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Unsustainable Consequences of Sustainable Energy: Occupational Diseases Related to Wind Turbine Production

Sürdürülebilir Enerjinin Sürdürülemez Sağlık Etkileri: Rüzgar Türbini Üretim İşinde Mesleki Hastalıklar

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ABSTRACT

Objective: We discussed health problems encountered during the wind turbine production process and occupational diseases that may arise. Risk factors for occupational asthma are discussed.

Methods: This is a case-control study. The workers, who had been referred to the Occupational Diseases outpatient clinic between August 2018 and January 2021, were evaluated. Exposure histories and laboratory, functional, and radiological findings of patients diagnosed with occupational diseases were presented. The exposure and functional properties of cases with occupational asthma and normal workers are compared.

Results: A total of 154 workers had were evaluated. All the workers were male, the mean age was 34.6±6.9, median working time was 60 months and latency period was 36 months. The rates of occupational diseases such as occupational asthma, pneumoconiosis, and allergic contact dermatitis were 19.5% (n=30), 0.6% (n=1), and 5.8% (n=9), respectively. The patients with occupational asthma were younger (29.6±4.63 vs. 37.3±6.43). Working time- duration of exposure was lower [36 months (24-51) vs. 72 months (48-84)].

Conclusion: Wind turbines, which reduce the carbon footprint and are used to obtain sustainable energy, may have unsustainable health effects on employees during the production process.

Keywords: Wind turbines, occupational asthma, pneumoconiosis, epoxy resins, green energy

ÖZ

Amaç: Bu çalışmada rüzgar türbini üretim işinde kullanılan pek çok kimyasalın solunum sistemi başta olmak üzere insan sağlığı üzerine zararlı etkilerini ortaya koyulması amaçlanmıştır.

Yöntem: Çalışma olgu-kontrol çalışmasıdır. Ağustos 2018-Ocak 2021 tarihleri arasında Meslek Hastalıkları polikliniğine yönlendirilen bu sektördeki olgular değerlendirilmiştir. Mesleki astım, pnömokonyoz, alerjik kontakt dermatit tanısı alan olguların maruz kalım öyküleri, laboratuvar, fonksiyonel ve radyolojik bulguları sunulmuştur. Mesleki astımlı olguların ve normal çalışanların maruziyet ve fonksiyonel özellikleri karşılaştırılmıştır. Mesleki astım risk faktörleri irdelenmiştir.

Bulgular: İzmir ve çevresinde bulunan 2 fabrikadan gelen toplamda 154 olgu değerlendirilmiştir. Olguların hepsi erkek, yaş ortalaması 34,6±6,9, medyan çalışma süresi 60 ay ve latans süresi 36 aydı. Mesleki astım, pnömokonyoz ve alerjik kontakt dermatit gibi meslek hastalıklarının oranı sırasıyla %19,5 (n=30), %0,6 (n=1) ve %5,8 (n=9) idi. Mesleki astımı olan hastalar daha gençti (29,6±4,63'e vs. 37,3±6,43). Çalışma süresi-maruz kalma süresi daha düşüktü [36 ay (24-51) vs. 72 ay (48-84)].

Sonuç: Karbon ayak izini azaltan, iklim değişikliği nedeniyle ön plana alınan sürdürülebilir enerjinin elde edilmesinde kullanılan rüzgar türbinlerinin üretim sürecinde çalışanların sürdürülemez sağlık etkilerini ortaya koymuştur. Rüzgar türbini üretim işinde kullanılan pek çok kimyasalın solunum sistemi başta olmak üzere insan sağlığı üzerine zararlı etkileri gösterilmiştir.

Anahtar Kelimeler: Rüzgar türbini, mesleki astım, pnömokonyoz, epoksi reçine, yeşil enerji

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INTRODUCTION

Sustainable energy is energy that meets the demands of today's population while not compromising the sources of future generations.[1] Climate change related to the combustion by-products of fossil fuels and shortage of existing sources force a shift into options for sustainable energy. Among them, wind turbines are one of the most commonly used technologies, which has an increasing area of usage worldwide.[2] Despite offering a sustainable energy, the production process of wind turbines may still have some hazardous consequences. There are several chemicals to be mentioned: epoxy resin and hardeners (bisphenol-A, isocyanates), fiberglass and carbon materials (glass wool and silica), polyvinyl chloride, poliethilene terephtalate, polyuretane, polystyrene and styreneacrylonitrile etc.[3] Workers perform grinding and sanding of metal and composite material, painting, laying glass fiber with chemicals, which may increase exposure to certain chemicals.[4] In this study, we revealed possible health effects related to exposure to these chemicals and discuss possible risk factors that may facilitate these effects.

METHODS

Study Population

This was a descriptive study. We involved a total of 154 workers from the wind turbine manufacture phase of rotor blades in two different factories referred to the Occupational Diseases clinics. According to the reports of the workplace occupational health and safety management, all workers had a history of exposure to one or more occupational risk factors in this production process. The management did not provide ambient measurements because of administrative restrictions in the workplace. Workplace chemical (volatile organic compound and etc.) and dust measurements were requested officially. However, since the workplaces do not have a legal obligation to send this information, they did not send it.

All workers who had been admitted between August 2018 and January 2021 were included without selection. Data on demographic features, complaints, occupational history, and exposure characteristics, past periodic and pre-employment examinations, and functional and radiological findings were collected retrospectively. The present medical conditions were matched with the data of pre-employment screening, periodic examinations, and the procedures and the list of chemicals used in the production process to establish the diagnosis of an occupational disease by the means of objective causality.

Pulmonary Function Assessment

Tests were performed in accordance with the American Thoracic Society criteria. A standard spirometry measurement was performed using dry-seal-spirometry (Zan 100, nSpire Health Inc., Oberthulba, Germany).

Radiological Assessment

Postero-anterior (PA) chest X-rays were performed. A short exposure time with high -voltage technique was used (Trophy UFXRAY, 500 mA,TM). PA chest X-rays were evaluated in accordance with the International Labour Organization (ILO) 2011 standards. According to the ILO classification, the ones with profusion 0/1, 1/0, 1/1 and 1/2 have been classified as category 1; the ones with profusion 2/1, 2/2 and 2/3 have been classified as category 2; and the ones with profusions 3/2, 3/3, and 3/+ have been classified as category 3. All subjects, whose X-rays were suspicious in terms of abnormal, underwent thoracic high-resolution computed tomography. Slices in 1 mm size at 1.5-s intervals, which increased by 10 mm with the use of a high-resolution algorithm were used.

Occupational and work-exacerbated asthma, pneumoconiosis, and allergic contact dermatitis were diagnosed by combining different procedures in an iterative process by using specific guidelines and made a trained specialist (occupational medicine specialist, dermatologist, chest physician, and allegist). An occupational physician determined the dermatological problems of all subjects by both physical examination and a questionnaire. Procedures included assessment of non-specific bronchial hyperresponsiveness (NSBH) or reversible airway obstruction, assessment of immunological sensitization (skin prick tests, specific IgEs, patch test), and serial measurements of PEF/FEV_1 and/or NSBH at work and off work. The diagnosis of occupational asthma, work-exacerbated asthma, pneumoconiosis, and allergic contact dermatitis was performed according to existing international guidelines.[5-10] Together with descriptive data on occupational diseases diagnosed in this worker cohort, we have also given an analysis on the possible risk factors of occupational asthma. The study population was divided into two groups according to their diagnosis. The independent variables of the exposed workers who were diagnosed with occupational asthma and healthy exposed workers were compared.

Statistical Analysis

Data were evaluated with the Statistical Package for the Social Sciences 22.0 package program. The distribution characteristics of the variables specified by the measurement were evaluated using the Kolmogorov-Smirnov test and the coefficients of kurtosis and

skewness. If the coefficients are between 1.5 and +1.5, then the data are assumed to be normally distributed. Descriptive statistics are presented as numbers and percentages for categorical variables, mean±standard deviation for normally distributed numerical variables, and median (minimum–maximum) for non-normally distributed numerical variables. The t-test was used to evaluate the relationship between the variables specified by the measurement and the dependent variable. If the data did not comply with parametric conditions, Mann-Whitney U test was used to evaluate the variables specified by the measurement. The chi-square test was used for categorical variables. Significance level was accepted as $p<0.05$. The study was approved by the Local Ethics Committee of University of Health Sciences Turkey, Dr. Suat Seren Chest Diseases and Surgery Training and Research Hospital (no: 9/2021).

RESULTS

A total of 154 workers were evaluated. Several features of the workers are summarized in Table 1. All workers were young males; the mean age was 34.6±6.9 years. One hundred and nine workers (70.8%) were smokers, and 45 workers (29.2%) were ex-smokers or never smoked. Pulmonary symptoms (dyspnea, cough, wheezing) were the most common. The median latency time was 36 months. Brief data on the occupational history of the workers are given in Table 2, and the final diagnoses in Figure 1. The rates of occupational diseases such as occupational asthma, pneumoconiosis, and allergic contact dermatitis were 19.5% (n=30), 0.6% (n=1), and 5.8% (n=9), respectively. Respiratory bronchiolitis was diagnosed in 6.5% (n=10) of the case; however, a possible causality link between the disease and occupational history could not be established because all cases were active smokers. After being diagnosed with asthma, serial measurements of PEF/FEV_1 and/or NSBH at work and off work were performed to establish work-relatedness (Figure 2). Several features of the patients with occupational asthma in comparison with healthy workers are given in Table 3. The patients with occupational asthma were younger (29.6±4.63 vs 37.3±6.43). Working time-duration of exposure was lower [36 months (24-51) vs. 72 months (48-84)]. Ten (8.2%) patients were found to have centrilobular nodular densities on high-resolution computerized tomography of the lung. As they all have a history of smoking, the diagnosis was assumed as respiratory bronchiolitis; smoking cessation was advised and they were put on follow-up. One patient was diagnosed with pneumoconiosis (International Labor

Table 1. Several features of the workers

Several features			**Cases (n=154)**
Age (years)		Mean±SD (min-max)	34.6±6.9 (23-58)
Sex (males)		n (%)	154 (100)
Smoking status			
	Active	n (%)	109 (70.8)
	Never	n (%)	30 (19.5)
	Ex-smoker	n (%)	15 (9.7)
Smoking (pack years)		Median (25-75 percentiles)	7 (2-15)
Route of admission			
	Workplace physician	n (%)	111 (72.1)
	Other specialists	n (%)	26 (16.9)
	Patient self application	n (%)	16 (10.4)
	From social security institution	n (%)	1 (0.6)
Respiratory symptoms			
	Present	n (%)	73 (47.4)
	Absent	n (%)	81 (52.6)
Dermatological symptoms			
	Present	n (%)	9 (5.8)
	Absent	n (%)	145 (94.2)
Duration of exposure (months)		Median (25-75 percentiles)	60 (36-84)
Latency period (months)		Median (25-75 percentiles)	36 (18-60)

SD: Standard deviation

Organization Classification of Chest Roentgenogram p/p 1/1) (Figure 3). Nine (5.8%) patients had allergic contact dermatitis; sensitization to epoxy resin was confirmed with a patch test.

DISCUSSION

Solar energy, wind energy, marine energy (wave and tidal), and geothermal energy are classified as sustainable energy sources.[2] The production of sustainable energy and economy creates several "green jobs" that seem to be accelerated in the near future. The ILO defines green jobs as activities (agricultural, manufacturing, research and development, administrative, and service) that contribute to preserving or restoring environmental quality. These jobs will protect ecosystems and biodiversit, reduce consumption; decrease carbon footprint, waste and pollution.[11]

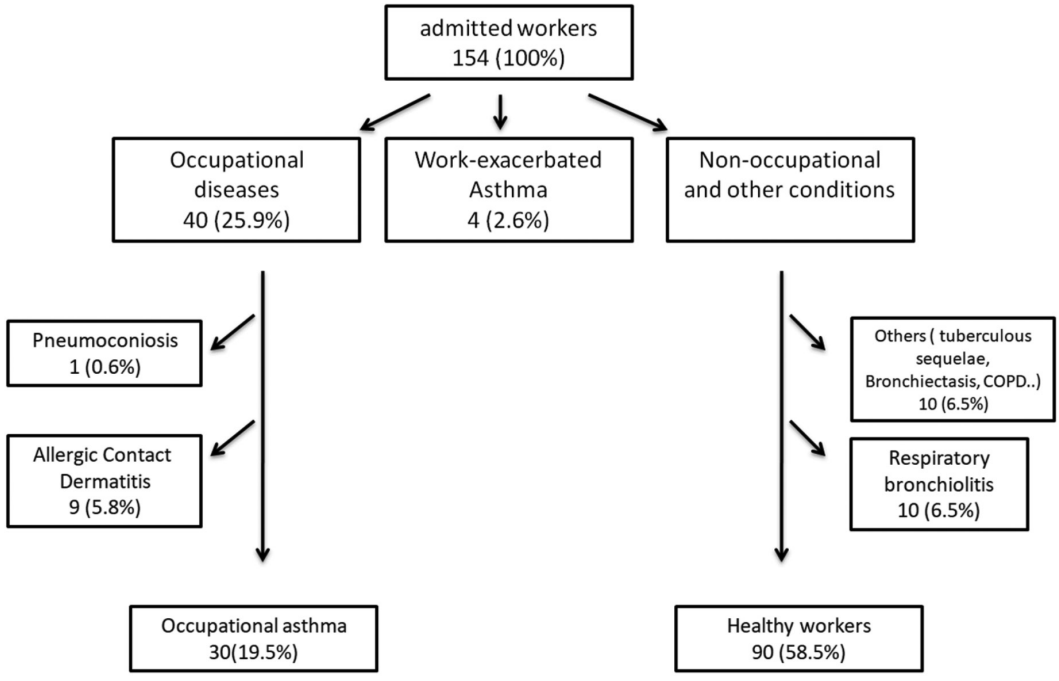

Figure 1. Flow chart and final diagnoses

Table 2. Exposure characteristics

Department	Job description	Possible occupational exposures	Number of workers (n=154)
Primary mold production worker	Lamination task; placement of the glass fiber, application of chemical glues, infusion of epoxy	Epoxy resin, hardeners (isocyanate)	43 (27.9%)
Minor parts production worker	Lamination task; placement of the glass fiber, application of chemical glues, infusion of epoxy	Epoxy resin, hardeners (isocyanate)	34 (22.1%)
Trimming and grinding	Trimming, cutting, grinding, and sanding of the outside edge to provide a smooth finish.	Epoxy resin, hardeners (isocyanate), glass fibers particles and dust, silica	20 (13%)
Final finish worker	Final evaluation of body and blade, application of paste, epoxy application with roller.	Epoxy resin, hardeners (isocyanate), glass fibers particles and dust, silica	33 (21.4%)
Metal grinding operator	Cutting or grinding metal and composites with grinding wheel	Metal dust, silica	5 (3.2%)
Warehouse worker	Preparation and distribution of raw material, cutting of fiber glass	Epoxy resin, hardeners (isocyanate)	13 (8.4%)
Other	Fixing mechanical failure, crane operator, field cleaners	Epoxy resin, hardeners (isocyanate)	6 (3.9%)

The 20th century, with a fossil fuel-dependent economy and continuously growing demands, had resulted in climate crisis, shortage of sources, and inevitably forced the humanity to switch into sustainable energy. The costs of wind energy plants have decreased by 70% since 200, which have attracted investments in this area.[12] The European Wind Energy Association predicts wind energy to offer 397 GW capacity (35% of European demand) and 716.000 jobs by the year 2030.[13] While improving economic and technological achievements, possible occupational risks carried by those employees in so -called "green jobs" should also be clearly defined.[14,15]

Wind turbine production has hired over 18.000 employees in Turkey. Three of these companies have settled in İzmir. It is estimated that there are over 3000 blue-collars and white-collars working in different positions.[16] Among them, 154 workers were referred to the out-patient clinic and involved in the study. After a detailed anamnesis on occupational history, we had contacted the companies and claimed the data on the used chemicals during the process. Safety Data Sheets (SDS) were evaluated to match with clinical and radiological findings and confirm possible causality. The rotor blades were constructed with an outer coating of a liquid epoxy resin system(s) (ERS) with an epoxy resin based on trimethylolpropane triglycidyl ether and several inner layers of glass fiber preimpregnated with ERS (prepreg). During production, exposure to certain chemicals such as glass and carbon materials, epoxy resin (bisphenol-A), vinyl/polyester resin, isocyanates, polyamine and

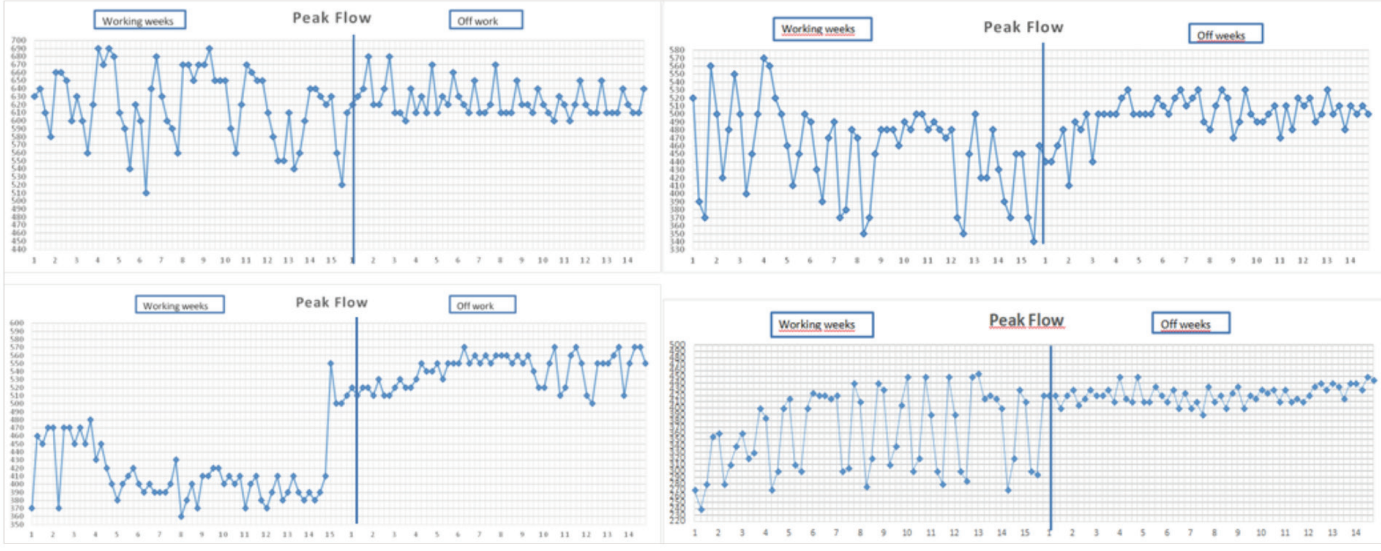

Figure 2. Peak flow meter measurements of patients with occupational asthma

Table 3. A comparison of several features between occupational asthma and healthy workers

		Occupational asthma (n=30)	Normal (n=90)	p
Age (years) [mean±SD (min-max)]		29.6±4.63 (23-40)	37.3±6.43 (24-58)	<0.001*
Sex (males) [n (%)]		30 (100)	90 (100)	N/A
Smoking status (active and ex-) [n (%)]	Non/ex smoker	7 (23.3)	28 (31.1)	0.417**
	Active smoker	23 (76.7)	62 (68.9)	
Pack years (median [25-75 percentiles])		5 (3-7)	10 (8-20)	0.008†
Duration of exposure (months) [median (25-75 percentiles)]		36 (24-51)	72 (48-84)	<0.000†
FEV_1 (%) [mean±SD (min-max)]		81±20 (20-101)	98.8±10.7 (79-127)	<0.001*
FVC (%) [mean±SD (min-max)]		85.6±20.1 (27-115)	95.9±10.2 (73-119)	0.003*
FEV_1/FVC (%) [mean±SD (min-max)]		79±8.3 (67-98)	85.2±4.6 (75-99)	<0.001*
MEF 25-75 (%) [mean±SD (min-max)]		68.4±29 (15-126)	99.8±22.7 (61-155)	<0,001*
PEF (%) [mean±SD (min-max)]		62.9±25.4 (15-100)	91.3±15.3 (59-133)	<0,001*

*Independent samples t-test, **chi-squared test, †Mann-Whitney U test, N/A: not applicable, min-max: Minimum-maximum

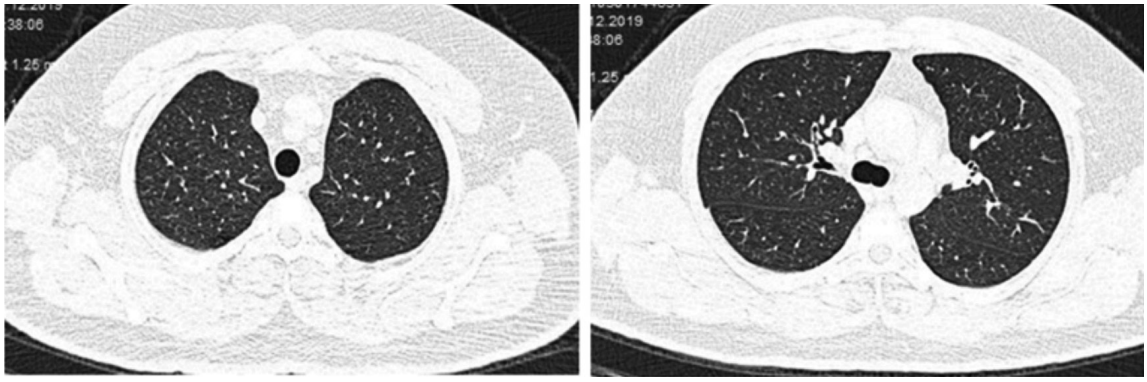

Figure 3. High-resolution computed tomography of chest of a patient with pneumoconiosis

acrylate hardeners occur and these chemicals are well-known irritants and sensitizers.[17-20] The National Institute for Occupational Safety and Health (NIOSH) reported that styrene concentration rises up to 300 ppm (<50 ppm is allowed) in a wind turbine production facility.[21] This finding is matched in a study by McCague et al.[22] The degree of exposure is shown to be related to an increase in respiratory symptoms (odds ratio of 2.9) and decrease in pulmonary functions. We have found a similar relation in our study. There were cases sensitization to these chemicals and diagnosed with occupational asthma whose lung volumes were significantly lower than otherwise normal workers ($p<0.001$).

Of those workers diagnosed with asthma, 30 of them (19.5%) had a causality relationship and it was clearly established with serial measurements of PEF/FEV_1 and/or NSBH at work and off work and peak flow meter measurements. They were all younger and had a lower working time. It is considered that the situation might be explained by personal characteristics. We could not conclude on the amount of exposure of chemicals, as field measurements demanded from the company but could not be obtained so occupational hygiene measurements were absent except dust measurements, which should be stated as a major limitation. Other workers invited for investigation but some workers with an obvious exposure did not attend further investigations as they had a fear of lose their jobs, which is common in occupational diseases in Turkey.[23] Otherwise, normal workers with longer duration of exposure should be followed for longer periods as the risk of development of occupational asthma increases in time and may retard beyond several years.[24,25] There might be some workers in our series who will develop occupational diseases in the future, which highlights the need for a systematical follow-up.

There were several cases with dermatological findings. Pontén et al.[26] reported that the prevalence of allergic contact dermatitis and irritant contact dermatitis in workers exposed to epoxy resin were 10.9% and 6.1%, respectively. Similar findings were seen in a wind turbine production facility in Spain. There were ten cases with allergic contact dermatitis due to epoxy resin and irritant contact dermatitis due to glass fibers.[27] We had nine (5.8%) cases with allergic contact dermatitis with confirmed sensitization to epoxy resin.

We diagnosed pneumoconiosis one case (1%) who was working at the Final Finish Section where he trimming and grinding the rotor blades. As far as we know, this was the first case in the literature, who developed pneumoconiosis in wind turbine production. Glass wool and silica as fibrinogenic fibers were detected in SDS forms. Respirable dust concentrations in mg/m^3 were 12.6 and 7.01 mg/m^3 as a time-weighted average in the Main Section and Final Finish Section.

Study Limitations

First, this was a retrospective analysis. We could not conclude on the amount of exposure of chemicals, as field measurements demanded from the company but could not be obtained so occupational hygiene measurements were absent except dust measurements, which should be stated as a major limitation. However the most important limitation was that we had not performed sampling in working place so that would not be able show the cause(s) of asthma. A bias related to selection would be seen and these results cannot be generalized because these information were only gained from the patients that were admitted to our outpatient clinic.

CONCLUSION

This study reveals the unsustainable health effects of so-called "green jobs" in the production of sustainable

energy. As a growing area, a wind turbine production will create thousands of these green jobs. However, the health of workers should be clearly kept with primary protection, and prevention and control of hazards by occupational hygiene. Standardized systematical follow-up procedures should be planned to find sensitized workers and policies to preserve the prevention of occupational diseases by occupational hygiene.

Ethics

Ethics Committee Approval: The study was approved by the Local Ethics Committee of University of Health Sciences Turkey, Dr. Suat Seren Chest Diseases and Surgery Training and Research Hospital (no: 9/2021).

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

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