Sixth National Symposium
on
Air Resource Management
in Sri Lanka

"AIR THAT WE BREATHE - 2016"

Abstracts of Papers

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Air Resource Management Centre
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FOREWARD

At a time, global warming becomes as a key issue and Civil Society in Sri Lanka concern about rapidly increasing air pollution depriving the right of Sri Lankan people to breath clean air, holding bi annual symposium on clean air on a theme "Air That We Breathe" disseminating all research findings to the general public in Sri Lanka and to the Global Community.

Gross Domestic Product (GDP) in Sri Lanka expanded 2.5 percent in the fourth quarter of 2015 over the same period in the previous year. GDP Growth Rate in Sri Lanka averaged 6.22 percent from 2003 until 2015 which shows rapid growth in industrial and service sector. This means that increasing consumption of electricity major part generated from the thermal power and fossil fuels. It is estimated that 55-60% of air pollution accounted by the transport sector.

Major air pollutants associated with main anthropogenic activities includes repairable particulate matter (PM), Carbon monoxide (CO), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Ozone (O_3), Lead aerosol, volatile organic compounds (VOC) and Persistent Organic Pollutant (Dioxin & Furans). These pollutants can cause cancers, respiratory diseases such as bronchial asthma, chronic bronchitis and cardio vascular diseases such as heart attacks and hypertension. One in eight of total global deaths are as a result of air pollution exposure.This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Regionally, low- and middle-income countries in the WHO South-East Asia and Western Pacific Regions had the largest air pollution-related burden in 2012, with a total of 3.3 million deaths linked to indoor air pollution and 2.6 million deaths related to outdoor air pollution.

It was found to be that the Indoor air pollution comes mainly from burning of biomass fuels such as wood and other fossil fuels like kerosene, LPG, and agricultural waste used in domestic cooking is in Sri Lanka. The effect of the indoor air pollutants such as nitrogen dioxide, carbon monoxide, radon, formaldehyde, asbestos, mercury, man-made mineral fibers and volatile organic compounds becomes a serious issue when there is no proper ventilation in the cooking environment.

Sri Lanka has made few steps on air resource management, includes Clean Air 2000 Action Plan in 1993, National Policy on Urban Air Quality

Management in 2000, ambient air quality standards in 1994, emission standards for in-use and new vehicles, fuel quality and vehicle importation standards in 2000, banned leaded gasoline and introduced of unleaded gasoline island-wide in 2002, introduced low sulphur diesel & petrol in 2003, banned importation of 2 stroke engine three wheelers from 2008 and discouraged further imports of 2-stroke three wheelers and conducted indoor air quality management pilot project in 2006, implementation of the Vehicle Emission Testing Programme since 2008 and in addition Source Emission standards has formulated and will be published as a regulation in 2016.

Sixth National Symposium on Air Resource management in Sri Lanka is a team effort to gather most of these needed scientific data on air quality. Our objectives of this symposium are to i) compiled national research findings and experience, best practices and information providing path to use them in policy decision making; and ii) provide a forum for researchers and scientists in the field of air quality management to discussed their findings together with global trends mobilizing policy makers and implementers, practitioners and media to march towards better future.

This Report of Synopsis contains 22abstracts of papers, which were organized in 10 sessions i.e. Biomass Energy for Industrial Emissions Management, Vehicular Air Pollution, Health Impacts of Air Pollution, Fossil Fuels, Indoor Air Pollution & Ambient Air Quality, air quality monitoring, modelling and emission inventory. We hope that the key findings and recommendations that emerge from these scientific presentations can be utilised in identifying policy directions and formulating strategies for sustainable development in the country. We wish to thank all authors, participants, and chairpersons of sessions, supporting staff and all UNEP Regional Office for Asia and the Pacific, South Asia Co-operative Environment Programme,Sustainable Biomass Energy Project, Clean Air Sri Lanka and AirMAC partners who made this event a reality. We look forward with high calibre participants an interesting thought provoking and rewarding symposium.

Symposium Organising Committee
Air Resource Management Centre (AirMAC)
Ministry of Mahaweli Development & Environment
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CONTENT

TECHNICAL SESSION 9 : AIR QUALITY MONITORING, MODELLING & EMISSION INVENTORY

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UTILITIZATION OF TECHNOLOGY IN BIOMASS ENERGY CONVERSION SYSTEMS IN SRI LANKA

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ABSTRACT

Utilization of biomass for energy has been increasing rapidly since 2000 and the estimated consumption exceeded 4,000,000 tons by 2013. Sustainable supply of biomass to meet this demand has become a challenge now. To face this challenge both demand and supply side must be re-organized/re-oriented towards better efficiency. Introduction of efficient technology has been considered a major option for achieving this. This study aims to establish the baseline on technology infusion in biomass energy conversion systems (BECS), and identify potential for improvement.

An inventory of some 320 modern thermal BECS installed in the country was studied. Twenty two selected BECS installed in multiple of industries were visited and collected necessary data for this study. BECS provide services such as Steam, Hot water, Hot thermic oil, Hot air and electric power by using wood logs, multi-fuels, paddy husk, wood chips, saw dust and coconut shells as fuel. Despite the fact that the BECS are designed to use certain quality of biomass, the biomass used in Sri Lanka varies widely in quality, and moreover, there are no local standards for biomass. It is, therefore, inevitable that our BECS underperform due to unavailability of quality biomass.

Technologies used to ensure proper combustion air supply in BECS were studied. Air staging is widely used to achieve this in BECS. Heat exchangers in BECS were studied to find out different designs and configurations used and to know their relative advantages in improving performance of BECS.

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Emission control of BECS is important to mitigate environmental impacts. However, technologies used were malfunctioning due to multiple of reasons. Energy recovery is a common method to increase the overall efficiency of BECS. Air pre-heater (APH) and water pre-heater (WPH) are most common.

The reason for limited use of Wood Gasification Technology in the industrial sector was studied, and lack of technology readiness was found to be the major reason. Studies undertaken by some world leading research institutes give guidelines on the Technical and Commercial Readiness of several combinations of BECS with respect to service applications.

Institutional barriers to promote sustainable BECS are discussed. In addition opportunities to introduce new technology for improving performance of BECS has been explored. There are other opportunities for local value addition with potential for improving the performance of BECS.

Key words: Biomass, Efficiency, Sustainable, BECS.

EVALUATION OF SAW DUST AS AN ALTERNATIVE ENERGY SOURCE: CASE STUDY OF MORATUWA DIVISIONAL SECRETARY DIVISION

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ABSTRACT

It is important for the Sri Lankan energy sector to utilise renewable energy as much as possible to attenuate the environment crisis resulted by fossil fuel. Furthermore, it would reduce the heavy dependence on imported fossil fuel/coal and decrease the draining out of foreign exchange. Saw dust is an emerging energy source to satisfy thermal energy needs of the Sri Lankan industrial sector with over 70 boiler installations [1]. In Moratuwa Divisional Secretary Division (DSD), saw mills are abundant. As an area proximate to the industrial zones, Moratuwa DSD has become an important supply area of saw dust and off cuts. This study has collected data of 121 saw mills, based on one to one interviews held during site visits.

In the 121 saw mills, average daily generation of saw dust is 162 MT/day. Mean price offered by the external parties is LKR 0.93/kg whereas its standard deviation is 0.417. Saw dust supply have created an annual income of about LKR 35 Million to the local community. Saw mills considered in the study provide approximately 35,000 MT of saw dust for the industries. It is equivalent to 10,200,000 litres of furnace oil worth LKR 816 Million to the end user. Expenditure for use of saw dust priced at LKR 3,000/MT is LKR 105 Million only. Therefore, Sri Lankan industries have retained a considerable amount of foreign exchange through using saw dust originated in Moratuwa DSD.

Moreover, using saw dust for energy applications is specially beneficial to the environment. In case of open dumping, land becomes unsuitable for an economic activity like constructions or cultivations (due to lengthy degradation period of saw dust), aesthetic pollution occurs and emission of methane and other gases related to global warming takes place. Disposal of saw dust into natural water bodies creates high bottom deposits, emission of bad odours, anaerobic conditions at the lower levels and discoloration of water making an irrevocable damage to the ecosystems. Bolgoda Lake and Lunawa lagoon had serious problems in past due to saw dust disposal.

Combustion of saw dust rather than on-site storage would provide a CO_2 offset of 1.2 tons for each tonne of saw dust burned [2]. Accordingly 42,000 tonnes of CO_2 equivalent is reduced through the supply of saw dust for energy applications. Furthermore, using this as an alternative to fire wood has reduced some pressure on fire wood. Over the years, an inevitable waste of wood based industries has been changed into a valuable resource.

COMPARISON OF ENERGY POTENTIAL OF *PROSOPIS JULIFLORA* WITH COMMONLY USE FUELWOOD SPECIES *LEUCAENA LUEUCOCEPHALA* IN SRI LANKA

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ABSTRACT

Sri Lanka's fossil fuel consumption has been dramatically increasing within past few years. Due to nation's depending on imported fossil fuels, its accelerating cost and environmental implications, Sustainable Energy Authority of Sri Lanka is focusing on replacing fossil fuel by other renewable energy resources. *Prosopis juliflora* is identified as a major Invasive Alien Species (IAS) in Bundala national park in Southern dry zone, Sri Lanka which in needed to be controlled with proper management practices. The study was designed with the primary objective of evaluating energy potential of *Prosopis juliflora.* Secondary objective was to compare energy potential of *Prosopis juliflora* with commonly used fuel wood species, *Leucaena leucocephala* grown in Southern province.

Part of the Bundala national park was selected as the study site according to a reconnaissance survey. Selected individuals were categorized into three diameter classes hypothesizing that there is no significant difference in energy characteristics among three DBH classes (10-19.99 cm; 20 cm-29.99 cm; 30 cm–39.99 cm). In each individual measured characteristic were moisture content (oven dry method), density (Archimedes principle), specific gravity (maximum moisture content method), ash content (loss on ignition method), volatile matter and fixed carbon. According to results, there were no significant differences among three DBH classes for moisture content, density, specific gravity and ash

content. Volatile matter and fixed carbon content showed significant differences among three DBH classes.

In order to fulfill second objective, 15 individuals of *Leucaena leucocephala* were selected from a site near Bundala national park where *Leucaena leucocephala* is relatively abundant. Certain characteristics including moisture content, density, specific gravity, ash content, volatile matter content, fixed carbon content of two species were significantly different. Calorific values of *Prosopis juliflora* (18.66 kJ/g) and *Leucaena leucocephala* (18.35 kJ/g) lie within the range of calorific values of most commonly used fuel wood species in Sri Lanka. Constructed Fuel wood Value Index (FVI) for *Prosopis juliflora* and *Leucaena leucocephala* were 3276 ± 274 and 3336 ± 389 respectively.

Drying profiles were constructed for both species at 25 ^{0}C to 29 ^{0}C and humidity at 81 % to 97 %. Fiber Saturation Point was almost the same for both species.

Study findings demonstrated that 0.50 L of diesel, 0.45 L of furnace oil and 5.185 kWh of electricity could be replaced by 1 kg of *Prosopis juliflora* wood and *Leucaena leucocephala* could replace 0.48 L of diesel, 0.43 L of furnace oil and 5.09 kWh, electricity units. Fuel wood produced by an average size individual (DBH = 23.16 cm and height =15 m) using standard equation of Y= 2.10 + 5.08X and it is 119.74 kg .Therefore average size *Prosopis juliflora* individual can be used as a fuel wood to replace 60 L of diesel, 54 L of furnace oil and 620 kWh of electricity which is a significant contribution for nation's energy demand. Since there is no difference among different sizes of *Prosopis juliflora* for certain fuel wood properties, sizes over 10 cm DBH can be harvested to use as a dry matter energy source.

Key words: *Prosopis juliflora,Leucaena leucocephala,*Fuel wood, Energy,IAS

PERFORMANCE OF ENVIRONMENTALLY PREFERRED VEHICLE TECHNOLOGIES IN URBAN & RURAL AREAS OF WESTERN PROVINCE

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ABSTRACT

Performance of environmentally preferred vehicle technologies in urban & rural areas of Western Province, Sri Lanka were studies to identify the relative environmental performances under the local context. Based on the literature referred, questioner was developed and data was collected from 100 vehicle users during the months of July to October in 2015. Important points are gathered from the analysis of the data and they are deliberated along with the research objectives. Appropriate aspects are evaluated for the hybrid and conventional vehicles with respect to the usage fuel type, engine capacity, vehicle brand, type of vehicle use, usage of the vehicle in years, driven kilometers per week, used techniques, average energy consumption, maintenance frequency of the vehicle.

From the study, 75 % of the vehicle users, owners or drivers from various institutions that were participated prefer urban environment for their daily activities and most of the vehicle owners themselves take their motor cars for their daily activities by reporting 80.6% among vehicle users. This have led to heavy traffic congestion in the city limits. Local automobile market is dominated by Japanese brands

and European brands are considered as luxury vehicle and has a confined market. It is seen that based on the lifestyle and distance travel over the month have increased the amount of charges for the fuel and both conventional and hybrid vehicle consider on vehicles as per the vehicle manufacture instructions and according to distance travelled.

It is concluded that there is a tendency of vehicle users to adapt environmentally preferred vehicle techniques in their daily life and this need to be considered in policy making by considering consumer choices. Therefore current legislation needs to be focused to improve the air quality to lessen the emissions by following an integrated approach of having various EST concepts to influence consumer choice to produce driving behavior and purchase choices. This information would not only help a better consumer choice, but also assist the government to make more rational policy decisions in the transport sector.

TRANSPORT INDUCED VOLATILE ORGANIC COMPOUND CONCENTRATION IN THE CITY OF COLOMBO

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ABSTRACT

Volatile Organic Compounds (VOCs) constitute an important fraction of air pollution contributing to variety of health and environmental impacts directly as well as indirectly through generation of secondary air pollutants, but there is a lack of data for understanding of VOC concentrations in urban environment of Sri Lanka. In order to fill this gap, field measurements of Total VOC (TVOC) were conducted at seven locations in Colombo, which were selected based on predetermined criteria covering traffic pattern, population density, outdoor air pollutant sources such as vehicles, power plants and industries, major transportation hubs in the city, highly commercialized areas, and coastal areas having sea breeze. The seven junctions thus selected are Dehiwala, Kollupitiya, Fort, Maradana, Boralla, Narahenpita and Grandpass. Hourly spot measurements were carried out beside the road during the medium traffic flow at these sites using MiniRAE Lite TVOC monitor in the month of May 2014. Further TVOC levels were measured on road by fixing TVOC monitor inside a moving vehicle keeping air flow tube outside the shatter of vehicle to understand concentration variations away from the junctions between the sites.

Weekly average TVOC hourly median concentrations beside the roads in ppb were 226.5, 194.5, 190.0, 99.0, 91.5, 72.5 and 56.0 at the sites Grandpass, Maradana, Borella, Dehiwala, Narahenpita, Kollupitiya, and Fort, respectively. The corresponding on the road TVOC concentrations in ppb were 536.0, 321.5, 216.0, 195.0, 189.0 and 183.0 between Narahenpita to Grandpass, Maradana to Borella, Borella to Narahenpita, Fort to Maradana, Kollupitiya to Fort and Dehiwala to Kollupitiya, respectively. It was clearly showed that TVOC levels were high on the road than beside the road as the predominant source of TVOC is vehicles. This could be explained by the immediate tail-pipe emissions (undiluted) from the ongoing vehicles were higher than the beside the road measurements.

After analyzing the data of the seven junctions, it was showed that highest TVOC concentrations were observed at the Grandpass junction having most congested road, thermal power station and an industrial zone. Therefore 24 hour roadside measurements were carried out at the high residential flats, 20 meters away from the Grandpass junction. Instruments were fixed at a indoor environment having the air flow tubes open to the outdoor air. Time series data on TVOC concentrations follow the typical traffic pattern during the day at Grandpass site having a sharp peak from 6.30am to 7.30am in the morning and a broaden peak from 5pm to 8pm in the evening.

Results explained that TVOC concentration dependent on vehicle density on road with the level of traffic congestions, metrological parameters and sea breeze.

Keywords: Urban air quality, vehicular pollution, volatile organic compounds, Colombo

VEHICLE EMISSION TRACKER: A MOBILE SOCIAL APPLICATION MODAL TO SPOT VEHICLE EMISSION USING RINGELMANN SMOKE CHART

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ABSTRACT

Vehicular emission control is the one of main strategy to improve the urban air quality in Sri Lanka. With the advancement of the smartphones and the usage of the social media have aided in enhancing the social awareness among the communities on environmental concerns like air pollution. This mobile-social application modal is designed to enable individuals to spot the high smoke emitting vehicles and evaluate using the spotted vehicle based on Ringelmann Smoke Chart and share them on social networks.

Based on the collected literature on mobile-social applications with related to emission tracking and user feedback on using such applications were considered to develop this modal. Technologies of current smartphones offer advanced sensing, processing and storage capability with always-on internet connectivity with GPS location tracking and also most smartphone platforms provide an environment for diverse of application development. It is easy to develop mobile applications that can exactly track the courses of vehicles. Social networks such as Facebook has been shown to be able to become highly engaging and this could encourage more user participation.

This concept can be used to monitor in-use vehicles with heavy smoke,

evaluate and get user responsiveness on air quality management in Sri Lanka. It can be used as guidelines to evaluate existing designs and platforms, guide the design process and educate application designers to integrate new monitoring systems to measure air quality considering the new technologies which evolved among the social communities. It is intended to not only raise social awareness of vehicular emission, but also serve as a research platform for data collection for research in vehicular traffic and emission management, and user behavior analysis in social network based applications in order to use in policy formulation.

REDUCING AIR POLLUTION BY EASING TRAFFIC CONGESTION IN SRI LANKA: A COMPARATIVE SOCIO LEGAL ANALYSIS WITH SINGAPORE CONTEXT

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ABSTRACT

Sri Lanka's transport system is predominantly road transport which is mainly based on a road network and it is also reported that in the present context total active vehicle fleet in Sri Lanka is more than two million which remarks a rapid growth compared with past few years. As a result, this situation has already caused irreparable air pollution to the environment mainly due to fuel emission of vehicles. In addition, heavy traffic congestion cause due to road unsafe and poor traffic management boosts fuel emission on daily basis. Therefore, the objective of this study is to find possible socio-legal solutions on reducing air pollution by easing traffic congestion in Sri Lanka.

Therefore, the research problem of this study is mainly focus to solve whether the reasons for the traffic congestion in Sri Lanka is due to the socio-legal loopholes of road safety and traffic management in the existing traffic laws of the country or the implementation of such laws and regulations by public officers.

This study is based on qualitative research methodology which mostly depends on secondary sources of laws and regulations with regard to traffic rules such as Motor Traffic Act, government policies, publications, internet and research findings as well as primary sources such as information

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gathered through interviews with responsible authorities. Moreover, it is to compare and contrast with Singapore context, the prime example of managing traffic and congestion in South Asian region, by planning for the long term by extending road system, improving existing roads as well as harnessing technology.

In conclusion, it is the intention of this research to find possible remedies to reduce air pollution in Sri Lanka by easing traffic congestion and raise our country towards a sustainable environment in the near future.

Key words: Air pollution, Traffic congestion, Socio- legal remedies

DO HOUSEHOLD COOKING FUEL TYPE AFFECT THE LOW BIRTH WEIGHT IN SRI LANKA?

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ABATRACT

Introduction : Low birth weight (LBW) is defined by the World Health Organization as birth weight less than 2.5 kilograms. LBW is a key determinant of morbidity and mortality in neonates and infants reducing growth, impairing immune function and cognitive development, and increasing the risk of non-communicable diseases. Previous evidence from other countries indicate that exposure of pregnant mothers to household air pollution from solid fuel leads to low birth weight.

Objective : To determine the association between maternal, environmental and socio demographic factors and LBW in Kalutara Medical Officer of Health (MOH) area

Methods : A case-control study (1 case: 2 controls) was conducted in Kalutara MOH area. Cases were term babies <2.5 kg and controls were term babies ⩾2.5kg. Public Health Midwives administered a questionnaire to mothers during the second postpartum visit to ascertain data on socio-demographic characteristics, environmental risk factors, etc. Data relevant to health status in pregnancy were abstracted from pregnancy records. A

composite index was developed to assess the exposure to household air pollution based on the source of primary cooking fuel and place of cooking. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for potential risk factors. Ethical clearance was obtained from ethics Review of Committee of National Institute of Health Sciences.

Results : Mothers of 64 LBW and 122 normal birth weight term babies (i.e., babies completed gestational age of at least 37 weeks at the time of delivery) were interviewed. Study population was predominantly Sinhalese (cases = 95.2%; controls = 93.5%). Education of mothers were higher among the normal birth weight babies (GCE OL and above = 74.2%) compared to LBW babies (GCE OL and above = 61.0%). Compared to the mothers with normal birth weight babies, higher proportion of mothers with LBW babies had low income level (49.6% vs. 55.6%, OR = 1.3 (0.7 - 2.4), had exposure to high household air pollution due to cooking fuel (30.1% vs. 42.9%, OR = 1.7 (0.9- 3.3), had low hemoglobin levels at booking visit (28.9% vs. 35.9%, OR = 1.4 (0.7- 2.6), had Body Mass Index less than 18.5 (15.6% vs. 25.0%, OR = 1.8 (0.8 - 3.8), had not received micronutrient supplement at pre-pregnancy period (20.3% vs. 24.6%, OR =1.6 (0.7 - 3.4).

Conclusion: Risk factors for LBW babies were multifactorial and complex. Multidisciplinary actions are required to address the issue. Further studies are needed with higher sample size than the expected for definitive conclusions. It is likely that the household cooking fuel type affects the low birth weight in Sri Lanka.

Key Words: low birth weight, risk factors of low birth weight, indoor air pollution

HEALTH IMPACT OF PUBLIC BUS DRIVER'S EXPOSURE TO AIR POLLUTION IN COLOMBO CITY - SRI LANKA

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ABSTRACT

Health effects of air pollution have become a growing concern as a negative effect of rapid urbanization in capital cities in Sri Lanka. The main source of ambient air pollution in Sri Lanka is vehicular emissions. Seven bus routes were selected for the study based upon the traffic density and land use of the area. Six buses were selected in each route and Particulate matters ($PM_{2.5}$ & PM_{10}), Carbon monoxide (CO), Total volatile organic compounds (TVOC) and some Volatile Organic Compound (VOCs) concentration were analyzed in each sample bus. The in-vehicle & ambient PM_{10} concentrations within the Colombo city routes exceeded the Sri Lanka air quality standard and WHO guideline while both in-vehicle & ambient PM_{10} concentration of rural was well below the air quality standards. The in-vehicle & ambient $PM_{2.5}$ concentration were higher in Colombo city than the sub urban and rural. The CO, TVOC, Toluene, Xylene, and Carbon Tetrachloride concentration were found in acceptable level. The benzene level exceeded the guideline for good class in Colombo city routes. The traffic congestion and poor maintenance of vehicles had large effect on in-vehicle air quality. Colombo city drivers had more respiratory symptoms than the rural drivers. Lung function test showed that more than 75% of drivers had normal FEV1/FVC ratio. The FVC /predicted FVC ratio of the rural drivers was slightly higher than the urban routes drivers. Significant negative correlation was found among Lung function and in-vehicle PM_{10} concentration at the α=0.01 (r= -

0.494,p=0.006).

Keywords: In-vehicle air quality, lung function, respiratory illness,

THE IMPACT OF ATMOSPHERIC POLYCYCLIC AROMATIC HYDROCARBONS IN KANDY CITY ON AIRWAY EPITHELIAL CELLS AND NASOPHARYNGEAL CARCINOGENESIS

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ABSTRACT

Polycyclic Aromatic Hydrocarbons (PAHs) are a group of compounds of which some are known or probable carcinogens. They are formed mainly from incomplete combustion and emission from vehicles is a major source of these compounds in urban outdoor air. Any extensive research is yet to be done to ascertain the real status in Sri Lanka. Therefore, the present study focuses on Kandy city air quality, which is one of the most polluted and highly populated cities, exposing to emissions from more than 100,000 vehicles daily. The association between nasopharyngeal carcinoma and specific chemical compounds such as PAHs were confirmed using the several researches conducted within last few decades in elsewhere and some known carcinogenic PAHs such as Benzo [a] pyrenewere, Benzo [b] fluoranthene, Dibenz [a,h] anthracene were identified in Kandy city. Therefore, the current research focuses on carcinogenic potency of the identified PAHs on human upper respiratory tract.

Air samples are collected with high-volume air samplers from the selected

locations in Kandy city and they are analyzed using advanced analytical methods such as High Performance Liquid Chromatography (HPLC), Gas Chromatography (GC), Mass Spectrometry (MS) and Atomic Absorption Spectroscopy (AAS) to identify the specific pollutants. These include Particulate Matter (10 m), PAHs, heavy metals and their respective concentrations at the lower atmosphere of the city. A primary cell culture model is used with swine bronchial epithelial cells. A commercially available immortalized human air way epithelial cell lines is also used for the *in-vitro* bioassays to find out the molecular level changes occur in the cells upon the exposure to identified PAHs in Kandy city air. DNA damages, cell toxicity, cell proliferation, cancer related signaling pathways are assessed using the latest genomic and proteomic methods. Further, a clinical audit using cancer patients and patients with respiratory tract disorders will be carried out with a patient cohort seeking treatment at Kandy and Peradeniya teaching hospitals. We will also look into the possibility of establishing a biomarker based assay to identify the possible risks among the school children with an oral/nasal swab based assay. The outcomes of the current work can be used to make predictions about the air pollution level with the risk of having cancers, policy making and further research.

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KNOWLEDGE ON AIR POLLUTION, PREVALENCE OF SELECTED RESPIRATORY SYMPTOMS AND THE PEAK EXPIRATORY FLOW RATE AMONG TRAFFIC POLICE OFFICERS IN THE POLICE DIVISION OF COLOMBO

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ABSTRACT

Introduction: Outdoor air pollution is considered a significant environmental health issue in the world and by reducing air pollution could save millions of lives. Traffic emission is a major source of outdoor air pollution in urban areas and polluted air happens to be the major part of the air the traffic police officers breathe for long periods of time. As such, traffic police personnel are at a higher risk for the adverse health effects of air pollution, due to their occupational exposure, compared to the general population.

Objectives: To describe the knowledge on air pollution, determine the prevalence of selected respiratory symptoms and measure the peak expiratory flow rate among traffic police officers in the Police Division Colombo.

Methods: A descriptive cross-sectional study was conducted, among traffic policemen working at field level, in the police division, Colombo. Final calculated sample size was 406 and simple random sampling method was used to select the final sample. A pre–tested self-administered questionnaire, a peak flow meter, a UNISCALE electronic scale and a measuring board was

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used for collection of data.

Results: Out of 392 respondents 44.1% (n= 173) had very poor knowledge, 34.7 % (n=136) had poor knowledge and only 20.2% (n=79) and 1% (n=4) had good knowledge and very good knowledge, on air pollution, respectively. Knowledge on air pollution was significantly associated with the educational level ($p=0.01$), presence of respiratory symptoms ($p<0.001$) and presence of prior acquired knowledge ($p<0.001$). Expectoration was the most prevalent respiratory symptom 55.4% (n=217), among participants, followed by cough 40.1% (n=157). The prevalence of runny nose was 38.8 % (n=152) and of throat clearing was 26.0% (n=102) while it was 17.9 % (n=70) for shortness of breath. Around half of the traffic police officers studied (48.7%, n=191), had reduced peak expiratory flow rates.

Conclusions and Recommendations: Overall knowledge on air pollution among traffic police officers was poor with a high prevalence of respiratory symptoms and reduced peak expiratory flow rates, which needs immediate action to uplift occupational health of traffic police officers.

Key words: Outdoor air pollution, Traffic police officers, Respiratory symptoms, Peak expiratory flow rate, Knowledge acquiring modes

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I like to thank full Dr. Amitha Fernando, Consultant Chest Physicians for his great support in constructing my research questionnaire.

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EXPOSURE ASSESSMENT OF POLLUTANT GASES IN ROAD-SIDE OFFICE INTERIORS: CASE OF AIR-CONDITIONED AND FREE-RUNNING OFFICES

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ABSTRACT

With the increasing number of commuting vehicles and considerable slowing down of travel speeds will exaggerate the outdoor air pollution levels in localities closer to major traffic routes in the city of Colombo.

Characteristically majority of urban office buildings in Colombo are positioned along major roadways with high traffic densities. At present the urban building stock is dominated by artificially conditioned sealed building envelopes and the burgeoning trend of the current construction practice is to design and build more and more "Active Offices". So often fully air-conditioned urban office buildings demonstrate unhealthy indoor environments and numerous studies have suggested an association between living and working near traffic roads and the occurrence of health-related problems. Hence, proves indoor air pollution is a major global public health threat requiring greatly increased efforts in the areas of research and policy making.

A comprehensive literature review of indoor air quality studies in Sri Lanka reveals a limited research attention on indoor air pollution of urban buildings and studies on exposure assessment. Thus the study focuses on an appraisal of pollutant gases and an exposure assessment based on Sick Building Syndrome symptoms (SBS) in air-conditioned and free-running urban office interiors facing major traffic routes in the city of Colombo.

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Office building selected in this study portrait a broad-spectrum of design characteristics evident in urban office building stock of Colombo. Thus the underpinning research methodology of this study focuses on the notion of critical case. Field investigation was conducted in air-conditioned and free-running office interiors at ground and mid level of the building in the hottest month of March 2016. Study investigated the concentration of six indoor pollutants gases (CO, CO_2, SO_2, NO_2, O_3 and TVOC) and the status of indoor thermal environment. Simultaneously a structured questionnaire was utilized to explore office worker's experience on SBS symptoms.

Results explicitly establish SO_2 is the common indoor pollutant gas in all office interiors. However a difference in pollutant gases is evident in air-conditioned and naturally ventilated offices. With reference to indoor air quality guidelines of Asia, indoor concentration levels of CO_2 and O_3 are beyond the maximum permissible levels in air-conditioned and naturally ventilated offices respectively. Moreover these pollutant gases are well above the acceptable long term (ALTER) and short term exposure ranges (ASTER) specified in widely used exposure guidelines for occupational health and safety.

Statistical analysis on ranking of the sick building syndrome symptoms confirms fatigue, heavy head, dry facial skin and dry throat are frequently experienced SBS symptoms among the workers in air-conditioned offices. Prevalence of these symptoms proves a strong association between health effects and concentration levels of pollutant gases. Thus the findings highlight mechanical ventilation systems of the air-conditioned offices are unable to provide the acceptable ventilation rate to retain healthy indoor air. Although naturally ventilated spaces maintain acceptable ventilation rates to retain healthy indoor CO_2 levels, consequently, it is vital to explore innovative envelope designs to control penetration of polluted outdoor air towards the interiors of road-side office buildings.

ROLE OF STANDARDS IN ENHANCING THE QUALITY OF FOSSIL FUELS FOR MANAGING AIR QUALITY IN SRI LANKA

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ABSTRACT

This paper presents a role of standards in enhancing the quality of fossil fuels for managing air quality in Sri Lanka. Beginning of the air pollution in the world is discussed. Air quality of Sri Lanka two decades ago also was highlighted. Problems due to degradation of air such as health impact, impact of economy and loss of overall standards of living are presented. Measures taken to improve air quality during last two decades are studied. The standards designed to breath of fresh air are reviewed. To this aim, various standards and regulations are analyzed. Inconsistencies in selected parameters of the current fuel quality standards are identified. Harmonizations of petrol and diesel standards are proposed. To harmonized the fuel quality standards (petrol and diesel) with emission and ambient air quality standards; **SLS 768:1995 Petrol for motor vehicles** and **SLS 1103:1995 Automotive diesel fuel** have to be revisited while taking into consideration of technology status and present trends. Further, establishment of independent fuel quality testing laboratory and product certification system for effective implementation of relevant standards are also proposed. The study also highlights several supportive measures to protect the Air That We Breath from air pollution.

Key Words: Petrol Standard, Diesel Standard, harmonization of standards and breathe of fresh

THE OVERVIEW OF THE AMBIENT AIR QUALITY IN MAJOR CITIES IN SRI LANKA

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ABSTRACT

Degrading ambient air quality is becoming a growing issue in Sri Lanka due to rapid expansion in the industrial and commercial sectors and increasing living standards of the people. The recent monitoring records show that air quality in certain urban cities has been deteriorated to such an extent that human health is being threatened. The economic growth of the country is incorporated with energy demand which is mainly fulfilled by fossile fuel imported to the country. Some studies indicate the transport sector itself is contributing about 60% to the air pollution in Colombo city. Basically it is contributed by Criteria air pollutants (CAPs) and Hazardous air pollutants (HAPs) as well. The other source such as thermal power plants already established and planned in the country making a trend to considerable influence on ambient air quality in the country. Hence the ambient air quality monitoring data across the country make a vital role to pay attention of policy makers, administrators and environmentalists engaged with ambient air quality related studies and policy making activities.

Being a responsible key organization in Sri Lanka ,Central environmental Authority have been engaging with urban air quality monitoring program across the country since 2014 under financial sponsorship of the Vehicle Emission Trust Fund (VET).In this program the criteria air pollutants such as $PM_{2.5}$,PM_{10},SO_2,NOx,CO,O_3 and Non methane volatile organic compounds (NMVOCs) are measured in selected urban cities and recently

monitored locations were Nugegoda, Gampaha, Matara, Badulla, Kandy, Polonnaruwa and Nuwara eliya. The 24-hour continuous monitoring for seven days in each and every city were accomplished by using fully automated mobile ambient air quality monitoring station. The collected raw data were processed as 24-hour average in order to compare with National ambient air quality standards and WHO guideline values as well.

According to the monitoring data obtained from major cities in Sri Lanka, The maximum 01- hour average, 24-hour average and 8-hour average of pollutants concentrations have been calculated for seven days. The recorded PM_{10} and $PM_{2.5}$ levels showing slight increasing trend in almost the all the cities representing maximum PM_{10} and $PM_{2.5}$ level in Badulla city respectively 135.40μg/m^3 and 61.10μg/m^3.The NO_2 level in all the cities showing low concentrations and the maximum concentration of 0.073 ppm is recorded in kandy city among other cities. In the same way the highest 01-hour average of seven days O_3 concentration as 0.035 ppm is recorded in Kandy city while the other cities show low concentrations. However the major cities of Matara, Badulla and Nugegoda are recorded very low concentrations of SO_2 compared with other cities and it is notable highest in Nuwara-eliya as 0.059 ppm. Finally the monitored CO level of 9.85ppm is recorded as the highest in Polonnaruwa district while other cities lower than those concentrations.

As observed, the recorded maximum concentrations in each parameter, almost all in the cities considered in Sri Lanka have been maintaining below the national ambient air quality standards. But it seems that the little increasing trend of PM_{10} and $PM_{2.5}$ in major cities compared with other parameters monitored. It is also notable that the other parameters such as SO_2, NO_2, CO and O_3 have been recorded maximum average concentrations below the National ambient air quality standards. However these values are defined to 24-hour continuous monitoring for 07 days and it is an instant

nature on ambient air quality in the cities considered. Compared with the trend of industrial development, constructional activities and vehicle fleet of the major it is expectable the sort of harmful level of pollutants in long-term at major cities. On the other hand most of pollutants levels in cities nearing or exceeding as defined in WHO guidelines. Thus currently existing pollutants levels can be affected the health of the people specially those stay in the vicinity of urban cities.

These pollutants concentrations have been given for 24-hour consecutive 07 days for a particular city and once a year monitoring for a particular season. Hence the data is very limited and not representative for the entire year. It is also needed a large set of continuous monitoring data representing all seasons in Sri Lanka in order to introduce standard methodology at the data processing. Thus it is recommended to further improvement of exiting ambient air quality monitoring program in Sri Lanka taking in to account the draw backs recognized in the program. It is further recommended to install more fixed ambient air quality monitoring stations in major cities to obtain real time data for better assessment of air pollution status in the country.

Key words: Ambient air quality, National Ambient air quality standards, WHO standards, Criteria air pollutants, Hazardous air pollutants

OPTIMAL LOCATION ALLOCATION CRITERIA FOR AIR POLLUTION MONITORING NETWORK

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ABSTRACT

Spatial and temporal variation of air pollutants in urban areas is complex due to several factors such as numerous types of emission sources, different topographical and different atmospheric and weather conditions. As a result, accurate estimation of pollution level for decision making would require monitoring networks with high spatial and temporal resolution. However, the high cost associated with conventional air monitoring techniques makes it impractical to have such high resolution of monitoring. Use of electrochemical sensors to monitor air pollution is emerging over traditional air quality monitoring methods due to their low cost and ability to use them in high density networks with great spatial and temporal resolutions. Optimized location selection for these air quality monitoring networks are vital in order to assess the impact of human exposure to air pollution.

This study addresses developing optimal sensor location for multi pollutant (CO_2, CO, NO_2, NO, O_3 and SO_2) monitoring network to assess human exposure and for developing a comprehensive air quality model for Kandy city. The location selection methodology was designed based on population density and predicted emission data along with safety and accessibility for instrument installation. The number of sensor units available for the monitoring is six and so initially Kandy city and surrounded area was

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divided into six major sub areas considering the population densities and traffic conditions. Each of the sub areas were then gridded and relative estimates of emissions and population densities with appropriate weighting were put in to an algorithm that solves constrained optimization problem to calculate an index value for each location. According to the ranking of the indices the most suitable monitoring locations within a sub area were identified. In order to develop a comprehensive mapping of air pollution levels with maximum spatial and temporal resolution, a land use regression (LUR) method is then proposed by considering building height, wind velocity, elevation difference, tree cover and road structure as the predictor variables. When developing the LUR model to identify the relationships between predictor variables and pollution concentrations, a multiple layer perceptron neural network approach was used. Predicting model will be validated using the measured data. This method can be used for designing air pollution monitoring networks complying to the available resources and/or in places where previously monitored data is not available.

This is an initial stage of the research project titled "Monitoring and modelling of ambient air quality in Kandy city", funded by Vehicular Emissions Testing Trust Fund (VETT Fund), Department of Motor Traffic. We kindly acknowledge the VETT Fund for their commitment and continuous support for this project.

COMPARISON OF AIR POLLUTANT CONCENTRATION IN RELATION TO NOXVOCO3 SENSITIVITY IN URBAN ENVIRONMENT OF SRI LANKA

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ABSTRACT

In the troposphere near the Earth's surface, ozone forms through the splitting of molecules by sunlight as it does in the stratosphere. However in the troposphere, nitrogen dioxide provides the primary source of the oxygen atoms required for ozone formation. Sunlight splits nitrogen dioxide into nitric oxide and an oxygen atom. The process described above results in no net gain in ozone. Concentrations occur in higher amounts in the troposphere than these reactions alone account for that two additional chemical constituents of the troposphere contribute to ozone formation. These constituents are nitrogen oxides and volatile organic compounds, and they have both natural and industrial sources.

Physical phenomenon of the relation between O_3, NO_x and VOC governed by complex nonlinear photochemistry is explained based on ambient pollutant concentrations in five cities in Sri Lanka, namely Jaffna, Anuradhapura, Nugegoda, Rathnapura, and Kurunegala. Hourly averaged ambient real time air quality weekly data of Central Environmental Authority of year 2013 and 2014 for concentration of Hydrocarbon, NO_2, NO and O_3 pollutants with subsequent meteorological parameters were analyzed.

It was identified that there exist two regimes with NO_x-VOC-O_3 sensitivity. In the NO_x-sensitive regime (with relatively low NO_x and high VOC), O_3 increases with increasing NO_x and changes little in response to increasing VOC. In the case of Nugegoda, Kurunegala and Jaffna when high NO_2 is observed O_3 production is high and vise-vasa. In the NO_x-saturated or VOC-sensitive regime O_3 decreases with increasing NO_x and increases with increasing VOC. VOC-sensitive regime occurs when nitric acid represents the dominant radical sink. In this case, ambient concentrations of OH will be determined by the balance between radical sources and the reaction of OH with NO_2. Because the rate of nitric acid formation increases with NO_2, ambient OH decreases with increasing NO_2. Rate of ozone formation is determined by rate of the reaction of VOC and CO with OH. This rate increases with increasing VOC and decreases with increasing NOx.

In the immediate vicinity of very large emissions of NO (at Rathnapura and Anuradhapura having large industrial emissions), ozone concentrations are depressed through the process of NOx titration. This consists of removal of O_3 through reaction with NO. During the daytime, this reaction is balanced by the photolysis of NO_2. However, in the vicinity of large NO emissions, result is net conversion of O_3 to NO_2. At nighttime, there is no photolysis of NO_2 reaction also leads to removal of ozone.

Keywords: Air pollutants, NO_x-VOC-O_3 sensitivity, Sri Lanka

BIOMONITORING OF HEAVY METALS USING LICHENS AS BIO INDICATORS IN KANDY CITY LIMITS AND SUBURBS

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ABSTRACT

Bio-monitoring is an inexpensive and easy method compared to technical methods for assessing pollution in the atmosphere. Lichens are a type of bio-monitors that can be used for the determination of air pollution as they absorb inorganic ions from the atmospheric deposition. Lichens can accumulate pollutants in their thallus as proportionate to the concentrations of pollutants in the atmosphere.

Kandy is a City located at a valley in the hill country, Sri Lanka which has a highly polluted atmosphere. Deposition of atmospheric HMs was investigated in this study, through the analysis of lichens that have been grown at 12 locations within the Kandy Municipal Council area. Two types of lichens were selected for HM analysis with referring their common availability. Two types of lichens were sampled based on their morphological characters. After cleaning, dried lichen samples were digested with conc. HNO_3 in microwave digesting system (Mars 6). Digested Samples were analyzed for Al, Cr, Mn, Fe, Ni, Cu, Zn, Cd and Pb using inductively coupled plasma-mass spectrometry (ICP-MS), at Queensland University of Technology (QUT).

Average HM concentrations in lichens, were resulted with the order of Fe>Al>Zn>Mn>Cu>Pb>Cr>Ni>Cd. The highest average values recorded as 24397.1 and 11499.9 g/L for lichen type 1 and lichen type 2 respectively (for Fe). The lowest average values recorded as 0.8 and 1.6 g/L for lichen type 1 and lichen type 2 respectively (for Cd). For Pb it was 72.8 and 26.0

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g/L on lichen type 1 and lichen type 2 respectively. Lichens present at the railway station showed highest HM concentrations for all the metals tested, except Al, Mn and Cd. Lowest metal concentrations have been received for the lichen samples that collected at the Peradeniya University premises. Unexpectedly, sites selected from areas that are away from the heavy traffic, also have shown higher metal concentrations. Statistical principle factor analysis suggested two major factors; vehicular emission and geographical location, responsible for the HM concentrations. About 73% of the HMs in the atmosphere are by the two factors whereas majority from that to be from the vehicular emission.

Key words: Lichens, bio-monitoring, heavy metals, atmospheric deposition

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COMPARISON OF PARTICULATE MATTER, SULFUR DIOXIDE AND NITROGEN DIOXIDE IN AMBIENT AIR AT SELECTED LOCATIONS IN AND AROUND BIYAGAMA SAPUGASKANDA INDUSTRIAL AREA

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ABSTRACT

Clean air is an essential basic need of all living beings and purity of air we breathe is an important factor of human health. Quality of ambient air began to deteriorate along with the rapid development scheme by expansion of industrial activities in Sri Lanka. Sapugaskanda industrial zone is a significant area which was consisting number of industries situated in western province at Gampaha District closed to the capital city Colombo. Air pollutants from industrial emissions create numerous health and environmental impacts directly as well as indirectly.

Considering the importance of investigation status of ambient air quality in the vicinity of the industrial area, six locations were selected inside and outside of the industrial estate and measured Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Particulate Matter (PM-10) by using standard method laid down in National Ambient Air Quality Standards, Gazetted in Gazette extraordinary No: 1562/22 dated 15th August 2008. Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) concentrations were measured for 08 hour durations and Particulate Matter (PM-10) concentrations were measured for 24 hour durations.

All measured parameters PM-10, SO_2 and NO_2 concentrations were

comparatively high at the down wind direction with respect to all other sampling locations. All measured parameters PM-10, SO_2 and NO_2 concentrations were comparatively same and more or less similar distribution at sampling points in cross sectional directions respect to up wind and downwind directions. PM-10 concentrations are below the National Ambient Air Quality standard, but considerably high at downwind area compared to WHO guideline.

SO_2 and NO_2 concentrations were not exceeded National Ambient Air Quality Standards. But SO_2 concentrations reached closure to National Ambient Air Quality Standards at the down wind direction. The overall results indicated that measured parameters are comparatively on the higher side giving an indication of presence of high industrial emissions from Sapugaskanda industrial zone is a cause to concern in order to improve health conditions of the people living in the area.

Improvement of fuel quality, using cleaner fuel and incorporation of air pollution control measures are main considerations to improve the quality of ambient air in the vicinity.

AIRBORNE MICROBES IN PARTICULATE MATTER IN KANDY, SRI LANKA

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ABSTRACT

As atmospheric particulate matter cause range of human and eco system health problems it is necessary to develop effective mitigation strategies to minimize their adverse effects. This requires understanding the characteristics of particulate matter including the diversity of microorganisms associated. City of Kandy, which is centered as a valley between mountain ranges is expected to have greater air pollution due to temperature inversion effect and high level of emissions from the traffic congestion. The objective of study was to identify the bacterial and fungal community associated with particulate matter in Kandy, Sri Lanka. Sampling was conducted in five sites (National Institute of Fundamental Studies as the control, Railway Station, Police Station, Fire Brigade and Children's park) within the city depending on the traffic congestion. The samplers were mounted 1.5 m above the ground level. Particulate matter was collected with the use of direct impaction agar plates and filter papers on open petri dishes. The bacterial and fungi colonies, which were isolated from incubated plates, were then sub cultured in LB agar plate or LB broth at 25 °C for 24 to 72 h. DNA was extracted from the cultured isolates from modified CTAB method. PCR was carried out for extracted DNA using real time PCR Instrument System using 16S rDNA primers for bacteria to

amplify ~1500 bp fragment and the ITS4 and ITS5 region for fungi to amplify a 550 bp fragment. Amplified DNA fragments were purified using a gel extraction kit and were commercially sequenced. *Serratia marcescens*, *Providencia rettgeri*, *Pseudomonas aeruginosa*, *Pseudomonas monteilii*, *Pseudomonas taiwanensis*, *Pseudomonas stutzeri*, *Pseudomonas brenneri*, *Enterobacter ludwigii*, *Escherichia hermanni*, *Stenotrophomonas maltophilia*, *Acinetobacter soli*, *Acinetobacter baumannii*, *Brevundimonas vesicularis*, *Klebsiella pneumonia*, *Ochrobactrum intermedium*, *Leclercia adecarboxylata*, *Exiguobacterium acetylicum*, *Exiguobacterium indicum*, *Bacillus pumilus*, *Bacillus amyloliquefaciens*, *Bacillus aryabhattai*, *Bacillus megaterium*, *Bacillus cereus*, *Bacillus thuringiensis*, *Bacillus anthracis*, *Arthrobacter sanguinis*, *Sphingomonas* sp. and *Kocuria kristinae* were the bacterial species identified and *Aspergillus tamari*, *Aspergillus niger*, *Aspergillus fumigatus*, *Aspergillus oryzae* and *Fusarium equiseti* were the fungal species that identified from these five sites. Most of them could be pathogenic and these microorganisms in particulate matter could penetrate human respiratory tract causing a health risk on the general public.

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A COMPARATIVE STUDY OF HUMAN EXPOSURES TO HOUSEHOLD AIR POLLUTION FROM COMMONLY USED COOK STOVES IN SRI LANKA

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ABSTRACT

Introduction : The use of biomass for cooking is prevalent in Sri Lanka and is a major source of household air pollution (HAP). Determinants of HAP from biomass fuel vary across households (e.g., cook stove type, ventilation, availability of chimney, etc.) and it is estimated that HAP exposure is the third greatest global risk factor to health.

Objective : The aim of this study is to assess both real-time indoor concentrations and personal exposures to fine particulate matter ($PM_{2.5}$) in households using traditional or "Anagi stoves" (i.e., improved stove).

Methodology : A purposive sample of 53 households was selected from a rural community in Kandy, Sri Lanka based on the stove type (stove type - traditional or Anagi) and ventilation (chimney - present or absent). At each household, 48-h continuous real-time measurements of indoor kitchen $PM_{2.5}$ and personal (primary cook) $PM_{2.5}$ concentrations were measured using the RTI MicroPEM personal exposure monitors. Questionnaires were used to collect data related to household demographics and characteristics.

Results : All primary cooks were female and average age was 47 years, with

66% having completed primary education. Use of Anagi stoves was positively associated with a higher education level of the primary cook (P = 0.026), although not associated with household income (P = 0.18). The MicroPEM monitors were well-received by the female participants. Participant wearing compliance of MicroPEM during waking hours was on average 87.2% on Day 1 and 83.3% on Day 2. The median 48-h indoor $PM_{2.5}$ concentration for households using Anagi stoves for cooking and having a chimney was 64 $\mu g/m^3$ and households using Anagi stoves for cooking and not having a chimney was 181 $\mu g/m^3$. The median 48-h indoor $PM_{2.5}$ concentration for households use traditional stoves for cooking and having a chimney was 70 $\mu g/m^3$ and for households use traditional stoves for cooking and not having a chimney was 371 $\mu g/m^3$. Overall, measured indoor $PM_{2.5}$ concentrations ranged from a minimum of 33 $\mu g/m^3$ to a maximum of 940 $\mu g/m^3$, while personal exposure concentrations ranged from 34 to 522 $\mu g/m^3$. Linear mixed effects modeling of the dependence of indoor concentrations on stove type and presence or absence of chimney showed a significant chimney effect (65% reduction; $P < 0.001$) and an almost significant stove effect (24% reduction; $P = 0.054$). Primary cooks in households without chimneys were exposed to substantially higher levels of household air pollution than those in households with chimneys, while exposures in households with traditional stoves were moderately higher than those with Anagi stoves. Simultaneous measuring of both indoor concentrations and personal exposure levels indicate significant exposure misclassification bias for actual human exposure.

Conclusions : The results from the field survey confirm high levels $PM_{2.5}$ concentrations in sampled households, at measures much above WHO guidelines for HAP. Use of Anagi stove with the chimney is the best option among the assessed methods. In addition, the study highlights the importance of ventilation and/or chimneys in reducing risk associated with HAP.

CHARACTERIZATION AND SOURCE APPORTIONMENT OF FINE PARTICLES POLLUTION IN COLOMBO, SRI LANKA

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ABSTRACT

Due to the increased use of vehicles and other human activities in Colombo and suburbs, a study of long term Air particulate monitoring at fixed sites was initiated in 2000 and 2003 respectively. The specific objectives were to measure the elemental composition of the coarse and fine air particulates and to identify the main pollutant sources and quantifying the source contribution using statistical tools.
The importance of such a study is to lead studies on health effects of significant pollutants and their sources and take measures to mitigate effect.

Samples of air borne particulate matter (PM) in the 2.5 -10 m size range (PM2.5 and PM10) were collected using a "Gent" PM 10 stacked filter sampler from two urban areas of Colombo- Air Quality Monitoring station (AQM) of the Central Environmental Authority (CEA) for the period May 2000 to December 2007 and Atomic Energy Authority- (AEA) Orugodawatta from May 2003 to December 2007. The samples were collected during the 24 hourly on week days with a flow rate - 18-15 lpm in the sampler. The coarse and fine filter samples were analyzed for 18 elements by ED-XRF.

Measured range of annual averages of PM 10, PM 2.5 and BC at AQM station during 2000-2006 were (100-50), (32-16) and (15-8) g/m^3

respectively. In air borne particulate matter, Sulfur is generally present because of the atmospheric conversion of SO2 to sulfate through homogeneous and **heterogeneous** processes. Sulfur is a dominant element in fine particles and range of S in fine particles at AQM and AEA sites are (0.0007 to 3.6) g/m^3 and (0.0001 to 2) g/m^3 respectively.

The fine fraction data set including Black Carbon and major elements (Na, Mg, Al, Si, Cl, Fe, Zn, Ni, Cu, V, S, Br, Pb Cr,K,Ca and Ti) analyzed by EPA-PMF(positive matrix factorization) technique to explore the possible sources of atmospheric aerosols in the two study sites revealed four factors for elemental composition in both sites. The sources common for both sites are vehicular emissions, sea salt, soil and secondary sulfate.

Having determined the sources and their contributions to the fine particle mass at the site, we used to Hybrid single particle lagrangian integrated Trajectory (HYSPILT) back trajectory techniques to explore possible long range transport of pollution to the measurement site. Two natural: smoke and soil dust transboundary events were identified based on fine Si and K in the data base in 2003 and 2004.

DEVELOPMENT OF ATMOSPHERIC EMISSION INVENTORY IN SRI LANKA

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ABSTRACT

The present status of the development of national emission inventory (EI) of air pollution and challenges for completion are presented. Development of an EI, which is a fundamental element of a national air quality management programme, has been identified as a key activity under the Clean Air Action Plans since inception. In Sri Lanka systematic software tool for preparation of atmospheric EI was set up in 2008 and is managed since 2010 by Central Environmental Authority under the project on "Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia" under the technical guidance of the Stockholm Environment Institute (SEI). This software tool can provide emission estimates deriving from a combination of main interest for air quality by covering the pollutants SO_2, NO_X, CO, NMVOC, NH_3, PM_{10}, $PM_{2.5}$, BC, OC and CH_4 at country level or provincial level. The system and methodologies have been shared with IPCC guidelines for harmonization of methodologies and estimates among regional EIs. In Sri Lanka the preliminary estimates based on available data with default emission factors give the total emission loads for year 2005 and 2010 as 1280.73 kt/year and 2390.44 kt/year respectively. It is envisaged to diversify this tool by incorporating greenhouse gases emissions too.

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Air Resource Management Centre (AirMAC), Ministry of Mahaweli Development & Environment

National EIs should be transparent, consistent, comparable, complete and accurate. In Sri Lanka, although the basic tool is available, lack of local data with required format (activity data, statistical data and other required data) related to most of sub sectors and not having emission factors reflecting actual situation in the country are major challenges for completing accurate EI. Use of default emission factors from manuals and guidelines available globally will not reflect accurate quantification of the emissions in the country. Inadequate systems for data collection and reporting, absence of modelling tools, together with lack of corporations between responsible agencies for data sharing too become critical factors affecting the progress. This has prevented the periodic updating of the data related to the governing parameters and their level of accuracy, which in turn escalated the overall level of uncertainty in emission calculations.

In order to achieve a satisfactory progress in the development of the national EI, it is apparent that a sound stakeholder framework with delegated functions and shared responsibilities should be established for effective answering of the challenges highlighted above. Experience elsewhere in the world on preparation of EI clearly demonstrates that relatively fast upgrading of algorithm and emission factors, development of different effective tools (including modeling) in order to insert emission data with the correct codification through facts and data from relevant stakeholders are the key elements in a successful pathway for development of a sound EI for Sri Lanka.

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