Evaluation Report

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PROJECT ATMOSPHERIC BROWN CLOUD (ABC)

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Submitted to
ABC Programme

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Executive Summary

The advancement of human civilization exerts pressure to use fossil fuels and biofuels excessively to meet the demand for rapid development. Combustion of these fuels produces obnoxious substances as byproducts which pollute the air that we breathe. Air pollution consists of tiny particles and gases. Amongst these, the gases (e.g. CO_2 and others), which have longer lifetime in environment and possess the threat to climate, are termed as greenhouse gases (GHGs). A lot has been done to curb the emissions of GHGs, however, not enough efforts have been made to address the issue related to short lived air pollutants, namely, particles and certain gases, which possess a serious threat to human health and climate. These short-lived particles and the gases are collectively termed atmospheric brown clouds (ABCs). The ABCs, observed as widespread layers of brownish haze, are regional scale plumes of air pollution, consisting of mainly aerosol particles (such as black carbon (BC) and non BC), and precursor gases (e.g. CH4, CO, NMVOCs, NO_x) which produce aerosols and ozone. ABCs and their interaction with build-up of greenhouse gases (GHGs) significantly affect the regional climate, hydrological cycle, glacial melting, agriculture and human health.

The Indian Ocean experiment (INDOEX) was the first to discover the nature and extent of ABCs. The scientific findings of INDOEX also indicated that ABCs can significantly affect radiation, chemistry, and dynamics of the atmosphere, and also impact weather and climate, and possibly human health and agriculture. Considering the widespread nature of ABCs, that include several continents, it was felt that a comprehensive programme under the aegis of an international agency needs to be initiated with the following objectives: (1) understand the science behind appearance of ABCs by building a network of observatories, (ii) assess impacts of ABCs on climate, human health, and agriculture (iii) propose mitigation steps for reduction of adverse effects and create societal awareness.

The United Nations Environment Programme (UNEP) took this initiative and commissioned Atmospheric Brown Cloud (ABC) programme in 2002 with a team of renowned atmospheric and climate scientists with three main objectives, namely, long term observations and capacity building; impact assessments; piloting green technology for mitigation and create awareness.

The Phase 1 of the project ABC was successfully established a network of observatories in Asia and the Pacific region involving local[1] and the international scientists for creating a long-term time series of ABCs parameters to be used for a comprehensive assessment of impact of ABCs on climate, human health, and agriculture. Using long-term observational data from the observatories and modeling simulations, a comprehensive assessment report titled 'Atmospheric Brown Clouds: Regional Assessment Report with focus on Asia' was published by UNEP in 2008. This report was a notable outcome of the Phase 1 which can be

[1] To provide a country ownership, ABC programme involved local scientists of a country where the ABC observatory is located (e.g. India, Japan, Korea, etc.).

used for policy making in future. The evaluation report 2007 of Phase 1 noted the significant achievements of the Phase 1, and recommended for the phase 2 of the project.

Phase 2 of the project was implemented for the period 2008-2012, which is near completion. Therefore, it was decided to evaluate the activities of whole ABC programme for the period of 2008-2012. This evaluation report is organised as follows. Chapter 1 briefly introduces ABCs, and is followed by Chapter 2 which states the scope and aim of the report. Chapters 3 and 4, respectively, provide overview of ABC Project with a focus on Phase 2, and its outcome and overall impact. Chapter 5 summarises the main conclusions and future recommendations.

The project was executed in an efficient manner with proper utilisation of the budget. It has created wealth of knowledge pertaining to ABCs with excellent capacity building of the participating countries for measurements of climate influencing constituents. Over 140+ publications with more than 1150 citations in a relatively short time signify the scientific importance of ABC's research. A strong network of 12 climate observatories is built. These observatories are located in participating countries, some of which are placed at the most challenging strategic locations. To assess the impacts of ABCs, modeling groups are formed that work in a coordinated manner to achieve the goals of ABC project. Time series of high quality data has been created which will help to understand the long term effects of ABCs as well as to evaluate the modeling results. Over 100 young scientists were motivated and trained on ABCs measurements and interpretation of data. These young scientists were selected through open advertisement on RRC.AP website and email contacts with ABC Science Team. Gender equality and country ownership were taken care while selection of trainees.

ABC project provided an accurate assessment of ABCs' impact on hydrological cycle and Himalayan glaciers. It was the first project to reveal the net climate forcing due to combined effects of greenhouse gases and aerosols. Human-health impacts of ABCs were earlier known in developed countries. However, its impact on Asian population was not assessed. ABC modeling studies constrained with satellite data showed that the large population of Asia is exposed to significantly higher particulate matter than WHO prescribed limit. Additional modeling studies also focussed to estimate direct radiative forcing due to BC, cloud microphysical properties, and impact on harvesting.

ABC programme also led to technology development. The first measurement of atmospheric heating rate due to aerosols was achieved by stacked Unmanned Arial Vehicles (UAVs). Another new development was use of cheap cell phones to measure BC aerosol concentration.

During the second phase of the project, two important findings crucial to policy makers were achieved. First, sources of BC (fossil fuel and bio fuel) were clearly identified which will help in enacting the mitigation measures. Second, atmospheric heating was shown to be

dependent on BC to SO_2 emission ratio indicating that mitigation measures should be more concentrated on BC than SO_2 in order to achieve near term reduction in warming.

Knowledge gained from ABC hard science was translated into action when the Project Surya (within the framework of ABC programme), with an aim of mitigation of regional climate impacts by reducing atmospheric concentrations of BC, and Ozone precursors, was launched. Project Surya demonstrated that working at the ground level with technologically innovative solutions (in this case, cheap energy efficient, low emission cooking stove), one can reduce the risk of climate change by BC aerosols. In addition, the risk to health can also be reduced as a co-benefit.

ABC is a highly science-driven program that can form the backbone of national and international policy development. A professional information strategy may be contemplated for reaching desired results as soon as possible. NGOs, including public interest groups as well as industry, have a role to play. Relations to UNEP, ESCAP, UNFCCC and IPCC as well as to Asian regional initiatives such as SACEP, the Malé Declaration, EANET and the ASEAN Haze Agreement must be used to their full extent, not only regarding observations and assembly and analysis of data but also for underpinning policy action to the benefit of human health, food security, ecosystems and climate.

A possible shift of emphasis from science to policy and implementation must not be seen as a weakened role for ABC's scientific work. On the contrary, the ABC Science Team will become even more significant as a well-recognized long-term and stable basis for good policy decisions based on sound science. That's how political and socio-economic sustainability is maintained. The marriage between the two communities is essential for progress and both will benefit from that marriage. The present ABC will continue to produce justification for integration of issues regarding science-based political interventions, technical as well as structural. Science-driven progress can be gained much in the same way as action on ozone-depleting substances was agreed and implemented following the Vienna Convention of 1985 and the Montreal Protocol of 1987.

The evaluation find, by and large, the programme thus far has been successful in bringing the emerging issue of ABCs to the policy agenda at national, regional, and global levels and enhancing the capacity of developing countries to study the issue. Hence the programme is evaluated as highly satisfactory.

List of Abbreviations

ABC	Atmospheric Brown Cloud Programme
ABCs	Atmospheric Brown Clouds
AE	Angstrom Exponent
AIT	Asian Institute of Technology
AOD	Aerosol Optical Depth
AOT	Aerosol Optical Thickness
ASEAN	Association of Southeast Asian Nations
AUAV	Autonomous Unmanned Aerial Vehicle
BC	Black Carbon
CAPMEX	Cheju ABC Plume-Asian Monsoon Experiment
CCAC	Climate and Clean Air Coalition
CCN	Cloud Condensation Nuclei
EANET	Acid Deposition Monitoring Network in East Asia
EC	Elemental Carbon
EIM	Emission Inventory Manual
ESCAP	Economic and Social Commission for Asia and the Pacific
GCM	General Circulation Model
GHG	Green House Gas
GMEF	Global Ministerial Environment Forum
ICIMOD	International Centre for Integrated Mountain Development
IICT	Indian Institute of Chemical Technology
INDOEX	Indian Ocean Experiment
IPCC	Intergovernmental Panel on Climate Change
LFA	Logical Framework Analysis
MAC	Maldives AUAV Campaign
MCO-H	Maldives Climate Observatory Hanimaadhoo
MISU	Meteorologiska Institutionen Stockholms Universitet (Department of Meteorology, Stockholm University, Stockholm, Sweden)
NCAP	National Carbonaceous Aerosol Program
NCO-P	Nepal Climate Observatory at Pyramid
NGOs	Non Governmental Organisations
NIO	Northern Indian Ocean
NPF	New Particle Formation
OC	Organic Carbon
PM	Particulate Matter
PNAS	Proceeding of National Academy of Sciences
PT	Policy Team
QC	Quality Control
RRC.AP	Regional Resource Centre for Asia and the Pacific
SACEP	South Asia Co-operative Environment Programme
SC	Soot Carbon
Sida	Swedish International Development Co-operation Agency

SIO	Southern Indian Ocean
SLCPs	Short Lived Climate Pollutants
SSA	Single Scattering Albedo
SST	Sea Surface Temperature
ST	Science Team
TB	Terabyte
TIO	Tropical Indian Ocean
TOA	Top-of-the-Atmosphere
UAV	Unmanned Arial Vehicles
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

Chapter 1

Introduction

1.1 Genesis

Indian Ocean Experiment (INDOEX) experiment was conducted from 1996 to1999 in the winter monsoon seasons over the Tropical Indian Ocean (TIO). The intensive phase of the experiment was conceived during January-March 1999, and attended by 250+ scientists from United States, Europe, India, and other countries. Polluted air mass advected from South Asia, and pristine air mass from southern Indian Ocean, meet near Inter Continental Tropical Convergence (ITCZ) thus creating a large spatial gradient in aerosol loading. The major objectives of INDOEX were to characterise the spatial gradient of aerosol optical and microphysical properties, and to assess their radiative effects on the regional climate.

Findings of INDOEX resulted in a first consistent framework to understand aerosol's impacts on regional climate and human health. It was shown that the anthropogenic emissions of aerosols precursor gases are responsible for new particle formation in the troposphere which can alter the aerosol microphysical properties. Presence of high concentration of absorbing aerosols such as Black Carbon (BC) can cause large atmospheric warming, and significant cooling at the surface. Large concentration of aerosols also led to smaller cloud droplets in shallow and convective clouds, which in turn, change the thermodynamics of atmosphere. Also, the effect of aerosol vertical distribution on the heating rates due to aerosols was quantified for the first time and contrasted from the columnar heating due to greenhouse gases (GHGs). Modeling studies carried out as a part of INDOEX experiment also demonstrated that a large reduction in the surface-reaching radiation (dimming) and warming aloft can stabilise the boundary layer leading to reduced moisture and heat fluxes from the surface. This will act as a positive feedback resulting in trapping of aerosols in the boundary layer. In addition, modeling studies indicated that widespread aerosol pollution can significantly alter the rainfall pattern over south Asian countries.

The impact of GHG-induced warming on agriculture has been studied earlier. However, no study has been undertaken to study the impact of haze on agriculture. INDOEX was first to quantify the impact of aerosols on agriculture. Several pathways (most notable amongst those were reduction in direct and total solar radiation by atmospheric haze and slowing down of the hydrological cycle) were suggested through which haze can significantly affect crop productivity. Numerous studies in developed countries have documented the adverse impacts of Particulate Matter (PM) on human health which are further corroborated by the limited studies carried out in developing countries. The findings of INDOEX highlighted the potential threat to the large population of south Asia exposed to high level of particulate loading.

These major findings drew the attention of not only scientific community, but also of international media, and the policy makers and governments of the countries located in the

region, affected by atmospheric haze. It was felt that a programme needs to be initiated under the aegis of international body, under the guidance of scientists from different countries, in order to understand the overall impact of widely spread atmospheric haze on various aspects of human life, and propose means to mitigate their harmful effects.

1.2 Implementation

The United Nations Environment Programme (UNEP) took this initiative to probe into the atmospheric haze in a comprehensive manner with focus on Asia and the Pacific region, commissioned Atmospheric Brown Cloud (ABC) programme in 2002 with a team of renowned atmospheric and climate scientists with three main objectives, namely, long term observations and capacity building; impact assessments; piloting green technology for mitigation and create awareness (http://www.rrcap.ait.asia/abc/).

The institutional arrangement that has been established during the Phase I of ABC Programme was used for the implementing Phase II, which comprises Steering Committee, Science Teams (ABC-International, ABC-Asia,), Impact Assessment Groups, and Advisory Board. During phase II, ABC-Africa Science Team was established to enhance the capacity in Africa. The ABC programme worked with Regional Environment Ministers Forum for Latin America and the Caribbean. A team of policy and technological experts was also formed to develop policy guidelines and to implement mitigation programmes. The ABC programme was implemented through UNEP in collaboration with a wide range specialised experts and networks of institutions. The programme secretariat based at UNEP in Nairobi (ABC-Secretariat) coordinated the activities with support from ABC-Asia Secretariat (for implementation of activities in Asia and the Pacific region) located at Regional Resources Center for Asia and the Pacific (RRC.AP), Pathumthani (Bangkok), Thailand and ABC Secretariat (for science) located at the Center for Clouds, Chemistry and Climate (C4), Scripps Institution of Oceanography (SIO), University of California, San Diego (UCSD), California, USA,

The programme is being implemented in phases. Swedish International Development Co-operation Agency (Sida) provided financial support for the Phase I. Subsequently, the Government of Sweden and UNEP RRC.AP signed an agreement in November 2004 to support project ABC for four years. In 2006, Government of Italy provided financial support to implement the phase I activities on 'Aerosol observatory in Karakaorma and Himalaya mountain regions'. The scientific studies during phase I revealed that the ABC is a frequently occurring trans-boundary, trans-continental and trans-oceanic phenomenon downwind of all heavily inhabited regions including Africa. The ABC Science Team meeting in 2008 had recommended expanding the geographical coverage of the project to Africa and Latin America, and carrying out the ABC activities in these regions based on the experience from Asia. In view of this, the geographical scope of the phase II was extended in 2009 to Africa and Latin America. In 2009, Government of Sweden has provided a financial support for the phase II implementation. Likewise, Government of Italy has continued its financial support for implementation phase II of high altitude observation. UNEP and other donors have also

contributed financial support for the implementation of ABC activities. A detailed Logical Framework Analysis (LFA) was prepared (**Annex 1**) to evaluate the various outputs of ABC programme. The LFA include 4 major outputs and the programme was implemented following 3 programmatic themes. The LFA outputs and programmatic themes are tabulated as bellow:

Table 1: Summary of Programmatic theme, implementation and output

Programmatic themes	**Implementation**	**LFA Outputs**
1. Observatory and capacity building programme	✓ Established a network of 13 climate observatories ✓ UAV measurements campaigns. ✓ Data center at Secretariat. ✓ Capacity building and training	✓ Increased capacity and understanding of ABC radiative forcing on regional climate change
2. Impact assessment programme	✓ Established a team of scientists for assessing impacts of ABCs using observational data and models	✓ Increased understanding on the impacts of ABC on regional climate, water resources, agriculture and health (Atmospheric Brown Clouds: Regional Assessment Report with Focus on Asia, UNEP, 2008)
3. Awareness and mitigation programme	✓ Project Surya for mitigation of ABCs emission from biofuels. ✓ Publication of BC eBulletin (six monthly) ✓ Presented ABC programme on several forums	✓ Knowledge concerning ABC impacts, and mitigation and adaptation measures developed and effectively communicated to decision-makers and general public. ✓ Consensus among key stakeholders (policy and scientific communities) built to underpin emergence of regional and global action on ABC

Chapter 2

Scope and Aim of Evaluation

Atmospheric aerosol consists of various species such as dust, BC, sulphate, organic carbon (OC). BC that strongly absorbs solar radiation is emitted from anthropogenic sources, namely, biomass burning, biofuels, fossil fuel combustion, and forest fires. The emission of aerosols from multiple sources form regional plumes that may extend up to thousands of kilometres, and may persist for weeks-to-months in the atmosphere, and are termed as Atmospheric Brown Clouds (ABCs). Indian Ocean Experiment was the first to detect the widespread nature of ABCs and their potential impacts on climate. An ambitious, internationally coordinated programme ABC was commissioned in 2002 by UNEP with an objective to understand the effects of ABCs on climate, hydrological cycle, health and agriculture through three major programs: (1) Observatory, (2) Impact Assessment and (3) Awareness and Mitigation. Activities of ABC during 2002-2007 were successfully implemented, and major objectives were achieved as per the midterm review conducted in May 2007.

The review process follows the steps below:

- Desk review of project document, agreements with donors, outputs, monitoring reports (such as progress reports, minutes of meetings and relevant correspondence);
- Review of specific products including datasets, publications and other material and reports, information regarding the project for different stakeholders; internet accessible information; and
- Interviews with the Science Team Chairs, Project Director, other project staff, and stakeholders.

ABC Programme is moving from science and capacity building to implementation of mitigation measures. The evaluation will be conducted by a team of two evaluators with science expertise and implementation expertise. The evaluation will comprise the following elements.

- An evaluation of the project and all of its major components undertaken to date and a determination of progress towards achievement of its overall objectives.
- An assessment of the scope, quality and significance of the project outputs produced to date in relation to expected results specified in the logical framework matrix and the Project Document.

- An assessment of country ownership and replicability of produced outputs. Also an analysis in relation to environmental sustainability and gender issues.
- An analysis of the extent of cooperation engendered and synergy created by the project in each of its component activities, between national and regional level activities and the nature and extent of commitment among the countries and institutions involved.
- Identification of any programmatic and financial variance and/or adjustments made during the implementation of the project and an assessment of their conformity with decisions of the Steering Committee and their appropriateness in terms of the overall objectives of the project.
- Lessons learned during project implementation. Recommendations regarding any necessary corrections and adjustments to the overall project work plan and timetable for the purposes of enhancing the achievement of project objectives and outcomes.

More details of the evaluation process are given in **Annex 2**

Two independent evaluators have been engaged for the review of Project ABC. The first Evaluator was for science and reviewed the achievements of Project ABC in terms of increased understanding of the science of ABCs and their impacts. **Dr. Sachchida Nand Tripathi (S.N. Tripathi)**, Professor of Atmospheric Science in the Department of Civil Engineering, Indian Institute of Technolgy (IIT), Kanpur, India, worked as a reviewer for science. The second Evaluator was for policy and reviewed the prospects and potential of the Project ABC to contribute to national, regional, and global environmental policy development. **Mr. Lars Nordberg**, President of ScandEnvironment Advisory Services, Sweden, was responsible for this portion of the evaluation. Mr. Nordberg is a well-known global environmental policy researcher. Brief curricula vitae (CVs) of both the reviewers are present in **Annex 3**.

Chapter 3

Review and Evaluation of Activities

3.1 Activities of Phase 1

A good pictorial illustration of the activities carried out during the 2004-2007 period is given in the Review Report of Phase 1. Only a very concise description is provided here. In order to address the boarder impact of ABCs on the region, a three pronged Programme, as listed below, was undertaken;

i. Observatory Programme
ii. Impact assessment Programme
iii. Awareness and mitigation Programme

Given the highly variable nature of ABCs in space and time, it became imperative to conduct measurements of various properties of ABCs at different locations, which required a network of observatories across the region, equipped with the suitable instrumentation for measuring aerosol and radiation. Beginning with the iconic Maldives Climate Observatory at Hanimaadhoo (MCOH) in deep Indian Ocean, the first phase of ABC saw the rapid growth of observatory network. By the end of first phase, 12 observatories were fully functional. A list of observatories is given in box. These observatories are operated by local scientists with technical support from other ABC scientists. Except few, most observatories are financially supported by the host countries in which the observatory operated. Aerosol samples were collected at most of the ABC observatories, and centrally analysed for chemical speciation. Rain water samples were also collected at some of these observatories as a part of acid deposition network.

ABC Surface Observatories

1. China Observatories (4 observatories to be affiliated to project ABC)
2. Indian Climate Observatory – Pune
3. Japan Climate observatory - Okinawa,
4. Korea Climate Observatory - Gosan,
5. Kyrgyzstan Climate Observatory-Central Asia
6. Maldives Climate Observatory - Hanimaadhoo
7. Maldives Climate Observatory - Gan
8. Nepal Climate Observatory - Godavari,
9. Nepal Climate Observatory - Pyramid,
10. Thailand Climate Observatory - Phimai,
11. Pakistan Climate Observatory- Karakorum
12. Pacific Climate Observatory - Momote,
13. Pacific Climate Observatory - Midway
14. Pacific Climate Observatory - Mauna Loa

Under the capacity building Program, more than 40 young scientists were trained with theory and experimental aspects of aerosol science in the two ABC training schools held in 2004 and 2006. These young scientists were selected based on merit through open advertisement on RRC.AP website and email contacts of ABC scientists. Aspect of gender equality and geographical diversity were also be taken care while selection. Over 100 young scientists from Asian countries were trained during phase I & II of ABC programme. List of young scientists is given in **Annex 4**.

Impact assessment Programme of project ABC started with the first consultation workshop held in December 2005 followed by a series of meetings, workshops and discussions in interactive mode with the stake holders including scientists, networks of institutions which coordinated the ABC in the various regions, media and local representatives. Multiple MoUs were also signed between RRC.AP and other institutions to assess ABCs impact on climate, human health and agriculture.

The third component of the project ABC-Awareness and Mitigation-aims at creating awareness amongst the people of the region about possible impacts of ABCs on human welfare by formulating effective strategies such as reducing emissions of pollutants for mitigation of the risks associated with ABCs. This component also involves working closely with the policy makers who can incorporate the findings from science and impact studies undertaken by Project ABC into policy. Several control and mitigation measures were available for GHGs but only few for ABCs during the first phase of ABC. Although a sound mitigation approach towards ABCs requires the results of observatory and impact studies be available, the necessary policy measures cannot be postponed indefinitely. As a matter of fact policy can develop hand in hand with continuing scientific substantiation provided that the science/policy interface is operative. Ideally it is a two-way avenue (science can drive policy but policy requirements can also stimulate the scientific community to address important issues necessary to justify and win acceptance for political action).

ABC Programme took the first initiative by organising an expert meeting in December 2006 to define the major activities under this component. A white paper was later developed by the ABC Secretariat.

3.2 Activities of Phase II (2008-2012)

Evaluation of phase 1 concluded that project was exceptionally successful in achieving the overall objectives following the methods laid down in LFA, and it recommended the second phase of the project to be implemented for an improved understanding of the science and impacts of ABCs. The three programmatic themes viz. Observatory, Impact Assessment and Awareness and Mitigation also continued in the second phase.

3.2.1 Activities under Observatory Programme

Activities under observatory programme can be sub grouped into Measurements, Capacity Building, Data Archival and Modeling exercise. In this phase, considerable efforts were put to the continued operation of ABC observatories. Aerosols and rain water samples were collected at various observatories and centrally analysed. Several training schools were conducted with the help of ABC Science Team to impart training to young scientists involved in collecting the aerosol filter samples and rain water. The training included theoretical class-room lectures and practical training on the measurements of aerosols, trace gases, solar radiation, and meteorological parameters, and collection and analysis of rain water. Quality

of the data collected was ensured by exchange of the information between scientists working at various observatories.

As a part of the capacity building, first observatory group meeting took place at Asian Institute of Technology (AIT), Bangkok during May 26-27, 2008, which was attended by 19 participants including representatives from eight ABC observatories in China, India, Japan, Korea, Maldives, Nepal and Thailand. The meetings objectives were: (a) to share the information on data collection from all ABC observatories (b) to finalise a common Data Reporting and Sharing Format and (c) to formulate Data Policy for the project. The second observatory meeting was held on 7-8 July 2009 at AIT/UNEP RRC.AP with an objective to consolidate and harmonize the observation activities and data reporting. More specifically, in this meeting the discussion was focussed on the problems encountered in operating various instruments at ABC observatories, to suggest parameters and the location where these parameters can be measured to assess the health impacts of ABCs, and to suggest ways to enhance the existing observatories in terms of parameters measured and monitoring capabilities. The third observatory meeting held during 21-23 October 2010 at AIT, Bangkok besides discussing some of regular items pertaining to data collected at observatories, also agreed to prepare ABC data summary report, continue data analysis and provide inputs to proposed 'Intensive data analysis' that will commence from August 2011. This meeting was also attended by atmospheric modellers to initiate focussed modeling studies that will lead to a better understanding of ABCs impact on weather, climate, agriculture and health.

During 2008-2012, three science team meetings were organised. First full scale ST meeting, that was held in Kathmandu, Nepal during December 4-6, 2008, reviewed the operations of existing observatories, impact assessment studies, and approved the proposed activities for the second phase. Second ST meeting, that was held in Kathmandu during March 23-24, 2011, took the stock of all the activities carried out under the project ABC, including data collection, analysis, intensive data analysis, impact assessment preparation, and new science team membership. The third ST meeting, held in September 2012 in Beijing, reviewed the progress and developed the plan for next 5 years. The meeting recommended the ABC programme to focus on the implementation while continuing the scientific activities.

As a part of Precipitation and Aerosol Chemistry Program, intense data collection exercise was also carried out at Sinhagad, Pune in India, Hanimaadhoo in the Maldives and Godavari outside Kathmandu in Nepal. Several scientists from Department of Meteorology, Stockholm University, Sweden (MISU) and Indian Institute of Chemical Technology (IICT) participated in this campaign and exchanged information.

ABC Programme is mandated with the task of providing training to young scientists on various issues related to ABCs. Third international training school on Atmospheric Brown Clouds was conducted during 3-7 December 2008 in Kathmandu, Nepal to train 29 carefully selected young scientists including doctoral students, postdoctoral fellows and young researchers. The participants learned the theory and also had opportunity for hands on experience with instruments from the leading atmospheric scientists around the world.

Aerosol filter sampling is an integral part of project ABC. A focussed training school for technicians from Maldives and Nepal was organised at RRC.AP in collaboration with University of Wisconsin, Madison. The workshop imparted knowledge on the theoretical aspects of filter collection, working principles of different instruments, post processing of the data and data analysis. The 4th training school was organised in Kathmandu and Nagarkotm, Nepal during 21-26 March, 2011. In attendance were 20 male and 13 female participants. Leading scientists introduced the participants to the recent advances in atmospheric and climate science as well as provided hands on training with advanced monitoring techniques. The operational principles of various instruments of aerosols, trace gases and radiation were discussed in the class room lectures.

Archival of the valuable data at one place, which is accessible to scientists working on ABCs, is crucial for achieving the scientific goals of the project ABC. It will be also helpful to construct long term time series of the most important aerosol, trace gas and radiation parameters. An important step was taken in this direction when project procured and installed a storage server of 9 TB space at RRC.AP. Subsequently, ABC data are regularly analysed for the quality check and put in standard format for the ease of use. The data in standard format became available to scientific community from the first quarter of 2010.

The phase 1 of the ABC Programme was successful in building aerosol radiative forcing and heating rates dataset on a resolution of 50x50 km. However, during the observatory meeting held in Korea in 2009, it was felt that modeling should be carried out in coordinated fashion using a suite of global and regional models. As a result, several experts from modeling groups met to discuss the key modeling requirements from atmospheric/climate and impact assessment/mitigation perspectives. It was also suggested that modeling exercise should expand its activities to carry out multi-year simulations, regional simulations, extra regional simulations, emission inventory match up and downscaling of global simulations. In the background of these, modeling group met in Kathmandu and prepared a draft plan for a more consolidated and intensive modeling exercise for inter-model and model-measurement comparisons to provide more meaningful input to the impact assessment studies. The modeling group created a unique plan where, for the first time, about 10 models will participate in the inter comparison of decadal simulations (2001-2010).

3.2.2 Activities under Impact Assessment Program

Assessment of ABCs impact on climate, agriculture and human health forms one of the three major programs that constitute ABC Programme. Our knowledge of ABCs impact on society was significantly improved during the 1st phase of the project ABC. The first regional impact assessment report ‘Atmospheric Brown Clouds: Regional Assessment report with Focus on Asia’ with contributions by 50+ scientists and experts was by far the most comprehensive study till date summarising the impact of ABCs on weather, climate, agriculture and human health. The report was peer reviewed by three dozen scientists before its publication, and was released on November 13, 2008 in Beijing, China.

There was a workshop held at RRC.AP, Thailand on July 6, 2009 to formulate an implementation plan for the assessment of the impacts of ABCs on food security during the 2nd phase. The meeting reviewed and documented the findings in the ABC impact areas and agreed on a roadmap for detailed assessment. ABC impact groups also presented their proposed plan at the ABC symposium held during November 23-24 followed by the discussions at the ST meeting held on 24th for its consideration. New developments have put the emphasis on short lived climate pollutants. Hence the later part of 2nd phase of the project focussed on intensive data analysis to bring out new science which can act as input into regional impact studies. A workshop on ABC Modeling and Impact Studies, held in Korea during September 29-30, 2011 provided an appropriate forum for the water, health and agriculture impact study groups to exchange their ideas.

3.2.3 Activities under Awareness and Mitigation Program

Awareness and Mitigation Program of Project ABC aims at working closely with the policy makers such that they are in a position to take informed decisions based on sound science while formulating the mitigation measures.

To assess the ABCs emissions, ABC Programme took the initiative to prepare the first Emission Inventory Manual (EIM) for the estimation of ABC precursors and conducted the scenario studies based on economical and technological development. EIM was developed in consultation with experts from several countries. The first meeting of EIM experts 'Expert Group Meeting on ABC Emission Inventory' was held during May 19-20, 2008 at AIT Bangkok with two objectives. The first was to identify data pertaining to key pollutants to be included in EIM. The EI group also organised an 'International Workshop on Emission Inventory of the Precursors of Atmospheric Brown Clouds (ABCs)' at AIT during 18-19 November, 2008, which was attended by international experts on emission inventory studies. The 2008 ST group meeting endorsed the EIM, which was one of the most comprehensive to date, prepared by AIT. After the final approval in ST meeting in Kathmandu in March, 2012, the EIM was sent for publication. Meanwhile, the EI group also performed 2 case studies (Thailand and Indonesia) to test the methodologies described in EIM.

A large population of the world, including India, uses biofuel for cooking purpose. The emissions from biofuel include gases pollutants and BC aerosols which are known to have serious health effects. It has been estimated that more than half million people die prematurely due to acute lower refractory infections mainly due to exposure to high level of BC aerosols. BC is also responsible for global warming only next to GHGs. Therefore, reducing BC aerosols have a number of additional benefits which include immediate improvement in human health, air quality and agriculture productivity. A pilot project Surya, that was designed to reduce the emissions of air pollution including GHGs and BC aerosols, was launched in 2009. The project Surya is first implemented in a village in Uttar Pradesh province of India. Project Surya has a successful completion of the pilot phase. Several benefits that were derived from Surya include (i) economic - the customization and local fabrication of cleaner technology reduced the cost of the technology, (ii) technology

improvement-cleaner and greener technology was tested and deployed, (iii) social-improved health of women and children, and (iv) climate relevant reduction in BC and GHGs will have lesser impacts on global warming.

One of the goals of ABC Programme is to create consensus and awareness on ABCs impacts and mitigation measures through presenting the science and impact findings to a larger audience including policy makers.. Several activities were implemented in achieving this goal. Some of the activities are highlighted as examples. Chair and vice chair, ST, ABC presented the key findings of science and impact studies at 24th session of the UNEP Governing Council/Global Ministerial Environment Forum (GMEF) in Monaco on February 20, 2008. Release of ABC impact assessment report also received wide media attention in November, 2008. A side event was organised at the UNFCC COP 16 in Cancun in December 2010 to inform the climate change negotiators on the impacts of ABCs on climate change. A high-profile ABC Science Seminar held in Kathmandu on December 4, 2008, and attended by ABC ST Members, members of impact study team, participants of the 3rd international training school and others, such as experts, professors and young researchers. Minister of Nepal Government inaugurated the meeting and Prof. V. Ramanathan, Chair, ST, Project ABC, delivered the key note lecture on' Greenhouse gases, air pollution and climate change: What can and should Project ABC do?'. A dedicated website www.rrcap.unep.org/abc became available to the public and scientific community to learn about ABC scientific activities and data distribution.

To create awareness on mitigation measures, a workshop entitled 'Consultation on Soft Approaches for Achieving Co-Benefits from Black Carbon Emission Reduction' was organised by the ABC Programme during March 21-23 in Kathmandu. The meeting focussed on identifying and assessing cost effective ways for mitigation of black carbon emissions. The meeting was well attended by scientists, policy makers, civil society members, who also discussed the co-benefits of BC emission reduction. A new initiative was started in the form of Black Carbon e-Bulletin for raising awareness of Black Carbon among the policy makers. By the time of writing this report, nine such bulletins have been electronically circulated. In addition, many dozens of highly impactful scientific papers were published in top-tier international journals in the 2nd phase.

The programme has also implemented activities to influence the air pollution networks. Findings of ABC programme and need for integrated approach for atmospheric activities were presented at the meetings of intergovernmental air pollution networks such as the Malé Declaration and EANET. This has resulted in formation of Joint Forum on Atmospheric Environment in Asia-Pacific. The Joint Forum is a network of air pollution networks in Asia-Pacific region established with the aim of promoting clean air.

3.2.4: Expansion of Geographical Scope

The scientific studies during phase I revealed that the ABC is a frequently occurring transboundary, trans-continental and trans-oceanic phenomenon downwind of all heavily

inhabited regions. The ABC Science Team meeting in 2008 had recommended expanding the geographical coverage of the project to Africa and Latin America, and carrying out the ABC activities in these regions based on the experience from Asia. In view of this, ABC activities have been expanded to Africa and Latin America during Phase II.

In Africa, a scientific consultation focusing was convened on 23 August 2010 in Nairobi, Kenya with the aim of analyzing the gap to study the possible role of ABCs in regional environment and climate; and understand the needs of the region with respect to ABCs and their climate and air-quality links), possibility of setting up of a network of scientists and identification of the location for setting up of an observatory in Africa. The meeting discussed the way forward focusing on identifying the gap and the strategy to study the ABC issue in Africa, a stepwise approach to establish ABC observatories in Africa, and networking of scientists and ongoing activities related to ABC. Following up on the recommendations of ABC Africa consultation held on 23 August 2010 on initiating ABC-Africa Programme, the Steering Committee meeting of Project ABC held on 24 August2010 decided to establish a whitepaper working group and prepare a roadmap for ABC-Africa programme in the form of a white paper. The working group met during 5-7 December 2010 in Nairobi, Kenya and prepared a Draft ABC Africa White Paper "A proposal to set up an ABC-Africa Programme". The draft white paper documents the current situation regarding the ABCs in eastern and southern Africa, existing infrastructures, existing research capacity, and proposes activities for ABC-Africa programme. Since then, African scientists are participating in the ABC activities and the establishment of the first ABC observatory in Africa has been initiated. A demonstration project on mitigation measures has also been completed in Africa and it has been identified as the future we want in the Rio+20 Summit (http://www.un.org/en/sustainablefuture/stories_kenya_cooking_stove.shtml).

In Latin America and the Caribbean, ABC programme supported the discussions at the Meeting of the Forum of Environmental Ministers. The Sixteenth Meeting of the Forum of Ministers of the Environment of Latin America and the Caribbean held in January 2008 in Santo Domingo, through Decision 7: Atmospheric Pollution, decided to establish a regional network of authorities tasked with addressing atmospheric pollution, to effect technical exchanges and promote the development of capacities, and evaluate options to reduce the atmospheric pollution. As a follow-up to this decision, the Eighteenth Meeting of the Forum of Ministers, through Decision 4, decided to develop a Regional Action Plan which would provide orientation to the work of the Regional Intergovernmental network. Decision 4 also calls for build the regional capacity for generation of air quality information for national decision-making. As a follow-up to the Decision 4, a Regional Action Plan is being developed. A draft of the regional action plan was reviewed by an intergovernmental meeting held in October 2012.

Chapter 4

Review and Evaluation of Outcome and Impact

First phase of the project had produced a number of significant findings as to how ABCs influence weather and climate, which were published in the landmark UNEP report in 2008. New model simulation, integrating and assimilating surface data obtained from observatories of ABC network and satellite data, identified the five regional Atmospheric Brown Clouds hotspots (annual mean anthropogenic Aerosol Optical Depth (AOD) exceeds 0.3 and the percentage of absorbing aerosols exceeds 10%) around the world namely, (1) East Asia, (2) Indo-Gangetic Basin in South Asia, (3) Southeast Asia, (4) Southern Africa, and (5) The Amazon Basin. Furthermore, 13 mega-cities have also been identified as ABCs hotspots. For the first time, the chemical speciation of AOD over India and China has been characterised. A notable finding was that ABCs have masked 20-80% of the GHGs forcing in the past century. The trend in ABCs precursor's emissions were reported for the first time. The report also discovered large changes in radiation, surface and atmospheric temperatures, and monsoon rainfall over China and India which cannot be solely attributed to GHGs warming. The UNEP report stated that the observed retreat of Hindu Kush-Himalayan-Tibetan glaciers was one of the most serious environmental threats to Asia. These findings were also reported in peer-reviewed journal publications.

4.1 Science and Technology

Phase 2 of the ABC project led to major advancement in key areas of aerosol sources, chemistry, and their direct and indirect effects relevant to ABC science. The transport of ABCs from source to final destination is given in a most comprehensive manner in the review by Lawrence and Lelieveld (2010). A major breakthrough happened in the project when stacked (three flying in tandem between 0.5 to 3 km within 10 km areal distance) Unmanned Arial Vehicles (UAVs)were deployed with minitiaturised instruments that can measure total aerosol concentration, BC concentration and solar flux as part of Maldives UAV Campaign. These measurements resulted in the first simultaneous profile of the aerosol parameters that are required for aerosol heating rate computations and also demonstrated that the heating rates can be measured simultaneously by deploying multiple aircrafts. The observed parameters were further fed into Global Climate Models for calculating the heating rates of about 0.25 K per decade which is sufficient to cause melting of Himalayan glaciers. This was a remarkable finding using an innovative, novel technique.

The aerosol indirect effect which consists of two challenges is a complex issue. First challenge is to understand how cloud droplet number changes due to changes in aerosol concentration (also known as first indirect effect) and second one is to quantify the changes in cloud albedo resulting from aerosol number concentration changes (second indirect effect). While there are substantial means of observations available with regard to the first effect, measuring the second one was difficult due to the technological constraints. The Unmanned Aerial Vehicles, besides aerosol and solar flux, also measured cloud microphysical properties

such as cloud condensation nuclei (CCN) and cloud droplet number concentration. Simultaneous profiles of these parameters can reduce the uncertainty in the aerosol indirect effects (i.e. aerosol's influence on cloud microphysics-cloud droplet/ice distribution and cloud radiative properties such as albedo). The Maldives AUAV Campaign (MAC) was first time able to measure the changes in cloud albedo resulting from aerosol concentration on a cloud-to-cloud basis. Larger droplet concentration and brighter clouds (high albedo) were observed in the presence of long-range transport of aerosols. These observations also revealed higher sensitivity of radiative forcing by clouds than previously reported due to precise measurements of cloud liquid water content.

First phase of the project ABC clearly showed that there is very high fraction of BC in Asian ABCs. However, there was no consensus in source apportionment (fossil fuel or biofuel) of this BC between top-down studies (which uses the measured ratio of BC to total aerosol), and bottom-up approach (which relies on the inventories based on fuel consumption and laboratory measured emission factors). Whereas the first approach estimates that 50-90% of South Asian BC originates from fossil fuel sources, the contribution of this source reduces to 10-30% based on the second method. A clever, innovative application of radiocarbon technique to winter monsoon aerosols from western India and Indian Ocean first time determined that biomass combustion produced two-third of the total carbonaceous aerosols, and 50% and two-third of elemental carbon (EC, chemically derived part of carbonaceous aerosol) and soot carbon (SC, optically measured component).

Sulphate, which forms from SO_2 emissions, causes cooling because of its highly scattering nature and is invariably found as mixture with BC. The Cheju ABC Plume-Monsoon Experiment (CAPMEX) was aimed to understand how BC sources and BC-to-sulphate ratio influences the warming. The results of CAPMEX clearly showed that amongst the three plumes measured, the Beijing plumes had the highest ratio of BC-to-sulphate, and exerted largest influence on the net warming. A strong positive correlation between aerosol solar absorption coefficient (SSA, single scattering albedo) and BC-to-sulphate ratio was observed. It was also found that fossil-fuel dominated plumes cause twice more warming than biomass-burning plumes.

Modeling studies have estimated the net warming, and relative strength of warming and cooling due to BC, and organics generated by fossil fuel and biomass-fuel cooking sources. The direct radiative forcing due to BC and dust was also estimated via calculation of key variables such as aerosol optical thickness (AOT), Ångström Exponent (AE) and single scattering albedo (SSA). Modeling studies, performed in conjunction with GCM and the ocean mixed-layer model, indicated that anthropogenic aerosol loading causes significant decrease in the surface downward shortwave radiation flux, resulting in increased low-level clouds and reduced convective activity caused by surface cooling. The macro-structure and microphysical properties of cloud are shown to be influenced by – low level static stability and large aerosol number concentration and mode diameter. Besides, modeling results also indicated that joint reductions in ABCs and GHGs would have positive impact on harvesting.

New particle formation (NPF) which is an important source of aerosols in the atmosphere can significantly alter the CCN population and thus can contribute to aerosol indirect effects. A 16-month time series of aerosol size distribution from the Nepal Climate Observatory at Pyramid (NCO-P), the high altitude atmospheric observatory, clearly showed signatures of persistent NPF occurring on more than 35% of the days when the rising polluted air from the valley meets the clean free tropospheric air mass. The NPF was followed by observed increase in ion clusters.

4.2 Impacts

The new scientific findings discussed above also assessed the impacts of ABCs on weather and climate. The new estimates of atmospheric heating rates of 0.25 K per decade derived from UAVs may be responsible for retreat of Himalayan glaciers. The continued melting of these glaciers, which constitute one of the largest ice mass on the planet, may cause unprecedented environmental problems to downstream flowing rivers. Widespread coverage in international media of these findings drew the attention of governments of the region. Currently, several governments of the countries including India, Nepal and others have initiated focussed long-term research programs on glaciology to study all aspects of Himalayan glaciers. Ministry of Environment and Forest of India has also launched a new comprehensive program, National Carbonaceous Aerosol Program (NCAP), to study the impact of ABCs and more specifically of BC on glaciers. Some of the questions being addressed in NCAP are: the relative influence of carbonaceous aerosols and other absorbing species (dust) on snow structure and albedo, radiative forcing.

The ABCs can impact global and regional climate. The GHGs tend to warm entire atmospheric column leading to increased atmospheric relative humidity (due to increase in saturation vapor pressure) and increase in rainfall (because of surface warming). ABCs, on the other hand, exert an overall negative forcing at the Top-of-the-atmosphere (TOA), and cause dimming at the surface (negative forcing) which leads to reduction in evaporation and rainfall. The net effect of GHGs and ABCs on rainfall is still not clearly known.

Atmospheric warming and surface cooling by BC and non-BC aerosols can significantly perturb the monsoon system in three ways:

(i) Surface dimming over northern Indian Ocean leads to reduced evaporation which means lesser moisture supply to south Asian monsoon system.
(ii) Meridional sea surface temperature (SST) gradient between Northern Indian Ocean (NIO) and southern Indian Ocean (SIO) has decreased since 1950s due to presence of ABCs over NIO and absence of those over SIO. Such reduced SST during summer has been shown to slow down the pre monsoon circulation resulting in reduced rainfall over south Asia.
(iii) The differential atmospheric heating due to BC aerosol over south Asia and Indian Ocean has strengthened meridional atmospheric heating gradient which has invigorated monsoonal flow resulting in increased springtime rainfall over South Asia.

The UNEP report at the end of 1st phase documented the serious health impacts of ABCs in general and BC aerosols in particular. A significant modeling study (constrained with satellite observations) as a part of ABC phase 2 showed that vast population of Asia is exposed to high level of $PM_{2.5}$ that exceeds the annual mean (10 μgm^{-3}) prescribed by WHO by a factor of 2-4.

4.3 Mitigation and Awareness

Project ABC phase 1 focussed mainly on building the observatory network to create long-term time series of ABCs parameters which were used for addressing the science objectives of ABCs, and to certain extent also on assessment of the impacts of ABCs on weather, climate, human health and agriculture. The 2nd phase consolidated the science findings and also furthered it in three ways (i) by augmenting the observatories network (ii) developing new atmospheric measurement techniques such as UAV and instrument miniaturisation and (iii) also by initiating a comprehensive modeling activity. These activities resulted in some very impactful research as regards to ABCs. The new findings also enabled the ABC team to focus on the mitigation of ABCs.

Improved constraint on the sources is the first step towards enacting effective abatement strategies. A breakthrough finding as to the source (fossil fuel or bio fuel) of BC aerosols by ABC team clearly suggests that both fossil fuel and bio fuel combustions (residential cooking and agriculture burning) should be targeted to mitigate climate effects of BC, and improve air quality and health.

Cooking drives local outdoor BC concentrations. BC concentrations exhibit a strong diurnal pattern, with peaks during morning and evening cooking hours, at magnitudes five times higher than mid-day and nighttime concentrations. This large signal indicates that Surya's intervention could indeed create a BC hole.

Project Surya have tested technologies capable of creating a BC hole. Surya team found that certain forced draft technologies clearly outperform natural draft technologies in terms of BC reduction, and are capable of reducing emissions by a factor of 4 to 5.

Project Surya successfully developed and field-tested an ultra low-power wireless cell-phone based BC monitoring system which cuts measurement costs by a factor of 10 and can measure surface BC emissions with unprecedented spatial resolution.

Project Surya started a new initiative named as Carbon Credit Pilot Project (C2P2) through which women, who use improved cookstove, will be financially rewarded for avoiding CO_2 emissions (based on carbon credit market) and reduction in black carbon, ozone, and methane (SLCPs).

Abrief of Project Surya is present in **Annex 5**.

There is currently a consensus worldwide to reduce SO_2 emissions for achieving better air quality. Recent findings of ABC researchers showed that such reductions are accompanied

by larger reductions in BC such that reduction in BC-to-SO_2 emission ratio is also achieved. Such a mitigation step will reduce BC effects on climate, and also provide co-benefits to human health.

Knowledge gained from ABCs hard science was translated into action when Project Surya, within the framework of ABC programme, was started to mitigate BC emissions from use biofuels in domestic cooking in rural part of Asia and Africa, with an aim of mitigation of regional climate impacts by reducing atmospheric concentrations of BC, methane and Ozone was launched. The vision of Surya is: Project Surya has three specific objectives:

- To eliminate the detrimental health effects of indoor smoke;
- To reduce the negative effects of BC in ABCs on the summer monsoon rainfall, Himalayan glacier retreat and agriculture;
- To mitigate the global warming effects of CO_2 and BC.

The pilot phase of Project Surya has begun by deploying in-house developed low-cost, inexpensive solar and other energy-efficient cookers in rural India and documenting the reduction in BC and other warming agents and its co-benefits to human health. The key findings of Surya pilot phase are:

ABC also created massive awareness amongst all the stakeholders through very informative websites, regular interactive workshops and e-bulletins. Due to the programme Activities ABCs has become one of the widely published environmental issues in the media. For example, documentaries on ABC were presented by major television networks like the discovery channel, BBC, and CNN, Nova. An internet research indicates that at least 3 discussions related to ABC are occurring per week in the internet. A google search on “atmospheric brown clouds” in December 2012 provides 2,770,000 results.

The SHARE (Stations at High Altitude for Research on the Environment) project, promoted by Ev-K2-CNR and funded by the Ministry of Education, University and Research (MIUR) through the Italian National research Council (CNR), aims to contribute to the study of climate change and its impact in mountain regions, supplying unique information to international scientific community and decision-makers on sustainable development and adaptation strategies. In particular, this project provides information on atmospheric composition and climate, glaciology and hydrology, water resources, mammal and plant biodiversity, human health and indoor pollution. The core of all these research studies is represented by a monitoring network including more than fifteen stations installed in Italy and around the world which monitor in continuous the environment and the atmosphere. Moreover, technological research, information systems and capacity building activities are also promoted.

4.4 Overall Impact

The overall impact of the 2nd phase of project can be measured by (1) to what extent the scientific outcome of the project influenced the larger scientific community, (2) whether knowledge gained from scientific study and the impact assessment were sufficiently compelling to influence the policy resulting in mitigation of ABCs emission.
Total 140+ peer-reviewed journal publications, which includes 4 nature (including nature series) and science and half dozen PNAS publications, emanated from the project is a glowing proof that the project is very productive and highly impactful. It was a unique, ambitious project that first time demonstrated that the environmental problems of large magnitude such as ABCs required a different approach which is based on 'knowledge-solution-action' to find the solution. The project was able to achieve its goal of capacity building in the region by training more than 120+ highly trained scientists for the next generation, who are well placed to work in their own countries. More than a dozen new comprehensive research Programs on BC aerosols and non-BC aerosols were initiated in the member-countries of project ABC.

> A climate future in which human practices no longer result in significant black carbon, ozone-precursor, and other global warming emissions, and in which current and future palliative actions on CO_2 have time to take hold and arrest human-created climate change.

The programme publishes periodic regional impact assessments, elucidating the impacts of ABCs. A major regional assessment report, the first of its kind for Asia, was published in 2008. The 2008 report confirmed that the interaction between ABCs and the build-up of greenhouse gases has significant impacts on regional climate systems, including the monsoon and the Himalayan glaciers, water budgets, agricultural production, and human health. From 2008 to 2011, the ABC programme also published the first set of scientific and policy relevant papers on the importance of mitigating methane, black carbon, ozone and HFCs [now collectively referred to as Short Lived Climate Pollutants(SLCPs)] for reducing the warming trends by as much as 50 percent during the coming decades. To link the science to policy, a series of pilot mitigation projects are being carried out in developing countries. SLCPs are now attracting global attention, resulting in the formation of the Climate and Clean Air Coalition (CCAC) in February 2012 as a global initiative to reduce the emissions of SLCPs. The CCAC aims at maximizing the health, agriculture, and climate benefits of swift action on SLCPs.

Chapter 5

Conclusions and Recommendations

5.1 Conclusions

The ABC Programme has three important components: (1) Observatory Program (2) Impact Assessment and (3) Mitigation and Awareness Program. A Logical Framework Analysis (LFA) was provided for the efficient management and flexible implementation of the project in order to achieve the projected objectives. The project begins in 2004, in accordance with the LFA. The yearly reports submitted to Sida for the period 2008-2012 showed that the project strictly complied with the LFA.

Observatory Program: Starting from scratch, the project ABC built an impressive network of 14 observatories consisting of the high altitude (Nepal Climate Observatory-Pyramid (NCO-P) and remote in deep Indian Ocean (Maldives Climate Observatory-Hanimaadhoo (MCO-H), which are equipped with state of the art instruments to continuously measure precursor gas concentration, aerosols and radiation.

Data generation and archival: The observatory network has helped creation of long time series of quality controlled ABCs parameters. The project has put considerable effort on Quality Control (QC) of the scientific data. The QC data is also archived in the centrally located server at RRC.AP and detailed information about the data is provided through an exclusive website.

Modeling: Comprehensive modeling exercise was also undertaken in the 2nd phase which includes decadal simulations of aerosols impacts and multi-model intercomparison, calculations of direct radiative forcing due to BC and dust, cloud microphysical and macro-structure impacts and also impacts on harvesting.

Capacity Building: 120+ trained scientists in the region is a glowing testimony to the capacity building part of the project. Some of the trained scientists are already leaders spearheading large programs in their home country.

Scientific output: The 2nd phase of the project was able to capitalise on the foundation laid in phase 1. Project ABC was exceptionally productive in its scientific output which reflects from 115+ publications with 80+ arising from Phase 2. A list of publictions from year 2002 to 2012 is given in **Annex 12**. Some of the findings of the project were published in most competitive journals with highest impact such as Nature, Nature Geosciences, Science, and Proceedings of National Academy of Sciences (PNAS).

It can be summaries that the Programme has been largely responsible for bringing the emerging issue of air pollution-climate interaction to global attention and to some extent building the capacity of developing countries for studying the issue. Today, the air pollution –

climate interaction (normally referred to as Short Lived Climate Pollutants) is high on the political agenda at regional and global levels.

5.2 Impact Assessment Studies

Climate impacts: Based on rigorous scientific studies, project ABC climate team was able to provide accurate assessment of the ABCs impact on monsoon recirculation, hydrological cycle, and Himalayan glaciers. The team also quantified the net climate forcing due to combined effects of GHGs and aerosols for the first time.

Human-health: The ABCs impacted stable boundary layer will lead to trapping of pollutants, giving rise to poor air quality. Furthermore, the project demonstrated that large population of the region is exposed to significantly high level of $PM_{2.5}$ (up to 4 times larger) than the safe limit prescribed by World Health Organisation (WHO).

5.3 Mitigation and Awareness Programme

Mitigation: Identification of the major BC sources (fossil fuel combustion vs. biofuel combustion) was a breakthrough research. Also warming potential was related to BC to SO_2 ratio. These findings provide unambiguous guidelines to policy makers for enacting mitigation measures.

Action: A paradigm shift in terms of 'Knowledge to Action' was proposed to achieve the ultimate goal of sustainable development. Project Surya launched in 2009 was a major step towards that end. The deployment of low-emission, energy efficient cooking stove during pilot phase of the project demonstrated that the climate and health co-benefits can be achieved by taking correct intervention measures.

Technology development under ABC deserves special mention. Deployment of UAVs installed with miniaturised instruments showed that atmospheric heating rate can be directly measured. ABC project also demonstrated the innovative usage of cheap cell phones to measure BC.

5.4 Environmental Sustainability

The evaluation noticed evidence to ensure the environment sustainability of the outcomes of the programme. For example, the scientific contribution of the programme is contributing to higher level discussions on aerosols and climate change in the context of sustainable development. Project Surya has demonstrated the sustainable development benefits of improved cooktoves, which is currently being up scaled by several initiatives. The review could not detect any negative environmental impacts from the programme implementation.

5.5 Gender

Review of meeting reports indicates that a gender balance was maintained in the project implementation and capacity building activities as much as possible in this field. For example, 13 female participants were trained in the 4th international training school held in March 2011. Out of total 101 young scientists trained in ABC training schools, 30 were female (Annex 4). The project made positive impacts on gender equality by improving the living condition of women and children, who spend most of their time in indoor while cooking. The improved cooking and lighting system demonstrated by the programme has improved the indoor air quality by reducing the emission of air pollutants by nearly 80 per cent. In addition, the improved cookstoves require 50 per cent less fuel wood. This has reduced the fuel wood collection time and increased the free for women. Women can use the free time for learning or other social activities. The programme has provided training and facilitated establishment of women groups to manage the improved cooking and lighting programme at the village level. The evaluation could not detect any gender sensitive languages or activities during the project implementation.

5.6 Country Ownership

The project implantation has been using the national agencies for the national level activities. To facilitate the national level implementation, capacity building programmes have been organised and all the ABC observatories are owned by the countries with almost no financial support from ABC programme, except few. ABC observatories owned by the countries are listed in section 3.1. These observatories are affiliated with ABC programme through frame of agreement for sharing data and technical support. Additionally, secretary level officials from the Ministry of Environment of Asian countries (e.g. India and China) are a part of advisory committee of ABC programme. In science and implementation team meetings, official from the Ministry of Environment are always participated. Although not a part of ABC programme, Indian and China started a big aerosol and climate observation programmes by theirs own being inspired from ABC which indirectly fulfilling the objectives of ABC. Therefore, a high-level of country ownership can be seen in achieving the project outcomes.

5.7 Finance

The ABC Secretariat regularly reviews the expenditures and monitors the expenditure statements in accordance with the project document. Annual budgets were prepared at the beginning of each year. Financial adjustments were made during the project implementation based on the scientific and policy developments. For example, more resources were allocated to mitigation efforts when the scientific consensuses on the impacts were made. Overall, the financial resources were used to achieve the intended purpose of the programme as expected in the LFA.

5.8 Lessons Learned

It has been a challenge establishing observatories in remote areas without access to electricity. With the support of renewable energy sources such as solar panels, observatories have been established. Another challenge is operation of observatories in least developed countries without skilled manpower and financial resources. This requires long-term capacity building programmes.

5.9 Recommendations

Large ABC science outputs justify the 'science driven' status of the project. The impact assessment of climate and human health exercise of the project was also fruitful to a large extent. The first two phases of the project have been Asia-centric. Attempts have been made to expand the programme to Africa and Latin America during the second phase. Given the global nature of ABCs, the third phase of the project should continue the activities on all the developing regions. The project should capitalize on the success of its observatory network to transform it into 'action network'. Such a network can help to mobilise people on the ground level by working directly with them.

Emissions of BC, VOC and other pollutants from burning of agricultural waste and crop residues (and from some forestry practices) may contribute substantially to harmful impacts on air quality and climate. A study by IIASA (2011) suggests that for Europe the sector offering by far the most cost-effective potential for reduction of PM 2.5 and VOC is the control of burning of agricultural waste. Future emission inventories in the context of ABC may address these issues from an Asian perspective.

Farming activities, for example, burning of crop residue (biomass) is a big source of BC. The emissions from the agriculture sector are highly significant but not well quantified. There is a need to promote good practices to reduce BC emissions from the agricultural sector. Farmers can be advised to adopt (1) energy-efficient, emission free farming practises and (2) also the selection of crops, timing of sowing etc. in the changing climate conditions.

Attempt has been made to consult policy experts during phase II. The excellent ST can give bigger impact on policy by including some prominent, experienced policy representatives from the region and elsewhere. Or ST could possibly have been complemented with a Policy Team (PT) working closely with ST. PT could have addressed obstacles to progress, possibilities for progress, costs and benefits, implementation hurdles, socio-economic factors, competing interests, poverty alleviation, gender issues, inter-linkages with other national and international programs, etc).

Given that five hotspots (we would rather say sub-regions) are identified worldwide and since ABCs so far has concentrated on South and South East Asia it would have been beneficial if a comprehensive emission source apportionment could have been addressed for what is recorded for the latter two sub-regions. The lack of overall (for decision-makers) convincing knowledge of emission sources and their relative contribution to ABCs and their effects is a

memento for further efforts, taking into account that also natural, non-abatable sources may play a major role. A future ABC emission inventory regarding anthropogenic sources must include combustion sources along all the contributing coastal areas, e.g. East Africa, Arabian peninsula, Pakistan-India-Bangladesh, Indonesia and, not least, international shipping and harbor activities, as well as off-shore petroleum exploration. Local, national and regional problems could thus be addressed in an integrated fashion, considering both short- and long-term objectives. Only then can optimal, regional tentative mitigation programs be designed and intergovernmental cooperation developed in parallel with national and local action. Cost-effective measures can be assessed and sources of possible funding can be better defined. This can build on the ABC emission inventory manual already developed by the ABC Programme.

ABC is a highly science-driven program that can form the backbone of national and international policy development. A professional information strategy may be contemplated for reaching desired results as soon as possible. NGOs, including public interest groups as well as industry, have a role to play. The programme has been successful in reaching various stakeholders including intergovernmental networks on regular basis and reaching consensus and awareness. Relations to UNEP, ESCAP, UNFCCC and IPCC as well as to Asian regional initiatives such as SACEP, the Malé Declaration, EANET and the ASEAN Haze Agreement must be used to their full extent, not only regarding observations and assembly and analysis of data but also for underpinning policy action to the benefit of human health, food security, ecosystems and climate.

A possible shift of emphasis from science to policy and implementation must not be seen as a weakened role for ABC's scientific work. On the contrary, the ABC Science Team will become even more significant as a well-recognized long-term and stable basis for good policy decisions based on sound science. That's how political and socio-economic sustainability is maintained. The marriage between the two communities is essential for progress and both will benefit from that marriage. The present ABC will continue to produce justification for integration of issues regarding science-based political interventions, technical as well as structural. Science-driven progress can be gained much in the same way as action on ozone-depleting substances was agreed and implemented following the Vienna Convention of 1985 and the Montreal Protocol of 1987.

Given the fact that necessary regional policy action to curb emissions of pollutants leading to ABC must rest on stable and long-term scientific findings and assessments, we recommend that the ABC programme continue to operate for the foreseeable future. It is essential not only as a driver for national and international policy interventions but also as the foremost body for assessment of atmospheric response to such measures and associated environmental effects of ABC.

Chapter 6

Evaluation Grading

Based on the review of the programme in the earlier chapters, this chapter summaries the progress and assign grads. Results of evaluation against the LFA outputs and programmatic themes are summaries below:

Programmatic Theme	Intervention Logic	Objectively Measurable and Verifiable Indicators	Evaluation Results
Observatory	Increased capacity and understanding of ABC radiative forcing on regional climate change.	Established aerosol and radiation monitoring observatories Established precipitation and aerosol chemistry observatories Models to assimilate observed data and to conduct impact studies Trained expertise to operate the observatories/study ABC in the region	Capacity has been increased. It is evident from the established observatories, available models, and trained scientist from developing countries
Impacts	Increased understanding on the impacts of ABC on regional climate, water resources, agriculture and health and increased capacity to carryout impact assessment change.	Projected trends, Impact assessments, and trained scientists	Understanding on the impacts of ABC has been increased. It is evident from the publications by the ABC scientists and others.
Awareness & mitigation	Knowledge concerning ABC impacts, and mitigation and adaptation measures developed and effectively communicated to decision-makers and general public.	Available mitigation measures-Adoptable alternative scenarios, strategies, and recommendations Increased government attention – number of projects focused on mitigation Increased media attention – volume and quality of coverage	Knowledge concerning ABC impacts and mitigation measures has been drastically increased. It is evident from the emergence of national level activities on SLCPs. Outcome of the Project Surya was a motivating factor for national level mitigation activities. Improved cooking and lighting systems for reducing ABC emissions from indoor cooking are now available. The programme has also made huge awareness. A google search on "atmospheric brown clouds" provides 2,770,000 results.
Awareness & mitigation	Consensus among key stakeholders (policy and scientific communities) built to underpin emergence of regional and global action on ABC	Increased intergovernmental cooperation on ABC	Consensus on the need to address ABC including SLCPs has been increased during the programme implementation. This can be seen from the formation of new intergovernmental level activities such as the Climate and Clean Air Coalition.

Based on the ToR, a set of indicators as the evaluation attributes developed for the purpose of performance assessment of the programme implementation in achieving the programme

objectives in accordance with the LFA. The grade assigned for the activities and outputs in each programmatic theme are given below:

	Observatory	**Impacts**	**Awareness & Mitigation**
Project Attributes			
Programmatic adjustments	Within the scope of the project, adjustment made with the development of science and awareness		
Financial adjustments	Within the scope of the project, adjustment made with the development of science and awareness		
Conformity with decisions	Conformity and appropriateness with the Steering Committee decisions		
Review Attributes			
Scope of outputs	HS	HS	HS
Quality of outputs	HS	HS	HS
Significance of outputs	HS	HS	HS
Country ownership and replicability of outputs	S	S	HS
Environmental sustainability	S	S	S
Gender issues	S	S	HS
Project management efficiency	HS	HS	HS
Cost efficiency	HS	HS	HS
Overall grading	HS		

Attributes considered:
HS: *Highly Satisfactory*-Activities and outputs are insubstantial compliance with the defined LFA objectives and implementation targets. The project can be presented as "good practice".
S: *Satisfactory*- Most of the activities and outputs are in substantial compliance with the defined LFA objectives and implementation targets except for a few that need (s) remedial actions.
PS: Partially Satisfactory – Many activities and outputs are not in substantial compliance with the defined LFA objectives and implementation targets that need (s) remedial actions.
U: Unsatisfactory - Most of the activities and outputs are not in substantial compliance with the defined LFA objectives and implementation targets.

Annex 1

Logical Framework Analysis

Objective: Develop science, capacity, and policy relevant synthesis of findings to study and address the issue of ABC and its interactions with climate change in Asia, Africa and Latin America and Caribbean and promote mitigation measures.

LOGICAL FRAMEWORK LEVEL	INTERVENTION LOGIC	OBJECTIVELY MEASURABLE AND VERIFIABLE INDICATORS	SOURCES OF VERIFICATION	IMPORTANT ASSUMPTIONS/ EXTERNAL FACTORS
OUTCOME 1	**Increased capacity and understanding of ABC radiative forcing on regional climate change in Asia, Africa, and Latin America and Caribbean**	Established aerosol and radiation monitoring observatories Established precipitation and aerosol chemistry observatories Models to assimilate observed data and to conduct impact studies Trained expertise to operate the observatories/study ABC in the region	Data, progress and technical reports on the aerosol and radiation monitoring Data, progress and technical reports on the precipitation chemistry observatories Models and model-simulated data, centre for excellence Reports and publications of scientists from the region	Close cooperation from National governments and other collaborating partners in establishing the observatories; financial support from the donors.
OUTCOME 2	**Increased understanding on the impacts of ABC on regional climate, water resources, agriculture and health and increased capacity to carryout impact assessment change in Asia, Africa, and Latin America and Caribbean**	Projected trends, Impact assessments, and trained scientists	Comprehensive scientific reports on the impacts of ABCs on regional climate and water Comprehensive scientific reports on the impacts of ABCs on agriculture Comprehensive scientific reports on the impacts of ABCs on health Publications from scientists in the region, Centres of excellence	Sufficient information will be available for impact assessment
OUTCOME 3	**Knowledge concerning ABC impacts, and mitigation and adaptation measures developed and effectively communicated to decision-makers and general public.**	Available mitigation measures-Adoptable alternative scenarios, strategies, and recommendations Increased government attention – number of projects focused on mitigation Increased media attention – volume	ABC emission inventory manual, emission inventories, reports and policy actions, mitigation options, renewable and alternative energy scenarios Assessment by project members: government initiatives focused on mitigation. Assessment by project members: number of	The outcome of the project fits the requirements for emission reduction and sustainable development

		and quality of coverage	newspaper articles, Radio/TV reports	
OUTCOME 4	**Consensus among key stakeholders (policy and scientificcommunities) built to underpin emergence of regional and global action on ABC**	Increased intergovernmental cooperation on ABC	Proceedings of consultations	Active participation and agreement of member governments on collective policy action
ACTIVITY 1	**Conduct aerosol, radiation and precipitation observatory programs together with capacity building activities for scientists in change in Asia, Africa, and Latin America and Caribbean.**	6 new observatories (addition to 11 existing) for aerosol and radiation monitoring in Asia 1 new observatory (addition to 3 existing) for precipitation and aerosol chemistry monitoring in Asia 1 new climate observatory in Africa 1 new climate observatory in LAC Development of ABC Models Training programs	Data and reports from the observatories; biannual progress reports. Data and reports from the observatories; biannual progress reports Models and Data Report of the training	Active participation of participating organizations, related countries, consultants, and other stakeholders in the activities
ACTIVITY 2	**Conduct impact assessment program (impact on water budget, impact on agriculture, impact on health) together with capacity building activities in Asia, Africa, and Latin America and Caribbean.**	Impact assessment study on regional climate and water resources Impact assessment study on agriculture Impact assessment study on health Impact working group meetings	Biannual progress reports, Regional Assessment Reports Biannual progress reports, Regional Assessment Reports Biannual progress reports, Regional Assessment Report Biannual progress reports; meeting reports	Active participation of Participating organizations, related countries, consultants, and other stakeholders in the activities
ACTIVITY 3	**Archive ABC data for sharing, develop and compile mitigation measures, conduct targeted dissemination and awareness raising events in Asia, Africa, and Latin America and Caribbean.**	Data for scientists and researchers, information package for policy makers which include: quantification of pollutant damages and mitigation measures. Legal/economic/technological instruments Awareness programs for head of the governments, parliamentarians, sub regional environment policy dialogues, youth groups and civil societies.	Information package; biannual progress reports Technical reports; biannual progress reports Reports of SEPD and relevant meetings	Active participation of participating organizations, related countries, consultants, and other stakeholders in the activities
ACTIVITY 4	**Develop policy brief, convene consultation and convene intergovernmental meeting**	Policy brief on ABC, Bulletins, results of consultations, network of policy makers	Progress reports	Active participation and agreement of member governments on collective policy action

Annex 2

Terms of Reference of Review

ABC Programme is moving from science and capacity building to implementation of mitigation measures. The evaluation will be conducted by a team of two evaluators with science expertise and implementation expertise. Under the overall supervision of the Deputy Director, RRC.AP, the evaluators shall undertake an evaluation of the project during the period of 5 November 2012 – 30 January 2013.
The evaluation will comprise the following elements.

- An evaluation of the project and all of its major components undertaken to date and a determination of progress towards achievement of its overall objectives.
- An assessment of the scope, quality and significance of the project outputs produced to date in relation to expected results specified in the logical framework matrix and the Project Document.
- An assessment of country ownership and replicability of produced outputs. Also an analysis in relation to environmental sustainability and gender issues.
- An analysis of the extent of cooperation engendered and synergy created by the project in each of its component activities, between national and regional level activities and the nature and extent of commitment among the countries and institutions involved.
- Identification of any programmatic and financial variance and/or adjustments made during the implementation of the project and an assessment of their conformity with decisions of the Steering Committee and their appropriateness in terms of the overall objectives of the project.
- Lessons learned during project implementation. Recommendations regarding any necessary corrections and adjustments to the overall project work plan and timetable for the purposes of enhancing the achievement of project objectives and outcomes.

Annex 3

A short description of the evaluators

Dr. Sachchida Nand Tripathi (S. N. Tripathi, Evaluator for Science)

Dr. Sachchida Nand Tripathi, an Indian, is a Professor of Atmospheric Science in the Department of Civil Engineering, Indian Institute of Technology (IIT), Kanpur, India. He did his Ph.D. in Atmospheric Science from the University of Reading, UK, specializing on aerosol modeling.

Dr. Tripathi is a well-known atmospheric scientist, working on atmospheric brown clouds (ABCs), in particular on aerosol-cloud interaction, aerosol radiative effects on earth-atmosphere, and chemical transport models (CTMs) in Indo-Gangetic Plan (IGP) of India. Dr. Tripathi has published more than 70 peer reviewed researcher articles in high impact factor international journals with citations of over 1000. He also wrote several book chapters and media (TV/Newspapers) reports. He got several fellowships/awards at the national and international levels, namely, FELIX award for Ph.D.; AICTE Young Teacher Career Award; NASI-SCOPUS Young Scientist Award for highest citation in Earth Sciences; NASA Senior Fellowship; Sir M. Visvesaraya Research Fellowship for excellence in teaching and research; and travel grants for Aerosol society bursary European Aerosol Conference and Royal meteorological society. He has been leading more than 20 research projects supported by various funding agencies.

He hold short-term positions in various organizations, namely, Visiting Scientist at Bhabha Atomic Research Centre (BARC), Mumbai, India; Post-Doctoral Researcher at Oxford University, U.K.; Visiting Researcher at NOAA Aeronomy Laboratory, Boulder, USA; Visiting Associate Professor at The University of Tokyo, Japan; Senior Fellow at NASA Goddard Space Flight Center, Greenbelt, USA; and Professor at Orleans University, France.

He is a reviewer of Department of Science and Technology (DST) and Council of Scientific and Industrial Research (CSIR), the Government of India for project proposals submitted for funding. He is also a reviewer for leading scientific journals like Journal of Geophysical Research (JGR), International Journal of Remote Sensing, Atmospheric Sciences, Atmospheric Environment, Geophysical Research Letters, Atmospheric Research, Atmospheric and Terrestrial Physics. Current Science, Aerosol Science and Technology, Tellus B, Space Science Review, Journal of Applied Meteorology, Planetary and Space Science, Advances in Space Research, and the United Nations Environment Programme (UNEP).

Mr. Lars Nordberg (Evaluator for Policy)

Mr. Nordberg, a Swedish citizen, is a President of ScandEnvironment Advisory Services, Sweden. He has a long career in the United Nations and other international agencies.

- Representing International Cryosphere Climate Initiative (ICCI) for possible action to reduce black carbon and particulate matter from agricultural and forestry practices for the protection of the Arctic. Member of the Board of the foundation ICCI-Europe.
- Adviser, Institute for Global Environmental Strategies (IGES) and its Asian Co-benefits Partnership (ACP), Japan
- Member, International Advisory Group for the Global Atmospheric Pollution Forum (GAPF)
- Adviser, International Legislation on Air Pollution to the Swedish International Development Cooperation Agency (Sida)
- Chairman of Programme Advisory Group (PAG), Evaluator of International Training Programme on Air Pollution Management and Technology,
- Commentator, UNEP's project proposal on Atmospheric Brown Clouds (ABC)
- Lecturer at Sida-funded Advanced International Programmes on Air Pollution Management (2005-2010).
- Consultant, United Nations Environment Programme (Asia and the Pacific) on multilateral cooperation on air pollution and related issues
- Consultant, United Nations Economic Commission for Europe (UNECE), Geneva, Switzerland on worldwide outreach regarding the science-policy interface of the Convention on Long-range Transboundary Air Pollution; including advisory services to the Central Asian Republics
- Adviser, Acid Deposition Monitoring Network in East Asia (EANET), Niigata, Japan/Bangkok, Thailand on organization and science-policy interlinkages
- Senior Environmental Affairs Officer/Deputy Director, Environment and Human Settlements Division of the United Nations Economic Commission for Europe, Geneva, Switzerland.
- Secretary, Convention on Long-range Transboundary Air Pollution (CLRTAP).
- Leader, Air and Water Team in the Commission. Emphasis on intergovernmental negotiations for multilateral agreements under the air convention. Planning and coordination of integrated science/policy development in Europe and North America for programmes on air pollution emissions, chemical transformations, atmospheric transport, environmental effects, abatement techniques and strategies, cost optimizations, political negotiations, agreements and institutional aspects, as well as follow-up, implementation, compliance monitoring and response action. Head of Convention Secretariat, management of secretariat services and staff. Cooperation with UN Headquarters, UNEP, WHO, WMO, OECD, EU, governments, non-governmental organizations (industry and public interest groups), scientific institutes and institutions.

Annex 4

List of young scientists trained in ABC Training Schools

S.N.	Name of young scientist	Gender	Country
	Training School of 2004 was held at Maldives Climate Observatory Hanimaadhoo, Maldives		
1.	Amjad Abdulla	Male	Maldives
2.	Mohamed Adam	Male	Maldives
3.	Ms. Raheema Gasim	Female	Maldives
4.	Harish Kumar Gupta	Male	India
5.	Md. Abdul Hannan	Male	Bangladesh
6.	Abba Elizabeth Joseph	Male	India
7.	Ms. Sverdlik Leonid	Female	Kyrgyztan
8.	Ms. Mizna Mohamed	Male	Maldives
9.	Abdulla Naeem	Male	Maldives
10.	Ms. Bidya Banmali Pradhan	Female	Nepal
11.	Anup Krishna Prasad	Male	India
12.	K. H. M. S. Premalal	Male	Sri Lanka
13.	Yoosuf Qasim	Male	Maldives
14.	Ahmed Sameer	Male	Maldives
15.	Ms. Boossarasiri Thana	Female	Thailand
	Training School of 2006 was held at Asian Institute of Technology, Bangkok and Maldives Climate Observatory Hanimaadhoo, Maldives		
16.	Dr. Abdus Salam	Male	Bangladesh
17.	Ms. Mingxia Ji	Female	China
18.	Mr. Xin Wang	Male	China
19.	Mr. Krishna K. Budhavant	Male	India
20.	Dr.(Ms.) B. Padma Kumari	Female	India
21.	Dr. A.N.V. Satyanarayana	Male	India
22.	Mr. Shivraj Sahai	Male	India
23.	Ms. Maria E. Vuillermoz	Female	Italy
24.	Dr. (Ms.) Angela Marinoni	Female	Italy
25.	Mr. Ahmed Muslim	Male	Maldives
26.	Mr. Yazeed Ahmed	Male	Maldives
27.	Mr. Ahmed Saleem	Male	Maldives
28.	Mr. Sharfulla Thoaha	Male	Maldives
29.	Mr. Faruhad Moosa	Male	Maldives
30.	Mr. Pradeep Dangol	Male	Nepal
31.	Mr. M. Athar Haroon	Male	Pakistan

S.N.	Name of young scientist	Gender	Country
32.	Ms. Seung Yeon Kim	Female	Korea
33.	Ms. In-Jin Choi	Female	Korea
34.	Mr. Akkaneewut Chabangborn	Male	Thailand
35.	Mr. Thawatchai Sudjai	Male	Thailand
36.	Ms. Boosarasiri Thana	Female	Thailand
37.	Dr. Daam Settachan	Male	Thailand
38.	Ms. Patricia Castellanos	Female	United States
39.	Ms. Kathleen A. Mar	Female	United States
40.	Ms. Tuyet Mai Tran Thi	Female	Vietnam

Training School of 2008 was held at International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

41.	Mr. Mahmodul Hasan	Male	Bangladesh
42.	Mr. Yun Peng Li	Male	China
43.	Mr. Shiguang Qin	Male	China
44.	Mr. Sumit Kumar	Male	India
45.	Mr. Bhishma Tyagi	Male	India
46.	Dr. John P. George	Male	India
47.	Dr. Pradeep Khatri	Male	Japan
48.	Ms. Yumi Kim	Female	Korea
49.	Mr. Yongjoo Choi	Male	Korea
50.	Mr. Sanjar Imashev	Male	Kirgizstan
51.	Mr. Jagdish Karmacharya	Male	Nepal
52.	Dr. (Ms.) Bandana Prahan	Female	Nepal
53.	Mr. Ram K. Sharma	Male	Nepal
54.	Mr. Sandeep Shrestha	Male	Nepal
55.	Dr. Atindra Sapkota	Male	Nepal
56.	Mr. Khem Poudyal	Male	Nepal
57.	Mr. Ahmad K. Majumder	Male	Nepal
58.	Mr. Niranjan Sharma	Male	Nepal
59.	Ms. Silu Bhochhibhoya	Female	Nepal
60.	Mr. Saraju K. Vaidya	Male	Nepal
61.	Mr. M. Zeeshan Shahid	Male	Pakistan
62.	Dr. (Ms.) Susan Kaspari	Female	Switzerland
63.	Ms. Jinchula Chotpitayasunon	Female	Thailand
64.	Mr. Nguyen Hong Phuc	Male	Vietnam
65.	Mr. Rudra Shrestha	Female	United Kingdom
66.	Mr. Pradeep Dangol	Male	Nepal
67.	Ms. Rejina Pradhan	Female	Nepal
68.	Mr. Laxman Adhikari	Male	Nepal

S.N.	Name of young scientist	Gender	Country
	Training School of 2011 was held at International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal		
69.	Ms. Makiko Hasimoto	Female	Japan
70.	Dr. Daisuke Goto	Male	Japan
71.	Mr. Muhamed Ibrahim	Male	Maldives
72.	Mr. Supattarachai Saksakulkrai	Male	Thailand
73.	Mr. Radchagrit Supakulopas	Male	Thailand
74.	Mr. A. K. M. Enamul Haque	Male	Bangladesh
75.	Mr. Masud Rana	Male	Bangladesh
76.	Mr. Zeeshaan Shahid	Male	Pakistan
77.	Ms. Shilpa C. Shirodkar	Female	India
78.	Ms. Sudha Singh	Female	India
79.	Mr. Harikishan Gandham	Male	India
80.	Mr. Rajesh Kumar	Male	India
81.	Mr. Dipesh Rupakheti	Male	Thailand
82.	Mr. Gyan Prakash Gupta	Male	India
83.	Dr. (Ms.) Ranjana Jha	Female	India
84.	Ms. Sangeeta Maharjan	Female	Nepal
85.	Ms. Shradda Dhungel	Female	Nepal
86.	MS. Nirjala Koirala	Female	Nepal
87.	Ms. Medina Shakya	Female	Nepal
88.	Mr. Gynendra Mani Gautam	Male	Nepal
89.	Mr. Neerajan Nepal	Male	Nepal
90.	Mr. Khadak Singh Mahat	Male	Nepal
91.	Mr Suman Kumar Regmi	Male	Nepal
92.	Mr. Prasantamani Niraula	Male	Nepal
93.	Mr. Ajay Rajbhandari	Male	Nepal
94.	Ms. Linda Maharjan	Female	Nepal
95.	Ms. Richa Bhattarai	Female	Nepal
96.	Ms. Anjila Manandhar	Female	Nepal
97.	Ms. Krity Shrestha	Female	Nepal
98.	Mr. Sanam Askh	Male	Nepal
99.	Ms. Ritu Meher Shrestha	Female	Nepal
100.	Mr. Utsav Maden	Male	Nepal
101.	Mr. Suyesh Pradhan	Male	Nepal

Annex 5

Project Surya

In the residential sector, solid biomass plays a key role in the energy mix of developing countries. In incomplete combustion of biofuels, such as wood, leaves, charcoal, cow-dung-cake, and any plant residue, produces smoke. This smoke is a mixture of various pollutants, such as black carbon (BC), organic carbon (OC) particles, and other trace gases, which collectively termed as atmospheric brown clouds (ABCs).

Combustion of biofuels in traditional cookstoves (thermal efficiency < 15%) produces a large amount air pollution, causing a severe health impacts to the people, especially women and infants who spent more than 4-6 hours in the kitchen. Due to the long exposure to these pollutants, women and children are more susceptible to get respiratory diseases like asthma, bronchitis, and lung cancer. Nearly 2 million people die prematurely from illness attributable to indoor air pollution from household biofuels use (WHO). In addition, large scale use of biofuels accumulates ABCs in the atmosphere by forming wide spread layers of air pollution. Black carbon (BC), a fraction of ABCs, strongly absorbs incoming solar radiation causing imbalance in earth radiative budget, which in turn resulting a significant climate change. Studies suggested that weakening of Indian monsoon, shifting of precipitation from north to south in China, melting of Himalayan glaciers, and increased intensity of extreme weather episodes, are likely caused by large BC emissions.

Project Surya has been initiated to develop the knowledge concerning mitigation measures for solid biomass uses in the residential sector. Project Surya aims to test and demonstrate clean technology interventions which will provide sustainable, pro-environment, pro-poverty, pro-health, pro-women, politically and socially acceptable alternatives for polluting traditional cooking stoves and kerosene lamps.

Project has successfully implemented a pilot phase in a rural village of 485 households in India to field test pro-environment, pro-poverty, pro-health, pro-women, politically and socially acceptable alternatives for polluting traditional cooking stoves and kerosene lamps. Based on the success in India, Project Surya has also been replicated in a Kenyan village.

Major highlights of pilot phase results include:

- **Economic benefits:** Customization and local fabrication of cleaner technologies are expected to reduce the cost of the technology. For example, price of cleaner cooking stove will reduce from US$120 per unit to US$ 40 per unit, which is affordable to poor rural population. In addition, cost of purchasing biomass for cooking is also expected to be reduced by half. In addition, the cost of purchasing kerosene is also expected to reduce as the kerosene lamp was replaced by the cleaner lighting system. Although the expected economic benefit has not been quantified due to the variation in the price of

fuel wood, the project has resulted in significant economic benefits for the people of the village.

- **Technology improvements:** The project tested, and demonstrated available cleaner technologies for the reduction of emissions of short-lived climate forcing. It is expected that the new technologies will facilitate adoption of climate friendly life styles in developing countries. Kitchen performance tests and social surveys were conducted to monitor the adoption of the intervention. After the tests and surveys indicated the adoption of the intervention, a shop was established to widely market the interventions.

- **Social benefits:** Improved health and living conditions for women and children- Households in the project village traditionally cook in stoves using locally available biomass, which is either collected or (in some cases) purchased. Introduction of improved stoves to these families had three immediate benefits: (1) reduction of black carbon emission a major component of particulate matter (PM) by 50 to 70 per cent have significantly improved the kitchen air quality, which is expected to reduce the respiratory diseases in women and children who spend most of their cooking time sitting next to mud cook stove ; (2) drudgery in collecting biomass fuel like wood chips have reduced as the improved stoves require 50 per cent less biomass fuel than the traditional stoves; and (3) efficient cooking stoves reduced cooking time. Reduced cooking time will provide more time for women to engage in productive activities, acquire new skills, fulfill other domestic responsibilities, or simply rest.

- **Contributions to climatic benefits at the regional and global level:** Improved cleaner technologies reduced emissions of short-lived pollutants from burning biomass for cooking in the Surya village. For example, cleaner cookers reduced black carbon emission by 50 to 70 per cent compare to the traditional mud-stoves. This will help in climate change mitigation efforts at the regional and global levels

Annex 6

Questionnaire for the Interviewees

Identification

Name	
Affiliation	
Field of expertise	
Responsibilities and implementation arrangement	

Overall appreciation

Science (and technology)

1. What are the major scientific advances project has made in understanding the source and physical, chemical, and optical characteristics of regional ABC? For example how well do we understand the size distribution and spectral optical properties of BC?
2. What about Brown Carbon and its mixture with BC?
3. What is the current level of uncertainty in aerosol direct radiative effects over South Asia and other regional hotspots?
4. What about indirect and semi-direct effects of aerosols over these regions?
5. How did ABC observatory program help in characterising the regional ABC?
6. Are the observatories equipped with state of the art instrumentation?
7. Were some novel devices developed for measuring aerosols?
8. Can the process level understanding gained from project be implemented in operational models of weather and climate in near future?
9. A major focus of project has been on ABC - summer monsoon connection. But lately a large area of Pakistan and India faces intense fog episodes during winter time which creates most severe pollution episodes with severe reduction in visibility. Does ABC plan to look into this aspect in future?

Impact studies

1. How accurately do we know today the impact of ABC on climate, hydrological cycle, human health and agriculture?
2. Do we have modelling tools for reliable prediction of impacts of ABC on climate and human health?
3. How did ABC observatory program help in improving the models?

4. Is there a need for strategic environmental impact assessment; prediction in time horizons; value of economic/social loss; damage avoidance (response, systems recovery) through measures, co-benefits of integrated action (climate, air quality, socio-economic development, sustainability)?

Mitigation

1. Was the outcome of the project communicated to decision makers in international bodies as well in the affected countries?
2. Were some of the recommendations implemented to reduce the level of emissions in affected regions? If so, has it percolated to the local levels to reduce the health-related impacts?
3. What are the constraints for mitigation (lack of clear evidence of impact, administrative and legal hurdles, competing interests, inadequate organizational structures, financing, national and international programs)?
4. How ABC can contribute to the Cost-benefits of implementing measures?
5. Do we need collaboration with other international programs (Malé Declaration - monitoring and policy development, SACEP-policy, ASEAN Haze Agreement implementation)?
6. Is there a need of Information campaigns (scientific journalism, NGOs - public interest groups as well as industry, outreach and extension service to local communities, good examples, replicability across borders)?

Need for source attribution for relevant emissions

- Significance of contributions from energy generation, other land-based stationary installations, agricultural and forestry burning, international shipping (could be a major culprit), aviation, mobile land-based sources, households
- Geographical distribution of emission sources (S and SE Asia, Africa, Ocean)- relative shares
- Source-receptor relationships
- Regional, transboundary issues and for a for cooperation

Policy considerations can be entertained at the same time as science continues to provide further information. The challenge, as so often with activities such as ABC, lies in bridging sound science with informed policy interventions. How do we create a fruitful two-way exchange of information between the two communities to the benefit of both of them? Further progress is dependent on external funding, as well as of national contributions. If a program can convincingly demonstrate that the "bridge" is operational it may more easily attract funds.

Annex 7

List of Interviews

1. **Professor V. Ramanathan**, Scripps Institution of Oceanography, University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0221, USA.
2. **Professor Teruyuki Nakajima**, Director, Centre for Earth Surface System Dynamics (CESD, Atmosphere and Ocean Research Institute (AORI, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8564, Japan.
3. **Dr, Jonathan Shaw**, Deputy Director, Regional Research Center for Asia and the Pacific (RRC.AP) - UNEP Collaborating Center, Asian Institute of Technology (AIT),3rd Floor, Outreach Building, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
4. **Mr. Surendra Shrestha**, Director, UN Focal Point for Sustainable Development Goals, New York, USA.
5. **Professor Henning Rodhe**, Department of Meteorology, Stockholm University, 10691 Stockholm, Sweden.
6. **Mr. Iyngararasan Mylvakanam**, Coordinator, ABC Programme, United Nations Environment Programme (UNEP), Nairobi, Kenya.
7. **Dr. Abdus Salam**, University of Dhaka, Bangladesh (participants of ABC training school).
8. **Mr. Ibrahim**, Deputy Director General, Environmental Protection Agency, Male', Maldives.
9. **Dr. Ram Lal Verma**, Programme Office at ABC Secretariat, Regional Research Center for Asia and the Pacific (RRC.AP) - UNEP Collaborating Center, Asian Institute of Technology (AIT), 3rd Floor, Outreach Building, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
10. **Ms. Nawaphorn Supakarn**, Senior Programme Officer (Finance), Regional Research Center for Asia and the Pacific (RRC.AP) - UNEP Collaborating Center, Asian Institute of Technology (AIT), 3rd Floor, Outreach Building, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
11. **Dr. Supat Wangwongwatana**, EANET Coordinator, Regional Research Center for Asia and the Pacific (RRC.AP) - UNEP Collaborating Center, Asian Institute of Technology (AIT),3rd Floor, Outreach Building, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
12. **Ms. Adelaida B. Roman**, MD Coordinator, Regional Research Center for Asia and the Pacific (RRC.AP) - UNEP Collaborating Center, Asian Institute of Technology (AIT),3rd Floor, Outreach Building, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand.
13. **Ms. Woralac Rodsumang**, Administrative Assistant, Regional Research Center for Asia and the Pacific (RRC.AP) - UNEP Collaborating Center, Asian Institute of Technology (AIT),3rd Floor, Outreach Building, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand

Annex 8

List of Documents Perused

- Project Atmospheric Brown Clouds (ABC), ABC Observatory in Thailand, Progress Report 2010 submitted by Thailand Climate Observation-Phimai.
- Report to Italian Government of SHARE-ABC by ABC Secretariat, Implementing partner: EVK2-CNR from June 2006 to December 2010.
- Atmospheric Brown Clouds: Regional Assessment Report with focus on Asia, Published by UNEP in 2008.
- Integrated Assessment of Black Carbon and Tropospheric Ozone, Summary for Decision Makers, Edited by Bart Ullstein (Danson, UK).
- Project Atmospheric Brown Cloud (ABC), Phase I Final Report (October 2004-December 2009), compiled by UNEP ABC Secretariat, on April 2010.
- Project Atmospheric Brown Cloud (ABC), Annual Report (January to December 2008), compiled by UNEP (RRC.AP), submitted to Sida on April 2009.
- Project Atmospheric Brown Cloud (ABC), Phase I Final Report (October 2004-December 2009), compiled by UNEP ABC Secretariat, on April 2010.
- Project Atmospheric Brown Cloud (ABC), Annual Report (January to December 2010), compiled by UNEP ABC Secretariat on April 2011.
- Project Atmospheric Brown Cloud (ABC), Annual Report (January to December 2011), compiled by UNEP ABC Secretariat on April 2012.
- Atmospheric Brown Cloud (ABC), Whitepaper on the future development, submitted by the ABC International Science Team, Chaired by V. Ramanathan on November 2012.
- Interim Review Report, Project Atmospheric Brown Cloud (ABC) authored Dr. A.L. Aggarwal in May 2007.

Annex 9

List of Websites Visited

1. RRCAP: http://www.rrcap.unep.org/abc/data/abc/index.html
2. Seoul National University: http://aerosol.snu.ac.kr/
3. ICIMOD: http://www.icimod.org/?q=461,
4. http://geoportal.icimod.org/NAE/NewsDetail.aspx?NewsID=271
5. Modeling group: http://cesd2.aori.u-tokyo.ac.jp/~nakajima/abc/
5. Project Surya: http://www.projectsurya.org/
6. E-bulletin: http://www.rrcap.unep.org/abc/
7. http://www.unep.org/delc/Portals/119/Black%20Carbon%20e-bulletin%20Volume%204%20April%202012.pdf
8. http://www.unep.org/ccac/

Annex 10

List of MoUs

1. MoU between AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand and International Cooperation Department, Ministry of Environmental protection, Beijing, China
2. MoU between Indian Agricultural Research Institute (IARI) New Delhi and AIT/UNEP regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand for Conducting Studies on Impacts of Atmospheric Brown Clouds on Agriculture.
3. MoU between International Centre for integrated Mountain Development (ICIMOD), Nepal and UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand to operate the Nepal Climate Observatory in Kathmandu.
4. MoU between AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand and Government of Italy, Foreign Affairs Ministry Development Cooperation (MAE-DGCS) and the Ev-K^2-CNR Committee for Aerosol Observatory Program in Karakoram and Himalaya (AOP-KH).
5. MoU between AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand and Ministry of Housing, Transport and Environment (MHTE), Maldives.
6. MoU between Meteorological institute of the Stockholm University (MISU), Sweden and UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand.
7. MoU between Government of Sweden and UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand.
8. MoU between AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand and Jawaharlal Nehru University (JNU), New Delhi.
9. MoU between AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand and Nexleaf Analytics (Nexleaf), USA.
10. MoU between AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand and Sri Ramachandra University (SRU), Porur, Chennai.
11. MoU between AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP), Thailand and The Energy and Resources Institute (TERI), New Delhi.
12. MoU between International Inter-governmental Organisation established by the General Assembly of the United Nations represented by its Division of Environmental Law and Conventions (DELC), Nairobi, Kenya and AIT/UNEP Regional Resource Centre for Asia and the Pacific (RRC.AP).

Annex 11

Financial Statements

1. Summary of financial report for the period of November 2004- December 2008 (in US$)

	Item	Reference Code[a]	Original Budget	Revised Budget[b]	Expd. 2004-07	Expd. 2008	Exp. 2004-2008	Commitments	Budget Balance
1	Observatories-Operation by National Institutions[1]	2111, 1201	183000	214985	108261	35697	143958	27200	43,827
2	Precipitation and Aerosol Chemistry	2121	1048800	1104182	1049093	50038	1099131	5000	51
3	Impact Studies on Agriculture, Health, Water Budget[2]	2131	795000	448635	158126	172853	330979	100000	17656
4	Awareness and Materials	2141	105000	182048	21209	56339	77548	100000	4500
5	Meetings and Workshops[3]	3301	210000	255685	116570	129112	245682	3650	6353
6	Secretariat in Bangkok	1999, 2999, 3304, 4999, 5299, 5399, 5502	560000	825341	497128	171674	673775	-	151566
7	Follow-up and Evaluation	5501	80000	27000	11739	-	11739	-	15261
	Total Expenditures		**2982800**	**3057876**	**1962126**	**620685**	**2582811**	**235850**	**239215**

SN	Income		Expenditures	
	Item	Amount (US$)	Item	Amount (US$)
1	I[st] Installment: 12 Jan 05 (SEK 8000000)	1159342	Jan-Dec 2005	461596
2	2[nd] Installment: 2 Nov 05 (SEK 8000000)	1002592	Jan-Dec 2006	734056
3	3[rd] Installment: 30 Aug 06 (SEK 6500000)	895942	Jan-Dec 2007	766474
			Jan-Dec 2008	620685
			Commitments	235850
Total		**3057876**	**Total**	**2818661**
Cash Balance				**239215**

2. Summary of Financial Report for the period of 2010-2012, estimated till Sep 2012 (in US$)

	Item	Reference Code	Budget Version 2010	Proposed Revision 2012	Expenditure 2010	Expenditure 2011	Est. Expenditure 2012 till Sep 2013	Total Expenditure 2010-2011	Budget Balance 2011
			(a)		(b)	(c)	(d)	(e) = b + c+d	(f)
1	Observatories & Capacity Building *	2111,1201	298,600	341,623	77,564	35,393	175,685	288,642	52,981
2	Precipitation and Aerosol Chemistry	2121	224,500	224,542	100,000	100,042	24,543	224,585	(43)
3	Impact Assessment	2131	150,000	3,591	-	3,591	(447)	3,144	447
4	Knowledge Management & Awareness	2141	65,000	45,885	1,577	14,229	15,816	31,622	14,263
5	Mitigation Programme	2151	158,000	158,520	83,354	30,086	43,164	156,604	1,916
6	ABC Africa	2161	60,000	5,764	5,764	-	-	5,764	(0)
7	Consensus Building for Policy Action	2171	98,000	54,163	-	14,083	-	14,083	40,080
8	Secretariat in Nairobi	5404	120,000	200,000	120,000	-	80,000	200,000	-
9	Steering Committee Meeting	3301	20,000	27,874	-	12,874	-	12,874	15,000
11	Secretariat in Bangkok	1101, 1601, 5303, 5502	304,478	431,616	151,771	142,345	147,725	441,841	(10,225)
10	Follow-up and Evaluation	5501	5,000	10,000		-	8,500	8,500	1,500
	Total Expenditures		**1,503,578**	**1,503,578**	**540,029**	**352,643**	**494,985**	**1,387,658**	**115,920**

** Item 1 includes resident consultant cost*

Budget Available for 2012	Expenses 2012	Budget Bal.
a	b	c = a-b
228,666	175,685	52,981
24,500	24,543	(43)
-	(447)	447
30,080	15,816	14,264
45,080	43,164	1,916
-	-	-
40,080	-	40,080
80,000	80,000	-
15,000	-	15,000
137,500	147,725	(10,225)
10,000	8,500	1,500
610,906	494,985	115,921

Annex 12

List of ABC Publications during 2002-2012

Journals

1. Lal S. and M. G. Lawrence (2001), Elevated mixing ratios of surface ozone over the Arabian Sea, *Geophysical Research Letters, 28,* 1487-1490

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and M. Lawrence (2003), The impact of monsoon outflow from India and Southeast Asia in the upper troposphere over the eastern Mediterranean, *Atmospheric Chemistry and Physics*, 3, 1589-1608, 2003.

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