

# Functional Diagnosis of Respiratory Efficiency of Cokery Mill Employees Working in a Polluted Atmosphere

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## Abstract

Reaction of the airways to inhaled Berodual was evaluated in two groups of metallurgists surveilled by systematic, complex medical examinations for appx. 25 years: 31 coke oven and 31 cold-rolling mill workers. All subjects under examination were active smokers, smoking more than 20 cigarettes a day. The frequency of ventilatory disorders (central bronchi obturation, small bronchi obturation, and emphysemal changes) and the microclimatic conditions of their living places (even mean anthropometric indices) were similar. The main differentiating factor was the presence of air pollutants in their workshops. Employees of the coke oven division were exposed to a variety of noxious substances: CO, NO<sub>x</sub>, SO<sub>2</sub>, benzene (and its derivatives), HCN, and polycyclic aromatic hydrocarbons. In the cold rolling division concentration of air pollutions was much smaller and virtually devoid of BaP. As revealed by Berodual, the provocation test in coke oven workers irreversible obturation and fixed emphysemal changes were far more frequent than in workers of cold rolling mill performing their jobs in favorable microclimatic conditions.

**Keywords:** coke oven workers, cold-rolling mill workers, flow-volume curve, inhalations of *Berodual*, irreversible obturation, fixed emphysemal changes

## Introduction

Environmental pollution and smoking of cigarettes often results in recurrent infections playing an important role in incidences of chronic obstructive pulmonary disease - (COPD) [3, 13, 22]. These factors are responsible for spastic constriction of bronchial muscles, resulting in a diminishing of the bronchioli diameter. The same effect is caused by hypertrophy of bronchial mucosa due to chronic bronchitis or diminishing elasticity of bronchial wall and lung tissues characteristic for emphysema, another dysfunction of lungs contributing to COPD [28].

Diagnosis of COPD is based on detailed anamnesis, physical examination and diagnostic tests [7, 28]. Recording of the flow-volume curve (used generally to detect bronchial obturation) belongs to the most important tests

allowing detection of COPD even when affected subjects do not report symptoms of pulmonary malfunction. This stage of chronic obstructive pulmonary disease is called "small bronchial disease" (SBD) [28]. In SBD decrease of flow rate in small diameter bronchioli (less than 2 mm) is evidenced by the characteristic shape of the flow-volume curve, whereas well-known spirometric tests such as Forced Vital Capacity (FVC) and Forced Expiratory Volume in 1sec (FEV<sub>1</sub>) are temporary still in a normal range. In later stages of COPD obturation of wider bronchi also plays a very important role, evidenced by decrease of FEV<sub>1</sub> and increase of airway resistance ( $R_{aw}$ ).

Worsening of pulmonary efficiency leading to COPD may be aggravated by the synergic action of smoking and air pollution in workshop or/and place of living [3]. Smoking employees of the cokery plant and those who work in

chemical processing of coal are in such a situation exactly. They are exposed to high temperature, industrial dust and harmful aerosoles. In their workshops excessive amounts of CO, NO<sub>x</sub>, SO<sub>2</sub>, benzene (and its derivatives), HCN and polycyclic aromatic hydrocarbons are present [5, 18].

Many years of systematic survey of health conditions of the employees of Steel Mill "Nowa Huta" proved that in the population of the cokery plant (CP) workers, frequency of emphysema and bronchial spastic states is higher than in comparable group of workers matched by age, stage of work and smoking habit, but not exposed to pollutants [17, 18].

The aim of this study was to find out whether obturation or emphysemal changes of the lungs were reversible as judged by airway reaction to bronchi-relaxing drug.

## Material and Methods

The subjects of this study were men working in a coking plant (Huta Sendzimir Steel-Mill, Cracow, Poland) as the operating personnel of cokery batteries. The first examination in the standardized conditions of 24-hour clinical hospitalization was performed during the period of 1972-1974. The group then consisted of 421 men comprising all employees of that division. All subjects under examination were active smokers, smoking more than 20 cigarettes a day. In 1989-1990 examinations were repeated on the group of 199 oven workers (subjects of previous examination) still working in this division. In 1997, all men who continued to work in cokery plant since 1970 and still smoking were called again for a detailed study. Those criteria were fulfilled by only 55 men. From that group, 31 men (56%) - aged  $55.7 \pm 9.1$  (SD) years; height  $172.4 \pm 6.6$  cm — had ventilatory disorders. These men were the subjects of the first group of the present study.

Among employees of a cold rolling Mill (CRM), 31 men aged  $57.1 \pm 8.6$  years; height  $171.9 \pm 5.9$  cm with similar ventilatory disorders matched for age, stage of work and stage as a active smokers, but working in favorable hygienic conditions, were chosen as subjects of the second (control) group.

All men under investigation were clinically healthy. Biochemical tests were performed by standard laboratory methods including ALAT, ASPAT, Gamma Glutamyl--Transpeptidase, alkaline phosphatase, bilirubin concentration, blood urea nitrogen, (Xi-antitripsin level and creatinine in blood serum and were within normal limits. Fifteen hematological parameters obtained from a Cell-Dyn 1500 analyser (Abbot, USA) did not reveal any abnormalities.

The concentration of gaseous irritants in the workshop of both examined groups and the concentration of industrial dust are shown in Table 1.

In the coking plant the concentration of sulphur dioxide exceeded the threshold limit value. Also, concentrations of nitric oxides were higher than that measured in the cold rolling mill. Both concentration of total dust and benzo(a)pyrene (BaP) were significantly higher in the coking plant than in the cold rolling mill environment. Mean geometric diameter of dust particles corresponded to the respirable fraction.

All the subjects answered questions of the Questionnaire of Medical Research Council [9] extended to a smoking habit, then underwent routine medical examination, electrocardiography, as well as x-ray chest examination. Blood was obtained by venipuncture after overnight fast. The values of ventilatory parameters: FVC, FEV<sub>1</sub>, and FEF<sub>25/75</sub> (Forced Expiratory Flow measured between 25% and 75% of FVC) and flow-volume curve were recorded by a computer-aided „Screenmate" spirometer manufactured by Jaeger (FRG). The measurements of respiratory resistance (R<sub>aw</sub>) and thoracic gas volume (TGV) were obtained from whole using a „Pulmostar SMB" body plethysmograph manufactured by Godart (Holland). All examinations were performed in the morning (9:00-11:00) by the same experienced technician. The results were compared with predicted values (N) for gender, age and anthropometric indices. Values higher than 70% of the predicted ones were regarded as being within normal limits, whereas values lower than 70% of N were pathologic. Also, values of R<sub>aw</sub> higher than 0.22 kPa /dm<sup>3</sup>/s were regarded as pathologic.

The results of tests listed above were taken as a baseline. Immediately after completing these tests, inhalations of BERODUAL (Hoehst, GFR) were done in both examined groups.

Berodual is a cholinolytic, bronchodilating drug, containing per 1 ml of solution 0.5 mg of fenoterol hydrobromicum (Berotec) and 0.25 mg of ipratropium bromide (Atrovent), acting as α<sub>2</sub>-receptor stimulator. Two doses of aerosol were inhaled in two consecutive inspirations using metering inhalator. Fifteen minutes after inhalations, a flow-volume curve was recorded, then 45 minutes and 3 hours after inhalations all mentioned earlier spirometric tests were repeated. Reversible obturation of airways was diagnosed if both FEV<sub>1</sub> and FEF<sub>25/75</sub> increased after Berodual inhalation 15% or more and simultaneously R<sub>aw</sub> values decreased at least 25% of the initial value. A threshold of 25% was chosen due to large variation of this parameter in different populations studied previously [16, 26]. Reversible obturation of central bronchi (an inside measurement

Table 1. Environmental monitoring data in coking plant (CP) and cold rolling mill (CRM).

	SO <sub>2</sub>	NO <sub>x</sub>	H <sub>2</sub> S	CO	Total dust SiO <sub>2</sub> = 2-50%	BaP
	(mg/m <sup>3</sup> )					(µg/m <sup>3</sup> )
Threshold Values	2.0	5.0	10.0	30.0	4.0	2.0
CP Range	3.5 – 7.9	0.5 – 3.2	2.8 – 10.5	3.0 – 19.5	8.3 – 40.2	1.3 – 60.4
CP Mean	5.2	1.86	5.4	10.6	25.0	30.8
CRM Range	0.8 – 2.0	0.1 – 2.9	0.5 – 4.8	0.0 – 0.3	2.8 – 10.5	0.1 – 0.2
CRM Mean	1.6	1.15	2.7	0.1	4.0	0.15

Table 2. Incidence of ventilation disorders in the group of 31 workers of the cokery plant (CP) and 31 employees of the cold rolling mill (CRM). Subjects of both groups were active smokers, smoking at least 20 cigarettes a day.

Type of ventilatory disorders	CP		CRM	
	n	%	n	%
Central Bronchi Obturation	5	16.1	6	19.3
Central Bronchi Obturation + Small Bronchi Obturation	11	35.5	10	32.3
Central Bronchi Obturation + Emphysema	15	48.4	15	48.4

higher than 2 mm) was diagnosed if FEV<sub>1</sub> increased more than 15%, and simultaneously R<sub>aw</sub> decreased at least 25%. Small bronchi (an inside measurement smaller than 2 mm) obturation was diagnosed if FEF<sub>25/75</sub> increased by 15% or more. Emphysemal changes were regarded as fixed if TGV values diminished after inhalations less than 15%.

The significance of differences between arithmetic means obtained from the two examined groups were checked using the nonparametric Mann-Whitney test.

## Results

According to the criteria outlined in the previous section, results of ventilation laboratory tests allowed evaluation of pulmonary disorders seen in the studied groups of workers (Table 2).

All 31 employees of CP had central bronchi obturation, but eleven persons from that group also had obturation of small-diameter bronchioli. Fifteen persons had coincidence of central bronchi obturation and emphysemal changes in their lungs. The frequency of ventilation disorders in the reference group and CP workers was almost identical.

The obtained results for the CP group before and after Berodual challenge are presented in Table 3.

The statistical analysis presented in Table 3 revealed no significant differences between arithmetic means of values before and after inhalations, except R<sub>aw</sub> values significant at the 0.05 level.

The obtained results for the CRM group are presented in Table 4.

The changes of respiratory parameters following Berodual challenge in the group of CRM workers was statistically significant (except FVC values).

In Fig. 1 it is evident that irreversible obturation and fixed emphysemal changes were more frequent in CP workers than in CRM workers.

Table 3. Values of ventilatory parameters obtained for cokery plant employees (CP) before and after 45 minutes following Berodual inhalations.

Ventilatory Parameter	CP Before Inhalations				CP After Inhalations				p ≤
	x	SD	Med	%INV	x	SD	Med	%INV	
FVC (ml)	3180	510	3290	66	3580	540	3610	74	ns
FEV <sub>1</sub> (ml)	2320	460	2420	63	2510	430	2610	68	ns
FEF <sub>25/75</sub> (l/s)	2.02	0.49	2.05	65	2.20	0.51	2.27	70	ns
TGV (ml)	4120	630	4180	120	3800	610	3820	103	ns
R <sub>aw</sub> (kPa/dcm <sup>3</sup> /s)	0.35	0.12	0.37	140	0.28	0.13	0.30	116	0.05

x – arithmetic mean; Med. – median; SD – standard deviation; % INV – % of individual normal values; ns – not significant

Table 4. Values of ventilatory parameters obtained for the cold rolling mill employees (CRM) before and after 45 minutes following Berodual inhalations.

Ventilatory Parameter	CRM Before Inhalations				CRM After Inhalations				p ≤
	x	SD	Med	%INV	x	SD	Med	%INV	
FVC (ml)	3240	550	3510	68	3780	510	3810	74	ns
FEV <sub>1</sub> (ml)	2410	480	2530	61	2790	460	2830	70	0.05
FEF <sub>25/75</sub> (l/s)	1.99	0.58	2.03	64	2.38	0.54	2.41	74	0.05
TGV (ml)	4330	690	4300	115	3580	640	3680	98	0.01
R <sub>aw</sub> (kPa/dcm <sup>3</sup> /s)	0.33	0.11	0.36	132	0.26	0.12	0.27	105	0.05

x – arithmetic mean; Med. – median; SD – standard deviation; % INV – % of individual normal values; ns – not significant

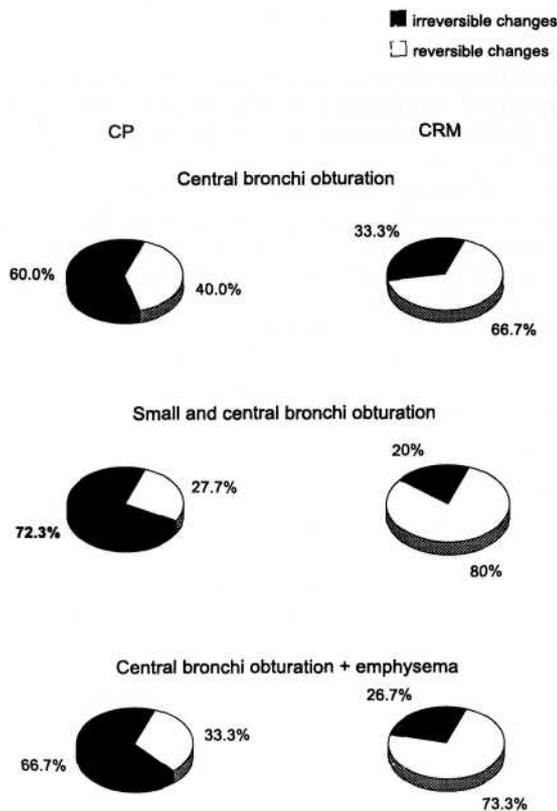


Fig. 1. The outcome of airway reactions to inhaled *Berodual* in the group of coke oven workers (CP) and in the group of cold rolling mill workers (CRM).

The number of persons with central bronchi obturation and emphysemal changes was equal in comparabled groups of workers ( $n = 15$ ). Research shows that ten workers of the group consisted of employees of the coking plant (CP) suffered irreversible obturation and emphysemal changes whereas five workers had reversible changes. Opposite effects were observed with cold rolling mill (CRM) workers. Only four employees had irreversible changes and eleven workers had reversible change.

## Discussion

The influence of environmental pollution on the health of coking plant employees working at their position for many years is well known [5, 10, 18]. Biological consequences of long-term exposure to harmful contaminants of the workplace affects many organs. There are well documented disturbances of the digestive tract [20, 23], central nervous system [19], circulation [27] and immunological defence mechanisms [4, 29]. In our previous study it was found that coke oven workers exposed to a complex mixture of air pollutants (composed primarily of polycyclic aromatic hydrocarbons) suffer immunosuppression [29]. It remains to be determined whether this immunosuppression is related to the frequent development of lung cancer reported in coke plant employees [5, 6, 8, 10]. It was also shown that the incidence of bronchial carcinoma is higher in the group of persons with obturative changes than in subjects

matched for age, gender and smoking stage, but with normal ventilatory function [31].

It was shown that all employees from of the steel-mill "Nowa Huta," particularly coking plant workers, had the highest contribution to the coefficient of morbidity of diseases of airways [15]. Frequency of chronic bronchitis and obturation of central and small bronchi was higher in coke oven workers than in the group of men employed for the same period of time under favorable microclimatic conditions [17]. About 80% of examined coke oven workers showed a decline of ventilatory parameters greater than expected after correction for aging [17].

Excessive spastic reaction of respiratory tract evidenced by a 20% decrease of FEV<sub>1</sub> and FEF<sub>25/75</sub> with simultaneous increase of  $R_{aw}$  after the work-shift was found in examination of coke plant employees. This excessive spastic reaction was observed in some workers with obturation diagnosed before shift and also in appx. 10% of healthy subjects [16]. As the result of eight-hours of exposure to contamination of the workshop environment, a decrease in the values of ventilatory parameters was greater for smokers than for non-smoking CP employees [16].

The habit of smoking is regarded by many authors as the most important factor for developing obstructive lung disease [7, 13, 26]. In the present study, smoking frequency was almost exactly the same in both groups. Namely, all subjects under examination were active smokers, smoking more than 20 cigarettes a day. Microclimatic conditions of their living places, socio-economic level, nutrition preferences, even mean anthropometric indices were similar. The only differentiating factor (as has been pointed out several times) was the microclimatic conditions in workshops. CP employees were exposed to a variety of substances noxious for the respiratory tract. Though nitric oxide is an important mediator of inflammatory responses in the lung and a key regulator of bronchomotor tonus, nitric oxides inhaled in the polluted atmosphere are known pathogens. Respiratory epithelial cells are key inflammatory cells in the airway, functioning in a host defense and potentially playing a role in airway inflammation [11]. In inflamed tissue, nitric oxide quickly reacts with superoxide anion, resulting in the formation of the toxic peroxynitrite which promotes lipid and sulfhydryl oxidation [21]. Nitrogen dioxide can also cause bronchospasm, and acute and chronic obstructive lung disease. It may also increase susceptibility to respiratory virus infection [3]. The exposure to low concentrations of nitrogen oxide even below the upper limit of the treshold value produces chronic symptoms of respiratory disease and leads to obturation of small and large bronchi [14]. Workers chronically exposed to sulfur dioxide may develop chronic bronchitis [24]. Results of the present study showed that workers exposed for many years to airborne mixed harmful contaminants in the workshop had irreversible obturation and fixed emphysemal changes far more frequently than workers performing their jobs in favorable microclimatic conditions.

It should be stressed that several years ago chronic pulmonary obstructive disease was regarded as an irreversible narrowing of the air tract. Only asthma was regarded as a reversible disease [1]. At present, asthma is defined as an inflammatory disease of airways concomitant with constriction of bronchi and secondary to supersensitivity of that tissue. In contrast to that, the predominant mechanism of chronic emphysemal changes is constriction of the bron-

chial tree. Therefore, it seems feasible to use inhalations of bronchodilator in order to distinguish between reversible and irreversible obturation of airways [3, 13, 30]. It is known that anticholinergic drugs (e. g. Atrovent - one of the components of Berodual) decreasing activity of cholinergic system are able, at least partially, to avert emphysema by widening the diameter of the bronchial tree [28]. It was also found by other authors [2, 12, 25], that bronchodilatory activity of Berodual was faster, stronger and longer in comparison to Fenoterol and Ipratropium Bromide (Atrovent and Berotec) in chronic obstructive pulmonary disease. The results of the present study fully confirm opinion that metered inhalations of Berodual may be helpful in differentiating reversible from irreversible constrictions.

### Conclusion

Irreversible obturation and fixed emphysemal changes were more frequent in cokery workers exposed chronically to harmful contaminants of the workplace than in the group of cold-rolling mill workers matched for age, gender and smoking habit, but working in favorable microclimatic conditions. For that diagnosis, inhalations of Berodual (Hoest) seem to be helpful.

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