

**ROLE OF AEROSOLS ON CARDIOPULMONARY FUNCTIONS OF
ECONOMICALLY DIFFERENT GROUPS OF MEGACITY DELHI
AND A TOWN HAMIRPUR HIMACHAL PRADESH**

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by

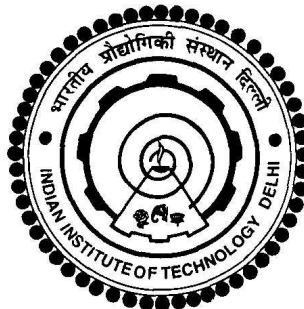
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Submitted

in fulfillment of the requirements of the degree of Doctor of Philosophy

to the



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Dedicated to

My Father (Mr. Bhim Singh)

&

My Beloved Mother (Smt. Shila Devi)

CERTIFICATE

This is to certify that the thesis entitled “**Role of Aerosols on Cardiopulmonary Functions of Economically Different Groups of Megacity Delhi and A Town Hamirpur, Himachal Pradesh**” being submitted by **Mr. Gaurav Singh** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** is a record of the original bonafide research work carried out by him under my guidance and supervision. The thesis work, in my opinion, has reached the requisite standards fulfilling the requirement for the Degree of Doctor of Philosophy.

The results contained in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

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Gaurav Singh

ABSTRACT

This study presents the development and validation of modified air pollution related quality of life (AP-QOL) questionnaire in Indian context. The modified AP-QOL aimed to investigate the association of dietary habits, social life style, medical history and air pollution exposure with cardiopulmonary illness in Indian society. Further, air pollution exposure (APE) scoring scheme was developed and validated using the Delphi technique. The study was carried out in two geographically and social different region including Delhi (Mega city) and Hamirpur town. Two economically different groups including academicians (477) and security guards (519) of Indian Institute of Technology Delhi (IITD) and National Institute of Technology Hamirpur (NITH) participated in a questionnaire survey and health monitoring. Higher number of active smoker participated in IIT Delhi (84) compared to NIT Hamirpur (28). Most of the participants reported routine exercise and clean working environment. A larger number of academicians reported the consumption of carbohydrates (77-90% of 272-205), sweet (44-54% of 272-205), and fruits (47-55% of 272-205) compared to security guards, indicated relatively better food habits of academicians. While unhealthy food habit reflected by high consumption of fried foods (74-96% of 448-71) among security guards. A lesser number of participants from academic group reported exposure to cooking (13-20% of 272-205) compared to security guards (62-70% of 448-71). The academicians groups at both institutes have access to clean fuel for cooking compared to security guards. Large number academic group of IITD and NITH have reported exposure to road dust (24-35% of 272-448), while minimal number (2-6%) have reported exposure road traffic emissions, waste burning (1-2%), and industries (1%). Compared to academic group large fraction of security guards of both campuses reported exposure to road dust (59-66% of 205-71), and road traffic emissions (34-51% of 205-71).

Overall the academic groups at both institute had better living and working environment compared to security guards, which affect their respiratory illness symptoms.

In comparison to NIT Hamirpur, higher number of IIT Delhi participants have reported respiratory illness symptoms such as cough, dyspnea, and phlegm. After scoring the responses based on quantitative assessment of expert's, it was found that 29, 22, 49% out of 477 participants at IITD and 27, 30, 42% out of 519 participants at NITH can be grouped under good (<16; below 1st quartile score) moderate (16-23; 1st to 3rd quartile score) and poor (>23; above 3rd quartile) health categories respectively.

Further, the cardiopulmonary parameters were monitored along with ambient PM_{2.5} concentration to investigate the link between them for identified groups of good, moderate and poor health. The PM_{2.5} mass concentration and chemical characterization were done for two year sampling period from January 2013 to December 2015. The high PM_{2.5} concentrations were observed in winters followed by post monsoon, summer and monsoon seasons. The secondary aerosol formation from inorganic ions dominated the PM_{2.5} mass in winter. The mean OC and EC and potassium concentrations were high in post-monsoon compared to other seasons indicated influence of biomass burning to ambient aerosol.

The odd ratios (ORs) of lung functions for IITD academician showed 6-8% increase with an increase in quartile range of PM_{2.5} concentrations. In academic group of NITH, ORs increased by 12.7% for increase in PM_{2.5} concentration in interquartile range. A similar trend was observed for the percentage reduction of Force Expiratory Volume in 1 sec (FEV₁)/Force vital capacity (FVC) with increase in PM_{2.5} concentrations by 1.4 times between Q1(25th percentile), and Q2 (50th percentile). In academic group of NITH, the ORs for the reduction in FEV₁ showed an increase by 14.4% increase in PM_{2.5} concentrations.

This finding clearly illustrated an increasing number of affected population with considerable change (>10%) in respiratory functions with increasing PM_{2.5} concentrations.

The relative risk for cardiac parameters relevant to heart rate variability which induce arrhythmia were analyzed. The standard deviation of normal to normal (R-R) peaks (SDNN) showed a negative association with PM_{2.5}, indicating the increasing risk of arrhythmia with increasing PM_{2.5} concentration. The SDNN in the range 50-100 implies medium risk and greater than 100 implies low risk of cardiac attack. The analysis showed there were 28 samples with SDNN between 50-100 and 42 with SDNN greater than 100. The proportion of NN50 (pNN50: NN50 is the number of pairs of the successive NN interval that differs by more than 50 ms to the total number of NN) LF/HF ratio also showed insignificant negative correlation with PM_{2.5}. Further relative risk of the change in cardiovascular function with 10 µg m⁻³ increase in PM_{2.5} concentration was estimated as 0.7-3.0 for a non-smoker and 0.3-4.0 for a smoker for various cardiac parameters. The findings from this study showed clear evidence of an increase in cardiopulmonary dysfunctionality with increasing fine aerosol mass concentration.

सार

यह अध्ययन भारतीय संदर्भ में संशोधित वायु प्रदूषण से संबंधित जीवन की गुणवत्ता (एपी-क्यूओएल) प्रश्नावली के विकास और सत्यापन को प्रस्तुत करता है। संशोधित एपी-क्यूओएल का उद्देश्य भारतीय समाज में कार्डियोपुलमोनरी बीमारी के साथ आहार संबंधी आदतों, सामाजिक जीवन शैली, चिकित्सा इतिहास और वायु प्रदूषण के संपर्क के संबंध की जांच करना है। इसके अलावा, वायु प्रदूषण एक्सपोजर (एपीई) स्कोरिंग योजना विकसित और डेल्टा तकनीक का उपयोग करके मान्य किया गया था। यह अध्ययन दिल्ली (महा नगर) और हमीरपुर शहर समेत दो भौगोलिक दृष्टि और सामाजिक विभिन्न क्षेत्रों में किया गया है। भारतीय प्रोद्योगिकी संस्थान दिल्ली (आईआईटीडी) और राष्ट्रीय प्रोद्योगिकी संस्थान हमीरपुर (एनआईटी) के अकादमिक (477) और सुरक्षा गार्ड (519) सहित दो आर्थिक रूप से अलग-अलग समूहों ने एक प्रश्नावली सर्वेक्षण और स्वास्थ्य निगरानी में भाग लिया। एनआईटी हमीरपुर (28) की तुलना में आईआईटी दिल्ली (84) में सक्रिय धूम्रपान करने वालों की उच्च संख्या में भाग लिया। अधिकांश प्रतिभागियों ने नियमित व्यायाम और स्वच्छ कार्य वातावरण की सूचना दी। बड़ी संख्या में शिक्षाविदों ने सुरक्षा गार्ड की तुलना में कार्बोहाइड्रेट (272-205 का 77-90%), मीठा (272-205 का 44-54%), और फल (27-205 का 47-55%) की खपत की देखी गयी, शिक्षाविदों की अपेक्षाकृत बेहतर खाद्य आदतों का संकेत दिया। जबकि सुरक्षा गार्ड के बीच तला हुआ खाद्य पदार्थों की उच्च खपत (44-96% 44-71%) द्वारा अस्वास्थ्यकर खाद्य आदत परिलक्षित होता है। अकादमिक समूह के प्रतिभागियों की कम संख्या में सुरक्षा गार्ड (62-70% 448-71) की तुलना में खाना पकाने (272-205 का 13-20%) के संपर्क में बताया गया। दोनों संस्थानों के शिक्षाविद समूहों के पास सुरक्षा गार्ड की तुलना में खाना पकाने के लिए स्वच्छ ईंधन तक पहुंच है। आईआईटीडी और एनआईटी के बड़े नंबर के अकादमिक समूह ने सड़क धूल (272-448 के 24-35%) के संपर्क में बताया है, जबकि न्यूनतम संख्या (2-6%) ने रोड यातायात उत्सर्जन से अनावरण, अपशिष्ट जलने (1-2%) की सूचना दी है, और उद्योग (1%)। अकादमिक समूह की तुलना में दोनों परिसरों के सुरक्षा गार्ड के बड़े हिस्से में सड़क धूल (59-66% 205-71), और सड़क यातायात उत्सर्जन (205-71 का 34-51%) के संपर्क में बताया गया। कुल मिलाकर दोनों संस्थानों के अकादमिक समूहों में सुरक्षा गार्ड की तुलना में बेहतर जीवन और कार्य वातावरण था, जो उनके श्वसन बीमारी के लक्षणों को प्रभावित करता है।

एनआईटी हमीरपुर की तुलना में, आईआईटी दिल्ली की बड़ी संख्या में प्रतिभागियों ने श्वसन बीमारी के लक्षण जैसे खांसी, डिस्पने और कफ के बारे में बताया है। विशेषज्ञों के मात्रात्मक मूल्यांकन के आधार पर प्रतिक्रियाओं को स्कोर करने के बाद, यह पाया गया कि आईआईटीडी में 477 प्रतिभागियों में से 29, 22, 49% और एनआईटी में 519 प्रतिभागियों में से 27, 30, 42% को अच्छे (<16; नीचे) के तहत समूहीकृत किया जा सकता है। पहला चौथाई स्कोर) मध्यम (16-23; पहला से तीसरा चौथाई स्कोर) और गरीब (> 23; तीसरे क्वार्टाइल से ऊपर) स्वास्थ्य श्रेणियां क्रमशः।

इसके अलावा, अच्छे, मध्यम और गरीब स्वास्थ्य के पहचाने गए समूहों के लिए उनके बीच के लिंक की जांच करने के लिए परिवेश पीएम 2.5 एकाग्रता के साथ कार्डियोपुलमोनरी पैरामीटर की निगरानी की गई। पीएम 2.5 द्रव्यमान एकाग्रता और रासायनिक विशेषता जनवरी 2013 से दिसंबर 2015 तक दो साल की नमूना अवधि के लिए की गई थी। उच्च पीएम 2.5 सांद्रता विंटर में मनाई जाती है, इसके बाद मानसून, गर्मी और मानसून के मौसम के बाद। अकार्बनिक आयनों से द्वितीयक एयरोसोल गठन सर्दियों में पीएम 2.5 द्रव्यमान पर हावी है। औसत ओसी और ईसी

और पोटेशियम सांद्रता अन्य मानदंडों की तुलना में मानसून के बाद उच्च थी, जो कि बायोमास परिवेश एरोसोल में जलती हुई प्रभाव का संकेत था।

आईआईटीडी शिक्षाविद के लिए फेफड़ों के कार्यों के अजीब अनुपात (ओआरएस) ने पीएम 2.5 सांद्रता की चतुर्भुज सीमा में वृद्धि के साथ 6-8% की वृद्धि देखी। एनआईटी के अकादमिक समूह में, ओआरएस में पारस्परिक सीमा में पीएम 2.5 एकाग्रता में वृद्धि के लिए 12.7% की वृद्धि हुई। पीएम 2.5 सांद्रता में क्यू 1 (25 वें प्रतिशत), और क्यू 2 (50 वें प्रतिशत) के बीच 1.4 गुना बढ़ने के साथ फोर्स एक्सपीरेटरी वॉल्यूम की प्रतिशत कमी (एफईवी 1) / फोर्स की महत्वपूर्ण क्षमता (एफवीसी) में प्रतिशत की कमी के लिए इसी तरह की प्रवृत्ति देखी गई। एनआईटी के अकादमिक समूह में, एफईवी 1 में कमी के लिए ओआरएस ने पीएम 2.5 सांद्रता में 14.4% की वृद्धि देखी है। इस खोज ने पीएम 2.5 सांद्रता में वृद्धि के साथ श्वसन कार्यों में काफी बदलाव (> 10%) के साथ प्रभावित आबादी की बढ़ती संख्या को स्पष्ट रूप से चित्रित किया।

हृदय गति परिवर्तनशीलता से संबंधित कार्डियक पैरामीटर के लिए सापेक्ष जोखिम जो एरिथिमिया को प्रेरित करते थे, का विश्लेषण किया गया था। सामान्य से सामान्य (आर-आर) चोटियों (एसडीएनएन) के मानक विचलन ने पीएम 2.5 के साथ नकारात्मक संबंध दिखाया, जिससे पीएम 2.5 एकाग्रता बढ़ने के साथ एरिथिमिया के बढ़ते जोखिम का संकेत मिलता है। 50-100 की सीमा में एसडीएनएन मध्यम जोखिम का तात्पर्य है और 100 से अधिक का तात्पर्य है कार्डियक हमले का कम जोखिम। विश्लेषण से पता चला है कि 100 से अधिक एसडीएनएन के साथ 50-100 और 42 के बीच एसडीएनएन के साथ 28 नमूने थे। एनएन 50 का अनुपात (पीएनएन 50: एनएन 50 लगातार एनएन अंतराल के जोड़े की संख्या है जो कुल संख्या में 50 एमएस से अधिक है एनएन के) एलएफ / एचएफ अनुपात ने पीएम 2.5 के साथ महत्वहीन नकारात्मक सहसंबंध दिखाया। पीएम 2.5 एकाग्रता में 10 माइक्रोग्राम एम -3 वृद्धि के साथ कार्डियोवैस्कुलर फ़ंक्शन में परिवर्तन का और सापेक्ष जोखिम 0.7-3.0 के रूप में अनुमानित किया गया था।

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LIST OF ABBREVIATION

Acronyms	Expanded form
AM	Alveolar macrophage
ATS	American Thoracic Society
BAL	Broncho-alveolar lavage
BMI	Body mass index
CNG	Compressed Natural Gas
COPD	Chronic obstructive pulmonary disease
CO:	Carbon monoxide
CPCB	Central Pollution Control Board
95%CI	95% confidence interval
CRP	C-reactive protein
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
FVC	Forced vital capacity
FEV ₁	Forced expiratory volume in one second
FEF _{25-75%}	Forced expiratory flow, 25-75%
IAQ	Indoor air quality
LRS	Lower respiratory symptoms
MMEF	Mid maximum expiratory force
NAAQS	National ambient air quality standards
NO _x	Oxides of nitrogen
O ₃	Ozone
OR	Odds ratio
PAH	Polycyclic aromatic hydrocarbon
PEFR	Peak expiratory flow rate
PFT	Pulmonary function test
PM	Particulate matter
PM ₁₀	Particulate matter with less than 10 µm diameter
PM _{2.5}	Particulate matter with less than 2.5 µm diameter
RBC	Red blood corpuscles
RSPM	Respiratory suspended particulate matter
SBP	Systolic blood pressure
SD	Standard deviation of mean
UFP	Ultrafine particle with diameter of less than 0.1µm
URS	Upper respiratory symptom
US EPA	United States environment protection agency
VOC	Volatile organic compound
WBC	White blood corpuscles
WHO	World health organization
HRV	Heart rate variability
SDNN	Standard deviation of NN interval
MSDNN	Mean standard deviation of NN interval
HF	High frequency (Heart Rate Variability)
LF	Low frequency (Heart Rate Variability)
STA	ST-segment amplitude

STD	ST-segment depression
STT	ST-segment and T-wave abnormalities
TWA	T-wave amplitude