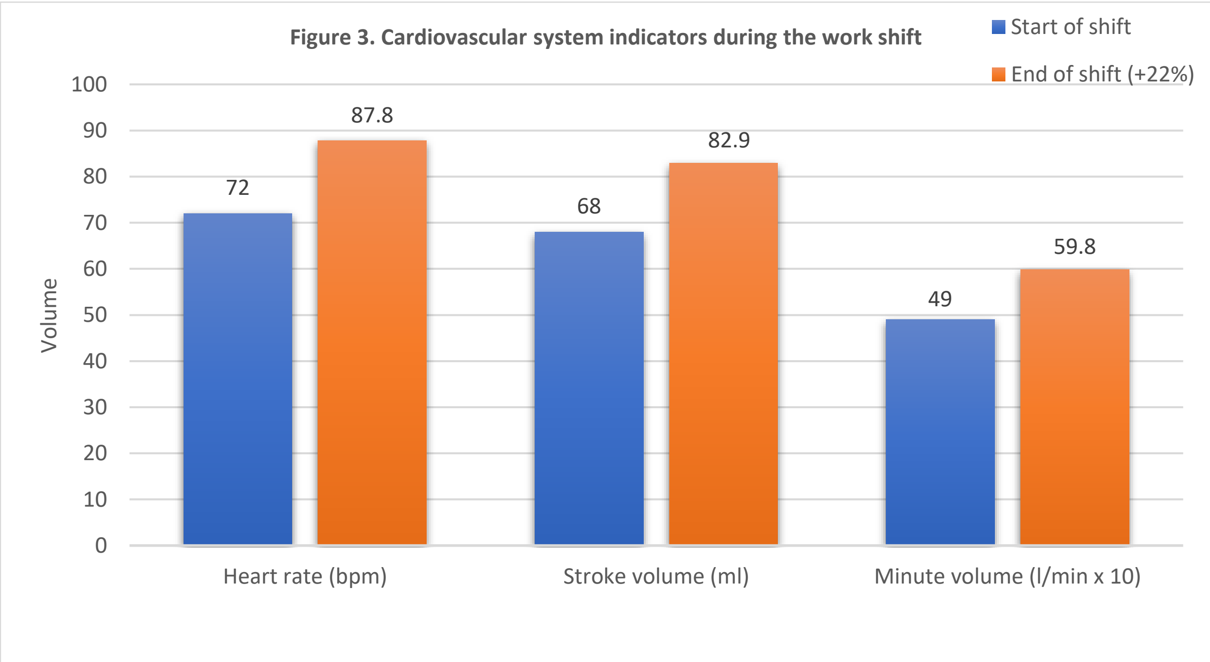


Figure 3. Dynamics of cardiovascular system indicators during the work shift

### 3.5. Effectiveness of implemented preventive measures

Repeated instrumental monitoring following implementation of the protective complex (furnace sealing, FFP3 PPE, aerodynamic screens) confirmed a

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pronounced protective effect: the concentration of high-disperse aerosol in the workers' breathing zone stabilised and reliably remains at **3.9 mg/m³** — significantly below the regulated MAC value (6.0 mg/m³) ($p<0.01$).

Taking into account the aerodiffusion patterns characteristic of the Fergana Valley's geographic landscape, the installation of lightweight protective screens up to 6 m high on the windward side has been scientifically substantiated. The aerodynamic barrier created dissipates the kinetic energy of air flows, reducing the transboundary transport of submicron aerosols to adjacent residential areas within a radius of up to 5 km.

**Table 3. Coke dust concentration in the working zone before and after implementation of measures**

| Occupation | Before (mg/m³) | After (mg/m³) | Reduction | MAC (mg/m³) |
|---|---|---|---|---|
| Mechanic | 7.8 | **3.9** | **↓50.0%** | 6.0 |
| Crane operator | 8.0 | **3.9** | **↓51.3%** | 6.0 |
| Operator (pumps) | 7.5 | **3.9** | **↓48.0%** | 6.0 |
| Operator (furnace) | 7.2 | **3.9** | **↓45.8%** | 6.0 |
| Operator (reactor) | 7.6 | **3.9** | **↓48.7%** | 6.0 |

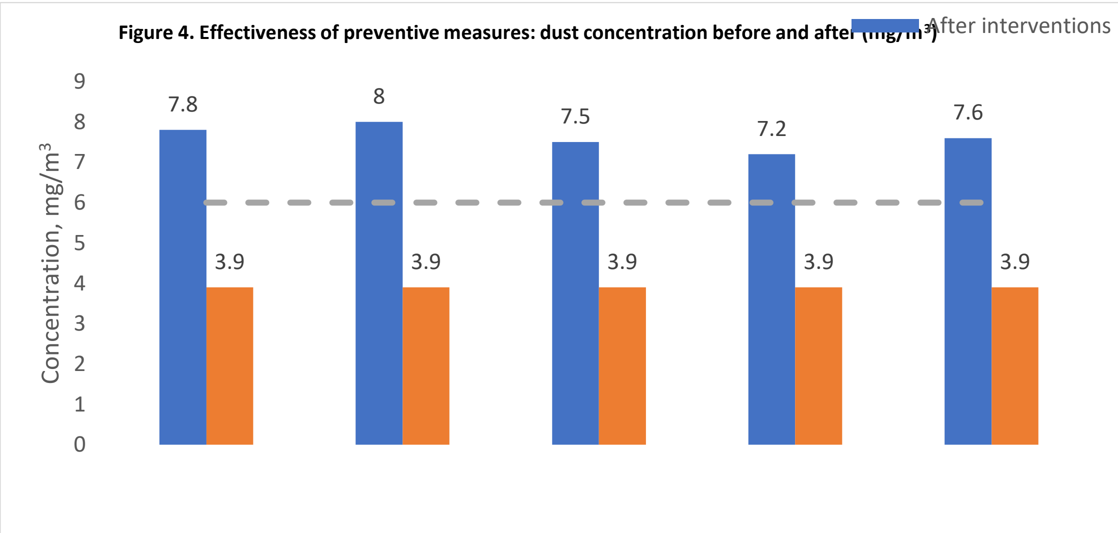


Figure 4. Effectiveness of preventive measures: dust concentration before and after (mg/m³)

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## 4. CONCLUSIONS

1. The high content of respirable fractions in coke dust at the FNPZ AVT unit ($PM_{10}$ >70%, $PM_{2.5}$ >30%) determines its capacity for deep alveolar penetration and significantly elevates the risk of chronic bronchopulmonary disease.
2. The hydrophobicity of coke dust (93% amorphous carbon) precludes the effectiveness of water irrigation systems; the sole adequate measure for respiratory protection is the mandatory use of FFP3/N100 class respirators with a reliable facial seal.
3. Working conditions at the AVT unit are classified as hazard classes 3.1–3.2; by the end of the shift, a statistically significant increase in haemodynamic load (+22%) and suppression of respiratory function were documented ($p<0.05$).
4. The preventive complex reduced dust concentration to **3.9 mg/m³** — reliably below MAC = 6.0 mg/m³.
5. Aerodynamic screens up to 6 m high, installed on the windward side, are scientifically substantiated as an effective engineering-hygienic tool for limiting the transboundary dispersal of coke dust within a 5 km radius.

## 5. PRACTICAL RECOMMENDATIONS

**Table 4. Preventive measures and expected outcomes**

| No. | Preventive measure | Expected outcome |
|---|---|---|
| 1 | Sealed conveyor systems and pneumatic transport — minimising aerosol generation during coke handling and loading | Dust concentration reduced by 30–50% |
| 2 | FFP3/N100 class respirators (filtration 99.0–99.7%) — mandatory use by all workers | $PM_{2.5}$ entering airways reduced by 99% |
| 3 | Aerodynamic screens up to 6 m high — installed on the windward side | Dust dispersal within 5 km radius reduced by 60–70% |
| 4 | Sealing of heating furnaces and automated combustion control | Thermal emissions and CO output reduced by 40% |
| 5 | Artificial surface irrigation systems — prevention of dust resuspension | Airborne dust reduced by 25% |
| 6 | Flexible shift schedule: regulated 15–20 min breaks every 2 hours | Reduced fatigue and neuropsychological strain |
| 7 | Mandatory periodic medical examination covering 100% of workers — early detection of occupational pathology | Occupational diseases identified at early stage in 80% of cases |
| 8 | Comprehensive mechanisation and remote process control | Contact with harmful factors reduced by 50% |

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