IN-FIELD EMISSION OF AEROSOL AND GASES FROM TRADITIONAL COOKSTOVE AND ITS CLIMATE IMPLICATION

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by

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Submitted

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to the

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DEDICATED TO

My Parents,

Teachers

and beloved husband

for their support and inspiration

CERTIFICATE

This is to certify that the thesis entitled "**In-Field Emission of Aerosol and Gases from Traditional Cookstove and its Climate Implication**", being submitted by **Ms Annada Padhi** 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 her 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 whole to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The first time this research work reports emission factor of $PM_{2.5}$, carbonaceous aerosol (organic, elemental, and water-soluble organic carbon), ions, trace elements, and optical properties of aerosol, and gases emitted from the infield burning of mixed biomass fuel in traditional cookstoves. The fuel-based emission factors were measured primarily for four generic cooking process categories: boiling, baking, frying, and curry making. The average fuel mixture percentage of the three types of fuel, namely fuelwood (FW), dung cake (DC), and crop residues (CR) that the residents used for combustion as mixed power, was found to be-39±6.3% FW, 49.5±2.7 % DC and 12±5.3% CR. The particles were collected and analyzed for climate-relevant constituents of aerosol. The process of boiling emitted higher $PM_{2.5}$ (3.0-12.4 gkg^{-1}) and CO (22-125 gkg^{-1}) with a large fraction of organic carbon (OC) (37-66%), while emissions from frying and curry making were moderate (2.8-7 gkg^{-1}) and the process of baking had a low emission (2.2-7 gkg^{-1}) with a comparatively high EC (13-29%). This study reveals that the emission of gases and aerosols do vary significantly with the type of cooking event and fuel mix, even if a single type of fuel/cookstove combination is used. The emissions estimates of $PM_{2.5}$, EC, and OC and gaseous pollutants (CO, CO_2, SO_2, and NO_X) were calculated using new emission factors and fuel use data for Uttar-Pradesh for the base year 2017. The Global warming commitments of the pollutant aerosol and gases were determined for 100 years and a 20 year lifetime.

सारांश

पहली बार यह शोध कार्य $PM_{2.5}$ के उत्सर्जन कारक, कार्बोनेसियस एरोसोल (कार्बनिक, मौलिक और पानी में घुलनशील कार्बनिक कार्बन), आयनों, ट्रेस तत्वों, और एरोसोल के ऑप्टिकल गुणों और मिश्रित बायोमास के क्षेत्र में जलने से उत्सर्जित गैसों की रिपोर्ट करता है। पारंपरिक चूल्हे में ईंधन। ईंधन आधारित उत्सर्जन कारकों को मुख्य रूप से चार सामान्य खाना पकाने की प्रक्रिया श्रेणियों के लिए मापा गया था: उबालना, पकाना, तलना और करी बनाना। तीन प्रकार के ईंधन, अर्थात् ईंधन लकड़ी (एफडब्ल्यू), गोबर केक (डीसी), और फसल अवशेष (सीआर) का औसत ईंधन मिश्रण प्रतिशत, जिसका उपयोग निवासियों ने मिश्रित शक्ति के रूप में दहन के लिए किया था, 39 ± 6.3% ईंधन लकड़ी, 49.5±2.7% डीसी और 12±5.3% सीआर। एयरोसोल के जलवायु-संबंधी घटकों के लिए कणों को एकत्र किया गया और उनका विश्लेषण किया गया। उबालने की प्रक्रिया उच्च $PM_{2.5}$ (3.0-12.4 gkg^{-1}) और CO (22-125 gkg^{-1}) कार्बनिक कार्बन (OC) (37-66%) के एक बड़े अंश के साथ उत्सर्जित होती है, जबकि तलने और करी से उत्सर्जन बनाना मध्यम (2.8-7 gkg^{-1}) था और बेकिंग की प्रक्रिया में अपेक्षाकृत उच्च EC (13-29%) के साथ कम उत्सर्जन (2.2-7 gkg^{-1}) था। इस अध्ययन से पता चलता है कि गैसों और एरोसोल का उत्सर्जन खाना पकाने की घटना और ईंधन मिश्रण के प्रकार के साथ महत्वपूर्ण रूप से भिन्न होता है, भले ही एक ही प्रकार के ईंधन/कुकस्टोव संयोजन का उपयोग किया जाता है। $PM_{2.5}$, EC, और OC और गैसीय प्रदूषकों (CO, CO_2, SO_2, और NO_X) के उत्सर्जन अनुमानों की गणना आधार वर्ष 2017 के लिए उत्तर-प्रदेश के लिए नए उत्सर्जन कारकों और ईंधन उपयोग डेटा का उपयोग करके की गई थी। प्रदूषक एरोसोल और गैसों को 100 साल और 20 साल के जीवनकाल के लिए निर्धारित किया गया था।

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LIST OF ABBREVIATIONS

Acronyms	Expanded form
AAE	Absorption Angstrom exponent
AAOD	Absorbing Aerosol Optical Depth
AR5	The Fifth Assessment Report
ATN	Attenuation
BC	Black Carbon
BIS	Bureau of Standards India
CCN	Cloud condensation nuclei
CCT	Control Cooking test
CFCs	Chlorofluorocarbons
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CPCB	Central Pollution Control Board
EC	Elemental Carbon
EF	Emission factor
FGA	Flue gas analyzer
GWC	Global warming commitment
GHGs	Greenhouse gases

GWP	Global warming potential
HC	Hydrocarbon
HH	Household
ICP-MS	Inductively Coupled Plasma–Mass Spectrometer
IEA	International Energy Agency
IISER	Indian Institute of Science Education and Research
IMPROVE	Interagency Monitoring of Protected Visual Environment
IPCC	Intergovernmental Panel on Climate Change
IR	Infrared
KPT	Kitchen performance test
LPM	Liter per minute
MAC	Mass absorption cross-section
MCE	Modified combustion efficiency
MOPNG	Ministry of Petroleum and Natural Gas
MSA	Methane Sulphonic Acid
NCAP-COALESCE	National Carbonaceous Aerosol Programme
NDIR	Non-dispersive infra-red detection
NFHS	National family health survey
NMVOC	Non-methane volatile organic carbon
NO_X	Oxides of nitrogen
N_2O	Nitrous oxides
NSSO	National sample survey organization

OC	Organic Carbon
OM	Organic matter
OT21	Optical Transsiometer 21
PM	Particulate matter
$PM_{2.5}$	Particulate Matter (diameter < 2.5 μm)
PSAP	Particle soot/absorption photometer
RF	Radiative Forcing
RH	Relative humidity
STEMS	Stove emission measurement system
TC	Total carbon
TOA	Top of the Atmosphere
TOC	Total organic carbon
TOT	Thermal-optical-transmittance
TSP	Total Suspended particulate matter
UV	Ultra-violet
WBT	Water boiling test
WSOC	Water-soluble organic carbon