

## CHRONIC EFFECTS OF ENVIRONMENTAL BIOMASS SMOKE ON LUNG HISTOPATHOLOGY IN TURKISH NON-SMOKING WOMEN: A CASE SERIES

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Biomass is widely used for fuel in developing countries. Particles and gases of biomass burning may cause changes in the lung. In this prospective study we investigated histopathological changes in the lungs of 42 non-smoking women [mean age (59±10) years] caused by biomass smoke. We evaluated exposure to biomass smoke, case histories, and the findings of physical examination, radiology, bronchoscopy, and lung histopathology. Mean exposure to biomass smoke was (28±9) hour-year (1 hour-year equals 365 hours of exposure per year with average exposure of 1 hour a day). The radiological findings were mass (42 %), reticulonodular opacities (31 %), mediastinal lymphadenopathy (26 %), pleuro-parenchymal fibrotic banding (19 %), widening of the pulmonary artery (14 %), ground glass (11 %), mosaic perfusion (9 %), consolidation (9 %), segmental or subsegmental atelectasis (7 %), and bronchiectasis (7 %). The patients were diagnosed with lung cancer (35 %), interstitial lung disease (31 %), sarcoidosis (9 %), tuberculosis (9 %), chronic obstructive pulmonary disease (4 %), chronic bronchitis (9 %), and metastasis (4 %). Bronchoscopy showed pilies, oedema, erythema, bronchus narrowing, endobronchial tumour, mucosal irregularity, increased vascularisation, blue-black anthracotic plaques, mucosal oedema, and purulent secretion. Transbronchial biopsies revealed neutrophil and lymphocyte leucocytes in the perivascular, peribronchiolar, and interalveolar septa, slightly enlarged connective tissue, thickening of the basal membrane, thickening of interalveolar septa, intimal and medial thickening of the vascular wall and vascular lumen narrowing, anthracosis between the cells and in the bronchiole epithelium. These findings confirm that biomass smoke has important toxic effects on the lung parenchyma, interstitium, and pulmonary vessels that may result in malignancies.

**KEY WORDS:** *biomass smoke exposure, bronchoscopy, histopathological changes, lung diseases*

Heat releasing sources composed of biological material are called biomass'. Burning biomass and poor indoor air exchange may cause chronic lung diseases, interstitial lung disease, and cancer. The use of biomass in Turkey is common due to social, economic, and cultural reasons.

The most important aetiological factor in biomass-related disease is the pollutant being released (1-3). In suburban areas of Turkey women who make fire, bake, and cook with biomass primarily composed of cowpat are exposed to its smoke. that may contain harmful pollutants such as aldehydes, phenols, and

toluene (4, 5). Incomplete burning of animal waste also releases CO, NO<sub>2</sub>, and SO<sub>2</sub> (5). Exposure in this population, who are poor and have little access to healthcare services, is often associated with chronic lung damage and respiratory infections.

Our earlier experimental study (6) showed histopathological changes in the trachea and the lungs of rats exposed to biomass smoke for one hour a day for three, six, and nine months. Histopathological findings included lymphocyte, eosinophil, and macrophage infiltrations in the interstitium, small papillary structures in the airway mucosa, thickening of the intima and media of the pulmonary vessels, narrowing of pulmonary vessel lumens, and papillary adenomatous proliferation of the mucosa (6).

The aim of this study was to determine if similar changes occurred in human lungs after biomass smoke exposure. The number of studies which include bronchoscopy in people exposed to biomass smoke is very small and we hoped to fill in this gap by analysing histopathological findings in transbronchial tissue samples from women who had bronchoscopy performed and who were exposed to biomass smoke.

## MATERIALS AND METHODS

This prospective study was approved by bioethics committees of the Yuzuncu Yil University Faculty of Medicine, and observed the Declaration of Helsinki. It was carried out between January 2007 and September 2009 in 42 women who had pathological findings on lung roentgenograms. The women were exposed to biomass smoke for various hour-years (1 hour-year equals 365 hours of exposure per year with average exposure of 1 hour a day). Biomass exposure in the absence of other pollutant exposure is rare in men, and we excluded male patients from the study. Women who smoked tobacco and were exposed to biomass smoke were also excluded from the study. All of the patients lived in the countryside, which excludes an influence of metropolitan atmospheric air pollution to a reasonable extent.

Cigarette smoking and biomass exposure were determined by interview. The length of exposure to biomass smoke was expressed in years and the density of exposure in hours per day. Total exposure is therefore expressed in hour-years.

Posterior-anterior lung roentgenograms and findings of computed tomography (CT) scans were

analysed to confirm that the patients met our inclusion criteria.

Bronchoscopy was performed in all of the patients included in the study according to our diagnostic algorithm. All patients signed an informed consent form before the procedure. They were also tested for platelet count, prothrombin time, and partial thromboplastin time. The patients underwent bronchoscopy after a four-hour fast and remained in the same operation room with resuscitation equipment ready throughout the procedure. Those experiencing a bronchospasm received a bronchodilator. For local anaesthesia they received an 8 mg kg<sup>-1</sup> dose of 2 % lidocaine solution in spray. The nasal passageway was preferred for the use of fiberoptic bronchoscope (Olympus, Center Valley, PA, USA). Patients were monitored by pulse oximetry. Macroscopic findings were recorded. Transbronchial biopsy was collected from sub-lobe basal segments of patients with interstitial changes and common lesions, and from the lobes with limited lesions. Three hours after the transbronchial biopsy, a posterior-anterior lung roentgenogram was taken to exclude pneumothorax. Forceps biopsy was performed in patients with endobronchial lesions, and transbronchial needle aspiration biopsy in patients with mediastinal lymphadenopathy. Bacteriological and cytopathological analyses were performed on the bronchial lavage and biopsy samples. Anthracotic changes, inflammatory infiltration, thickening at alveolar septum, fibrosis, and malignancies were assessed by an experienced pathologist. Photos of histopathological samples were taken microscopically.

Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as number and percentage. To determine the difference between the diagnostic groups in terms of continuous variables, we used the Mann-Whitney *U* test. To determine the relationships between the diagnostic groups and other categorical variables, we used the chi-square test and calculated the odds ratio. Statistical significance was set at *P*<0.05. Data were processed using the SPSS (version 16) statistical software.

## RESULTS

The age, biomass exposure, bronchoscopy findings, and diagnosis for individual patients are shown in Table 1. Average biomass exposure years and total

**Table 1** Age of the patients, duration of exposure to biomass smoke, bronchoscopy findings, and diagnosis

Age / years	Biomass exposure / hour-years	Years of exposure	Bronchoscopy findings	Diagnosis
36	8.5	11	Normal	Chronic bronchitis
59	25.7	35	Narrowing in the orifice of apicoposterior segment of the left upper lobe	Chronic bronchitis
51	25.7	29	Anthracotic plaque in the orifice of right upper lobe	Chronic bronchitis
69	38.5	45	Hyperaemia and swelling in the lingular segment of the left upper lobe	Chronic bronchitis
63	21.4	30	Normal	Chronic bronchitis+ILD
60	34.2	35	Normal	Chronic bronchitis+ILD
70	51.4	43	Anthracotic plaque in the orifice of right upper lobe, and pale mucosa	Chronic bronchitis +ILD
59	34.2	33	Normal	COPD+ILD
61	34.2	36	Normal	COPD+ILD
51	14.2	30	Mass in the lingular segment of the left upper lobe	Oesophageal cancer
43	25.7	15	Normal	ILD
69	25.7	41	Mucosal erythema and oedema	ILD
54	25.7	32	Normal	ILD
65	38.5	40	Widespread anthracosis and swelling in mucosa	ILD
77	42.8	50	Normal	ILD
69	42.8	37	Widespread anthracotic plaques	ILD
63	17.1	31	Indirect tumour findings in left bronchial system	ILD+PE
64	17.1	29	Narrowing in the orifice of right middle lob	Lung cancer
65	17.1	32	Anthracosis and narrowing in the orifice of anterior segment of right upper lobe	Lung cancer
57	17.1	28	A mass in right middle lobe	Lung cancer
58	17.1	35	A mass in right main bronchus	Lung cancer
46	21.4	20	A mass in left main bronchus	Lung cancer
57	25.7	32	A mass in right main bronchus	Lung cancer
71	25.7	50	A mass in the intermediary bronchus	Lung cancer
58	30.0	32	A mass in the intermediary bronchus	Lung cancer
43	30.0	18	A mass in the intermediary bronchus	Lung cancer
55	34.2	31	Narrowing in the orifice of right upper lobe	Lung cancer
66	34.2	43	A mass in left main bronchus	Lung cancer
65	38.5	40	Paralysis of left vocal cord and mass in left main broncus	Lung cancer
74	42.8	51	Submucosal swelling and narrowing in the orifice of right upper lobe	Lung cancer
76	42.8	60	Total obstruction in right lower lobe bronchus	Lung cancer
68	42.8	41	Narrowing in the orifice of left upper lobe	Lung cancer
68	38.5	39	Normal	Pancreatic cancer
34	1.1	14	Normal	Pneumonia
50	21.4	29	Subcarinal enlargement	Sarcoidosis
53	25.7	31	Subcarinal enlargement	Sarcoidosis
54	25.7	33	Subcarinal enlargement	Sarcoidosis
56	34.2	29	Subcarinal enlargement	Sarcoidosis
45	25.7	17	Erythema in the orifice of right lower lobe	Tuberculosis
59	25.7	40	Normal	Tuberculosis
55	30.0	35	Narrowing in the orifice of posterior and anterior segments of right upper lobe	Tuberculosis
67	34.2	42	Anthracosis and obstruction in the orifice of superior segment of right lower lobe	Tuberculosis

COPD = chronic obstructive pulmonary disease; ILD = interstitial lung disease; PE = pulmonary embolism

exposure were (13±5) years and (28.6±9.1) hour-years, respectively. The utilised biomass fuel is called *tezek*, and is produced by dehumidifying animal manure. The percent (mean ± SD) of the predicted FEV<sub>1</sub> and FVC were (90±7) % [(2.6±0.48) L s<sup>-1</sup>] and (87.8±7.1) % [(2.9±0.44) L s<sup>-1</sup>], respectively, and the FEV<sub>1</sub>/FVC was (85±6) %. Seven percent of the patients had an FEV<sub>1</sub>/FVC below 70 %.

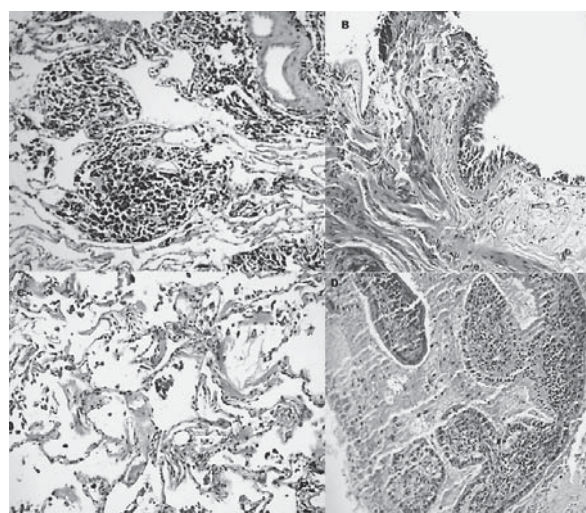
Radiological findings were as follows: mass (18 patients, 42.9 %); reticulonodular opacity (13 patients, 31 %); mediastinal lymphadenopathy (11 patients, 26.2 %); pleuroparenchymal fibrotic stripes (8 patients, 19 %); dilatation of the pulmonary artery (6 patients, 14.3 %); ground glass opacities (5 patients, 11.9 %); consolidation (4 patients, 9.5 %); mosaic perfusion (4 patients, 9.5 %); segmenter or sub-segmenter atelectasis (3 patients, 7.1 %); and bronchiectasis (3 patients, 7.1 %).

Bleeding was seen in only one patient as a bronchoscopy complication and was controlled by lavage with a solution including adrenalin. Pneumothorax was not observed in any of the patients. The main findings of bronchoscopy were indirect tumour findings such as oedema, erythema, and narrowing of the bronchus, indicating acute and chronic airway inflammation. Findings of chronic bronchitis included swollen mucosa, purulent sputum, and dark blue or black anthracotic plates, generally in the upper lung lobes, and especially in the bifurcation regions. Direct tumour findings included endobronchial neoplasm, mucous instability, and increased blood vessels.

We also performed bronchoscopic transbronchial biopsy (16 patients, 38 %); mucous biopsy (16 patients, 38 %); transcarinal needle aspiration biopsy (4 patients, 9.5 %); and bronchial lavage (6 patients, 14 %). Most of the patients had lung cancer and interstitial lung disease. Lung disease in these patients was diagnosed after more than 27 hours per year of biomass smoke exposure. However, one patient with 11 hours per year of biomass smoke exposure had a normal biopsy finding. The incision was performed to find the cause of haemoptysis.

There was a highly negative correlation between interstitial lung disease and lung cancer ( $P=0.001$ ). That biomass smoke exposure may cause different diseases in different people may partially be explained by a person's genetic predisposition to a disease.

Table 2 shows the histopathological findings in the patients with interstitial lung disease (ILD). Biopsy tissue of four patients was lost during examination.



**Figure 1** Histology of representative tissue samples obtained by bronchoscopy. The following tissue samples are shown with H&E staining at 100x magnification except where noted otherwise: (A) Anthracosis in the lung parenchyma with vascular wall thickening; (B) Basal membrane thickening, eosinophilic enhancement in bronchial mucosa (200x); (C) Inflammatory focal thickening of alveolar septipara and lung parenchyma; (D) Dominated by lymphocytes, few neutrophils and plasma cells showing signs of chronic inflammation of the bronchial mucosa

Transbronchial biopsy taken from 16 of 21 patients who were thought to have ILD. Bronchial lavage was performed on five patients. Cytological analysis showed no malignant cells in these patients. Neutrophils were the dominant cell type for many patients. In one patient, lymphocytes accounted for 70 % of the cells. Tissue samples stained with haematoxylin and eosin (H&E) were examined under a light microscope (Olympus BX50F-3, Olympus Optical Co., Japan) at either 100x or 200x magnification. Figure 1 shows the typical tissue samples obtained by bronchoscopy.

In the interalveolar septum, we observed perivascular and peribronchial neutrophils, lymphocytes, and alveolar macrophage infiltration. In some cases this cell infiltration led to the thickening of the interalveolar septa. In some patients, white blood cells infiltrated the spaces around vessels, the intima and the media of the vessels thickened, and their lumens narrowed. Black coal dust in the form of granular debris or little piles were scattered between the cells. Similar piles were found in the bronchioles on the apical surface of the epithelium and in the intracytoplasmic space. In one patient, nodular fibrotic thickening was observed in some places. Bilateral and many nodular lesions, more obvious in the sub-lobes, were detected by lung tomography in one patient, who

was thought to have ILD, but the bronchoscopic lavage histopathology did not support this diagnosis. However, a bulk was detected at the head of the pancreas in an abdomen tomography during examination of the patient, and the lung lesions were interpreted as metastasis.

Computer tomography detected a mass indicative of lung cancer in 14 patients, who then underwent bronchoscopy to confirm or rule out this preliminary diagnosis. The following histopathological types of lung cancer were detected: small cell in six patients, squamous cell in two patients, adenocarcinoma in two patients, and bronchoalveolar carcinoma in one patient. In two patients, the malignant epithelial tumour could not be determined by the cell type, and the tumour in one patient was evaluated as benign.

Chronic inflammation in a patient who complained of difficulty swallowing was followed up by endoscopy. Transbronchial biopsy revealed esophageal squamous carcinoma.

One of the four patients with mediastinal lymphadenopathy had right hilar lymphadenopathy and one had a consolidation at the right-mid lobe. The smear obtained by transcarinal thin needle aspiration biopsy did not show malignant cells. Patients diagnosed with sarcoidosis were introduced steroid treatment. All patients with lymphadenopathy showed a degree of regression due to treatment.

Tuberculosis was diagnosed in four patients. Mediastinal lymphadenopathy was established in one; a consolidation in the sub-lobe superior segment of the right lung in another; a consolidation in the sub-lobe of the right lung together with mediastinal lymphadenopathy in one patient; and a consolidation with fusion fields in the upper lobe of the right lung in one patient. Histopathological analysis showed a negative finding in the first patient, an active chronic inflammation in the second, chronic inflammation in the third, and anthracosis in the fourth. Tuberculosis culture of bronchial lavage tested positive and all four patients were started antituberculosis treatment.

## DISCUSSION

Exposure to biomass in buildings without proper ventilation increases the risk of acute airway infections in children and COPD, ILD, and lung cancer in the adults (2,3,7,8). In Turkey, biomass smoke exposure is an important risk factor for lung diseases in non-smoking women, especially in rural areas. However,

tobacco smoke and biomass smoke-related lung diseases have similar characteristics.

Biomass smoke contains carbon monoxide, nitric acid, sulphur oxides, formaldehyde, polycyclic organic substances, carcinogens like benzopyrene, and particles smaller than 10 micrometers (9). Most of these components are mutagenic *in vitro* (9). Smoke is an irritant toxic to cilia and contains coagulant agents which affect the respiratory system defence and increase the risk of chronic lung infection (10, 11). Domestically-acquired particulate lung disease (DAPLD) is a term used to identify biomass-related lung diseases (12). DAPLD manifests itself in a broad range of disorders from chronic bronchitis and COPD to advanced interstitial lung disease and malignancy.

Studies around the world have established a relationship between lung disease and exposure to biomass smoke. Pandey et al. (13) have shown that COPD prevalence rises with age and is greater Nepalese men than women (13). Akhtar et al. (9) identified chronic bronchitis in 100 of 1426 Pakistani women burning biomass and established a strong relationship between bronchitis and biomass use compared to a control group. Demirtaş et al. (2) found that women who exposed to biomass smoke were significantly more prone to COPD than unexposed women. Özbay et al. (1) detected a severe obstruction and an increase in the lung volume in pulmonary function tests of biomass-exposed women. They observed radiologically diffuse emphysema, thickening at interlobular septa, focal emphysematosa fields, and an increase in bronchovascular arborisation. They showed that biomass smoke increased obstructive and restrictive effects on the pulmonary function and structure. Our results seem to confirm the above studies, especially in reference to COPD. Sandaval et al. (14) have suggested that dense anthracotic staining is more characteristic of women exposed to biomass than of heavy tobacco smokers. Chung et al. (15) found anthracotic staining in people exposed to biomass smoke, in heavy smokers, miners, and city population. Bruce et al. (16) found that tuberculosis prevalence was higher in homes using biomass than in homes using cleaner combustibles. Similarly, Perez Podilla et al. (17) support the finding that heating with biomass at home contributes to tuberculosis. Shprikov et al. (18) found that tobacco smoke had a great effect on the structure of *Mycobacterium tuberculosis*. These structural changes suggest that smoke supports bacterial growth. In our study, in the four pulmonary tuberculosis diagnosed cases, dark anthracotic

pigmentation and chronic inflammation were detected that may have contributed to bacterial growth.

Biomass smoke contains numerous chemicals that are known or suspected human carcinogens. Mutations in human cancer are the most frequent in the p53 gene (19). Mutation in the p53 gene is found in 50 % of non-small cell lung cancers and in 90 % of small cell lung cancers (20).

Cigarette smoke contains almost 60 carcinogenic components including benz(a)pyrene (BaP) and nicotine-derived nitrosamine ketone (NNK), which induce p53 gene mutations (21). Wood smoke contains BaP, just like cigarette smoke (16). Delgado et al. (3) detected mutation in the p53 gene in lung cancer cases related to wood smoke and in cancers caused by cigarette smoke. They proposed that, just like cigarette smoke, wood smoke can play a role in lung cancer. Malatz et al. (22) found higher frequency of genetic polymorphism in glutathione S-transferase enzymes in non-smoking lung cancer patients who were exposed to wood smoke for more than 20 years. In the regions of China in which lung cancer is common in humans, Liang et al. (23) investigated exposure to coal and wood smoke in mice and rats and found that wood smoke exposure involved a higher risk of cancer than control, but a lower risk compared to coal smoke exposed animals. Consistent with all these studies, our study has shown that biomass smoke exposure is an important risk factor for human lung cancer

According to Gold et al. (24), cooking may produce high levels of BaP that equal a packs of cigarettes a day. In another study (16), BaP levels detected over three hours of cooking a day equalled two packs of cigarettes a day. These analogies help to explain how biomass smoke exposure can contribute to the growth of malignancy. Behera et al. (25) showed that adenocarcinoma was the dominant histopathological type of lung cancer in non-smoking women exposed to wood smoke. Similarly in Delgado et al. (3), the main histopathological type was adenosarcoma in

patients exposed to wood smoke (3). Hoffman et al. (26) showed that nicotine-derived nitrosamine ketone (NNK), contributed to adenocarcinoma and BaP to squamous cell carcinoma in lab animals. It is thought that wood smoke, like cigarette smoke, contains BaP, but it may also contain NNK and other carcinogens. In our patients, small cell carcinoma was the primary type of lung cancer, possibly due to a specific composition of the biomass.

Kajdaz et al. (27) found a significant correlation between wood smoke exposure and sarcoidosis. In another study (28) wood burning and organic dust exposure had a significantly higher correlation with sarcoidosis. In our study, four patients were diagnosed with sarcoidosis.

Chronic biomass smoke exposure changes the defense mechanisms of the lung mucociliary system and decreases the antibacterial capacity of macrophage (15, 29). It may cause bronchial narrowing or blockage due to anthracosis or mucoid secretion piles at distal lung fields, and development of pneumonia at segments or lobes. Repeating infections increase bronchiectasis. Consistent with our study, Kara et al. (30) concluded that biomass smoke caused many diseases, from chronic bronchitis to interstitial lung disease.

Like in some of our patients, a transbronchial biopsy conducted in a patient exposed to wood smoke in India showed the existence of coal macules (31). The main pathological changes in the transbronchial tissue samples of patients exposed to inorganic dust were similar to other interstitial lung diseases (32-34). The samples showed focal thickening of the alveolar septum and a mix of inflammatory infiltration, fibrosis and basal membrane thickening. Restrepo et al. (35) found similar pathological fibrotic changes in animals and patients exposed to wood smoke for a long time. Ramage et al. (36) identified a similar relationship between interstitial lung disease and wood smoke exposure.

**Table 2** Histopathological features of patients (N=11) with interstitial lung disease

Histopathology Feature	Patients with feature	
	n	(%)
Anthracotic pigment	7	(63)
Basal membrane thickening	6	(54)
Alveolar septal thickening	2	(18)
Goblet cell metaplasia	2	(18)
Fibrosis	1	(9)
Squamous metaplasia	0	
Chronic inflammation	11	(100)

Our study has showed that exposure to biomass can cause histopathological lung lesions that range from the upper airway inflammation to interstitial fibrosis and malignancy. These histopathological changes provide evidence of specific diseases attributable to biomass smoke exposure in non-smoking women. One of the limitations of our study is that we have not established whether the exposed women were also exposed to secondary tobacco smoke.

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### **Sažetak**

#### **KRONIČNI UČINCI AMBIJENTALNOGA DIMA IZ BIOMASE NA HISTOPATOLOGIJU PLUĆA U LJUDI: OPIS NIZA SLUČAJEVA**

Biomasa se u mnogim zemljama u razvoju rabi za gorivo. Čestice i plinovi izgorjene biomase mogu dovesti do plućnih promjena. Ovdje smo istražili histološke promjene u plućima ljudi uzrokovane biomasom. Ovo je prospektivno ispitivanje obuhvatilo 42 nepušačice izložene dimu iz biomase u kojih je ocijenjena izloženost dimu, uzeta povijest bolesti, napravljen fizikalni pregled te analizirani radiološki, bronhoskopski i histopatološki nalazi. Srednja dob ispitanica bila je (59±10) godina. Srednja izloženost dimu iz biomase iznosila je (28±9) sati na godinu. Radiološki nalazi upozorili su na tumorsku tvorbu (u njih 42 %), retikulonodularna zasjenjenja (31 %), limfadenopatiju medijastinuma (26 %), fibrozne promjene pleure i plućnog parenhima (19 %), proširenje plućne arterije (14 %), sliku smrvljenog stakla (11 %), sliku mozaične perfuzije (9 %), konsolidacije (9 %), segmentnu i subsegmentnu atelektazu (7 %) te bronhijektazije (7 %). U njih 35 % dijagnosticiran je rak pluća, u 31 % bolesti plućnog intersticija, u 9 % sarkoidoza, u 9 % tuberkuloza, u 4 % KOPB, u 9 % kronični bronhitis te u 4 % metastaze. Bronhoskopija je pokazala pilije, edem, eritem, sužavanje bronhija, endobronhijalni tumor, neurednu sluznicu, izrazitiju vaskularizaciju, plavo-crne antrakotične plakove, otjecanje sluznice te purulentnu sekreciju. Transbronhijalnom biopsijom pronađeni su neutrofil i limfociti u perivaskularnom, peribronhiolarnom tkivu i interalveolarnim septumima, zadebljanje vezivnoga tkiva, zadebljanje bazalne membrane, zadebljanje interalveolarnih septuma, zadebljanja stijenke žila intimalno i medijalno te suženje njihova lumena, crna antrakoza između stanica te u epitelu bronhiola. Sve to upozorava na značajne promjene uzrokovane biomasom, koje obuhvaćaju zloćudne formacije uslijed toksičnoga djelovanja na plućni parenhim, intersticij i žile.

**KLJUČNE RIJEČI:** *izloženost dimu biomase, plućne bolesti*

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