ACHIEVEMENT REPORT

RCA Research Project

on Air Quality and Environmental Impact Assessment of Industrial Activities in the Asian Region (RCARP01&02) – a Summary

RCA

Website
www.rcaro.org

ACHIEVEMENT REPORT

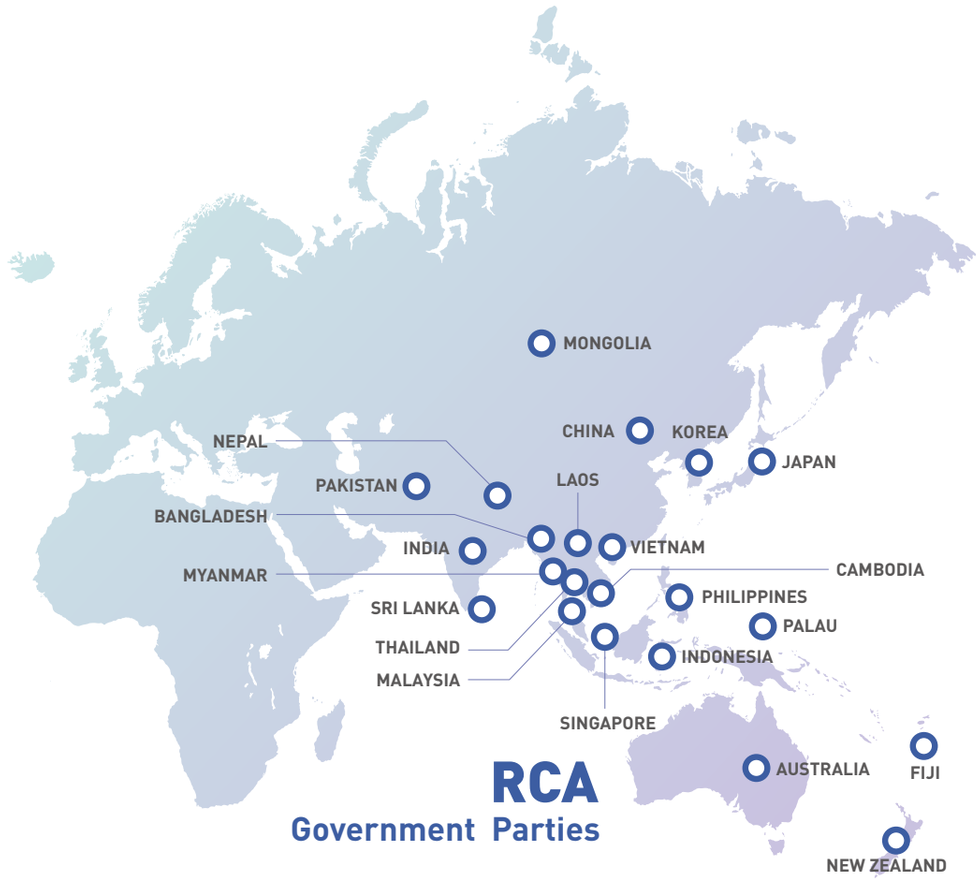
What is RCA?

The RCA (Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific) is an intergovernmental agreement among the 22 International Atomic Energy Agency (IAEA) Member States in the Asia-Pacific region.

Since its establishment in 1972 as the first regional cooperative agreement under the auspices of the IAEA, the RCA has had a long history of providing an effective framework for regional cooperation bringing socioeconomic benefits to the Government Parties and the region.

Under the umbrella of this Agreement, the Government Parties have effectively steered the RCA Programme to address their specifically identified needs and priorities as well as those of the Asia-Pacific region. Over the past half decade, RCA has implemented a total of 180 projects with a total budget of USD 92.2 million. It has not only delivered projects that have transferred a wide range of beneficial nuclear science and technology applications but it has also demonstrated the power of these technologies to contribute to the sustainable development and enhanced socioeconomic well-being of the region.

The RCA established the RCA Regional Office in Korea in 2002 to enhance the ownership of the RCA and contribute to increasing the awareness (Visibility) and international engagement (Viability) of the RCA.



Air and Environmental Pollution in the Asia-Pacific Region

Air pollution is a major environmental challenge in the Asia-Pacific region, significantly impacting human health and the surrounding environment. Factors such as rapid population growth, economic development, transportation, and industrial activities have exacerbated the issue. The increased levels of airborne particulate matter (mainly PM2.5) pose serious risks, with toxic heavy metals being significant components of this pollution. These PM2.5 particles can travel long distances, contaminating surface waters and soil, which in turn affects crops and vegetation. This creates additional health hazards for consumers, highlighting the critical need for targeted action to address air pollution in the region.

RCA Research Project

To address the urgent environmental challenges, the RCA Research Project (RP) was initiated by RCARO under the "RCARO Managed Projects" initiave, as a part of the RCA Programme that provides research opportunities in nuclear science and technology to the RCA Government Parties in collaboration with the IAEA and technical experts.

The project focuses on monitoring and assessing the impact of air pollution on the environment and on public health. By utilizing nuclear analytical techniques, the project evaluates the levels of airborne particulate matter and its effects on surrounding ecosystems, such as soil, water, and crops. The data generated helps identify pollution sources, assess health risks, and support policy decisions aimed at improving air quality and the surrounding enviroment in the Asia-Pacific region.

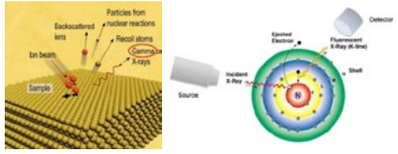
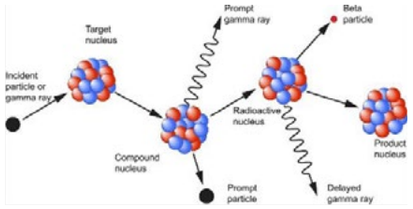
- **Project Name:** Air Quality and Environmental Impact Assessment of Industrial Activities in Asian Region
- **Implementation Period:** 2018-2020(RCARP01, Phase 1), 2021-2023(RCARP02, Phase 2)
- **Budget:** Approximately 705,000 USD (supported by RCARO)
- **Objectives:** (Phase 1) To support the improvement of quality of the environment through the provision of appropriate pollutant data to researchers and relevant stakeholders.

  (Phase 2) To extend research on other environmental samples such as water, soil and crops to assess the impact of industrial activities to the environment.
- **Participated countries:** Australia, Bangladesh, China, Indonesia, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Republic of Korea, Sri Lanka, Thailand and Vietnam_

Comprehensive Sampling and Analysis using Nuclear Analytical Techniques (NATs) → **Provision of science-based evidence to policy makers/ governments for formulating strategies for mitigating airand environmental pollution** → **Improving air quality and the surrounding environment in the Asia-Pacific region**

Nuclear Analytical Techniques in Alleviating Air and Environmental Pollution

This project used nuclear analytical techniques (NATs), which are powerful tools for monitoring environmental pollution by thoroughly characterizing various samples. The NATs provide various advantages for environmental research as they have high sensivitity, are non-destructive, simultaneous analysis can be done and there are minimal requirements for samples. These features make NATs especially valuable for analyzing air particulate matter (APM) and other environmental samples, providing essential data for understanding and addressing pollution issues effectively.

Nuclear Techniques	How does it work?	Characteristics
XRF (X-Ray Fluorescence)	High energy X-rays from a source (tube, radioisotope source or synchrotron) ➞ Emission of the **characteristic X-rays** from the elements in a sample ➞ **Element identification** by the energy of X-rays (qualitative analysis) & **Concentration Determination** by the X-ray intensities (quantitative analysis)	1. Characteristic X-rays to determine the **elemental composition** of a sample 2. Difficult to quantify elements lighter than sodium (Z = 11) 
PIXE (Particle-Induced X-ray Emission)	An external beam of **high-energy charged particles** (like protons, alpha particles) ➞ Emission of the characteristic X-rays ➞ Both **qualitative and quantitative analysis** like XRF	1. Characteristic X-rays to determine the **elemental composition** of a sample 2. Simultaneous determination of 72 elements from Sodium through Uranium on the Periodic Table
PIGE (Particle-Induced Gamma-ray Emission)	Measurement of the energies and intensities of **gamma rays** ➞ Both qualitative and quantitative analysis of various materials	1. Detection of **gamma rays** emitted by the nuclides present in the sample after bombardment with high-energy charged particles 2. Used for the analysis of **light elements** like Li, B, and F (difficult to determine by other techniques)
NAA (Neutron Activation Analysis)	Exposure to neutrons (i.e., in a nuclear reactor) to activate or create **radioactive isotopes** of the elements in the sample ➞ Return of excited isotopes to a stable state ➞ Emission of **charged particles and non-charged γ-rays** (radioactive decay)	1. Both the identification of **elements** originally present in the sample and the precise determination of their **quantities** 2. Nearly 70% of elements in the Periodic Table 
RBS (Rutherford Backscattering Spectrometry)	Collisions between atomic nuclei in a sample and high-energy charged particles (e.g., protons, deuterons, alpha particles) ® Measurements of the energy distribution and yield of the backscattered charged particles at a given angle	Quantitative determination of **the composition of the near-surface layer** of solid material and **depth profiling** of individual elements

Pollution Monitoring and Analysis: Driving Regional Action for a Cleaner Environment

The RCA Research Project focused on sampling, analysis, and capacity building to combat pollution across multiple countries, contributing to improved environmental quality, support for policy development and mitigation strategies, and strengthened capabilities in research applying nuclear analytical techniques

Comprehensive Sampling and Analysis

13,331 APM samples | **12,200** APM | **330** crop | **26** sediment | **580** soil | **135** water | **60** coal samples

Over 13,331 Air Particulate Matter (APM) and environmental samples were **collected near industrial areas in the Asia-Pacific region**

Cutting-edge analysis using nuclear and non-nuclear techniques to identify the pollution sources and assess the impact of industrial activities to the environment

7,800 APM samples

Data from 7,800 APM samples **contributed** to **the regional database** or **the Asia Pacific Aerosol Database** (APAD)

400 soil samples

Data from 400 soil samples from **5 countries submitted to the Indonesian Regional Database**

Pollution Source Identification

9 countries employed advanced statistical modeling methods like Positive Matrix Factorization (PMF) and Principal Component Analysis (PCA) to identify pollution sources.

Long-range (transboundary) pollution sources were identified through back-trajectory analysis (**HYSPLIT**) and **Potential Source Contribution Function (PSCF)** analysis.

Policy Development and Mitigation Support

Support for pollution reduction policies in **15 countries**, which assisted governments **in formulating strategies to minimize pollution impact**.

Enhanced understanding of pollution sources, benefiting **105 stakeholders**, **end-users**, and **researchers** such as governments, policy makers and releated research institutes

Strengthening Capabilities in the NATs and Fostering South-South Collaboration

65 peer-reviewed publications

65 peer-reviewed publications showcasing the key results and findings of the research

86 conference contributions | **55** national meetings

86 conference contributions and **55 national meetings** to disseminate findings and share knowledge

100 young scientists

100 young scientists trained in Nuclear Analytical Techniques (NAT) for pollution monitoring, equipping them with the skills needed to tackle environmental challenges

30 cases of South-South and North-South research

More than 30 cases of South-South and North-South research collaborations created synergy in sample analysis and interpretation, information sharing and training

Contributions to the SDGs

The research project on air pollution significantly contributes to achieving several Sustainable Development Goals (SDGs).

SDG 3

Good Health and Well-Being
by highlighting the health risks associated with poor air quality, which is linked to respiratory diseases and elevated mortality rates.

SDG 7

Affordable and Clean Energy
by promoting renewable energy sources and enhancing energy efficiency to reduce harmful emissions.

SDG 11

Sustainable Cities and Communities
and ensuring livable environments
by emphasizing the importance air quality management in urban areas.

SDG 12

Responsible Consumption and Production
through sustainable practices and technologies aimed at reducing pollution, while ensuring compliance with multilateral agreements on hazardous waste and emissions.

SDG 13

Climate Action
by recognizing the link between air pollution and climate change and advocating for measures to mitigate greenhouse gas emissions.

SDG 15

Life on Land
by addressing the impact of air pollution on terrestrial ecosystems, ultimately fostering policies and actions that promote human health, environmental quality, and sustainable development.

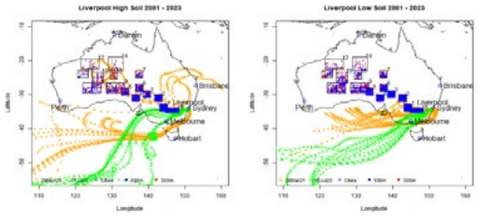
Case Examples

Australia

Alleviating environmental pollution in Australia: better understanding of air pollution from its fingerprint

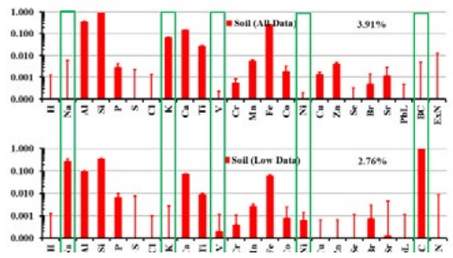
Mungo National Park, Lake Mungo,

In 2018 – 2023, under the Research Agreement with Regional Cooperation Agreement Regional Office (RCARO), Korea, the Australian Nuclear Science & Technology Organization (ANSTO) has conducted a project entitled "Characterizing and quantifying the long-term contribution of the dust burden transported into the Sydney Basin, Australia". ANSTO analyzed PM2.5 pollution and its sources using Positive Matrix Factorization (PMF) source apportionment technique, and applied Accelerator-based Ion Beam Analysis (IBA) techniques including Particle-induced X-ray emission (PIXE), Particle-induced Gamma Emission (PIGE), Rutherford backscattering (RBS), and Proton Elastic Scattering Analysis (PESA) to assess the elemental concentration of PM2.5. Multiwavelength absorption black-carbon instrument (MABI) was utilized for black carbon measurement. The novel approach on PMF identified 8 source fingerprints at the key site within the Sydney basin. The findings revealed the distinct low soil fingerprint is the presence of Na, V, Ni, Bc, which associated with automobiles related to localized retrained road dust.

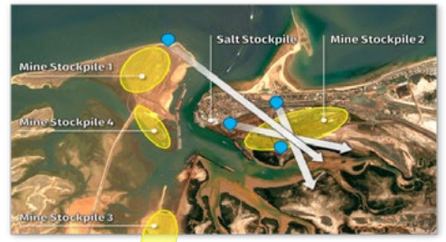


Wind Back Trajectories From The Liverpool Sampling Site

The HYSPLIT wind back trajectory determined the days when wind parcels intersected before arriving at the sampling site, which reveals the highest number of intersections like the Lake Mungo desert, and the Riverina agricultural industry region. Also, the Australian research team made a 3-year commercial contract with 3 sampling stations that was signed with NSW Office of Environment and Heritage to monitor emissions from open cut mining operations in the coal mining regions of the Hunter Valley and its associated port and shipping activities. By providing the data from PMF analysis, specific



PMF Soil Fingerprint



Stockpile Sources Contributed to high PM 2.5 Site

stockpiles contributing to high PM2.5 levels were identified, and the mine implemented a targeted mitigation strategy to reduce fugitive dust emissions from those identified stockpiles.

Indonesia

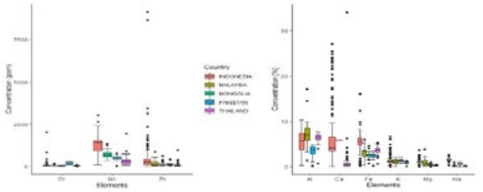
Air Quality Research Advancement in Indonesia: A Collaborative Initiative for Environmental Sustainability

The surge in industrialization and urbanization in Indonesia has amplified the air pollution problem, driven by increased vehicular traffic and the combustion of fossil fuels, thus leading to alarming levels of air pollution. A collaborative research project within the Asia Pacific countries through RCARO harnessed RCARO's expertise in project design, monitoring, and evaluation, while promoting the application of nuclear science and technology. It provided scientifically backed evidence to inform the formulation of effective pollution management policies. During the project, 971 samples including APM, soil, water, and crop samples were collected and analyzed using XRF, PIXE, and TXRF by Indonesia to assess the impact of industrial pollution. Identification of source fingerprints by Indonesia revealed that Surabaya has eight (8) sources of airborne pollutants with the three (3) highest contributors being vehicle emissions, the steel industry, and lead smelting. Also, Indonesia identified two (2) major sources of pollutants in soil, water, and crops: lead smelting and the iron industry, each containing critical pollutants.

EDXRF and Total-XRF (TXRF)

Our endeavors in performing an in-depth exploration of air and soil samples confirmed industrial activities as the primary contributor to air pollution, accounting for over 36% of the pollutants. The elemental analysis of soil samples across these five countries provided valuable insights into the soil composition and potential environmental factors influencing agricultural productivity. This information has been disseminated in stakeholders' meetings involving EPA of Surabaya, Gresik, and East Java province, and one (1) university (Institut Teknologi Sepuluh November - ITS).

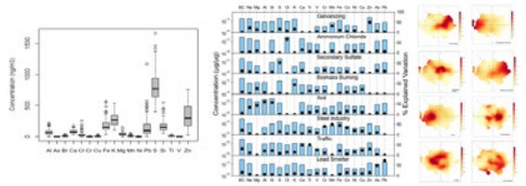
Indonesia was appointed as the coordinator for the soil database (APDIES) by participating countries. The soil database contains the inorganic elements present in soil from 396 samples, covering the percentage to parts per million (ppm) levels across five countries: Indonesia, Thailand, Malaysia, Mongolia, and Pakistan.



Boxplot regional elemental soil concentration in % (a) and ppm (b)

Additionally, we identified the probable source locations, enhancing our understanding of the environmental dynamics. Our air quality research aligns with several Sustainable Development Goals (SDGs), contributing to the pursuit of sustainable development. By identifying and mitigating harmful industrial emissions, the collaborative efforts between RCARO and Indonesia are making significant strides in enhancing air quality. RCARO's indispensable support underscores its commitment to sustained collaboration, driving continuous, long-term actions to improve air quality and safeguard the surrounding environment.

Sampling locations



Elemental concentrations and profile source apportionment for the Surabaya Site

Malaysia

Unveiling Sources and Status Through Nuclear Analytical Techniques

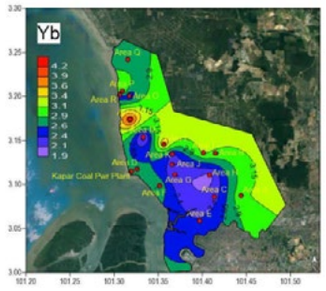
The Malaysian Nuclear Agency completed the project entitled "Assessment of Kuala Lumpur Air Quality and its Impact on the Klang Valley, Malaysia" by participating in the RCARO project. It encompassed the identification of sources of fine aerosols, including smoke, soil dust, industrial emissions, motor vehicles, and sea spray. The project further enabled the assessment of heavy metals and trace elements in air filter and crop samples, as well as the elemental pollution in soil samples. The outcomes of this initiative significantly contributed to a deeper comprehension of environmental quality in Malaysia. The levels of both major and trace elements in PM 2.5 filter samples were determined through Energy Dispersive X-Ray Fluorescence (EDXRF). In addition, the Neutron Activation Analysis (NAA) technique was employed at the TRIGA Research Reactor Facility to examine soil and crop samples.

The Malaysian Nuclear Agency's air quality surveillance has been critical in determining the extent of local air pollution. The typical contour map of trace element concentration of Yb in the soil of the Kapar area are presented in the figure. The elements As, Sb, Cr, Cs, Hf, and Th showed enrichment at all sampling locations. During the 2nd phase, 242 samples including APM, soil, and crop samples were collected and analyzed using XRF and NAA techniques to assess the impact of industrial pollution.

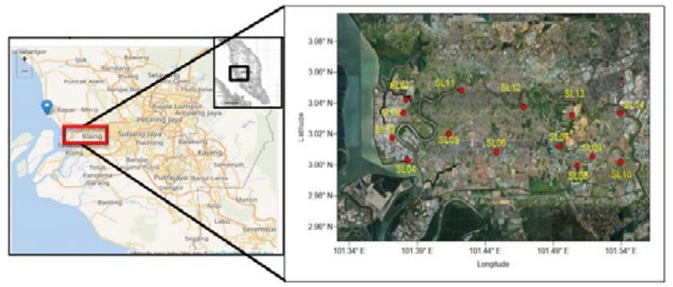
1. *Air Particulate Matter (APM) Sampling*
2. *Sample irradiation using NAA*

The sources of pollution identified in the APM samples found that they originated from soil dust (28.4%) and motor vehicles (12.9%). During the 2nd phase. 242 samples including APM, soil, and crop samples were collected and analyzed using XRF and NAA techniques to assess the impact of industrial pollution.

Malaysia identified the major sources of pollutants in soil, likely originating from anthropogenic activities (industrial activities) and geogenic processes (natural - landslides erosion and terrestrial runoff). This information has not only been disseminated in stakeholders' meetings but also published in international journals and national reports. The number of personnel capabilities in environmental sample characterization, data analysis and data interpretation has increased, which includes trained personnel and students involved in this



Contour map of rare earth Yb concentrations in the soil of Kapar area



Sampling location of air particulate matter (APM) at the Department of Museum Malaysia, Klang Valley, Malaysia

New Zealand

Better air quality in New Zealand: Understanding The source and the impact of air pollution through nuclear analytical techniques

Whakarewarewa thermal Village, Rotorua, New Zealand

As lead country coordinator, New Zealand participated in the Air Quality and Environmental Impact Assessment of Industrial Activities in Asian Region Project under Research Agreement with Regional Cooperation Agreement Regional Office (RCARO), Korea. This project was conducted in two phases: 2018-2020 (phase 1) and 2021-2023 (phase 2). To assess the impact of industrial pollution, New Zealand has collected APM samples from 9 sites (Whakarewarewa, Henderson, Auckland, Takapuna, Wainuiomata, Wellington. Hastings, Motueka, Westport) during the project, and analyzed these samples using IBA or XRF. New Zealand also contributed to maintaining the regional APM database of selected pollutants by submitting additional data of 4,583 pairs of APM samples. Source fingerprint identification showed several sources of air pollution which included motor vehicles, biomass combustion, shipping emissions, industry, secondary sulphate, and marine aerosol. This information has not only been disseminated at stakeholders' meetings, but has also been published in international journals and consultancy reports. The number of personnel capabilities in environmental sample characterization, data analysis and data interpretation has increased, including trained personnel and students involved in this project.

The scientific data from the RCARO project was utilized by stakeholders and governmental agencies involved in policy and strategy design in the field of environmental pollution and monitoring, such as New Zealand Transport Agency, Hawkes Bay Regional Council, Auckland Council/Auckland University, Lyttleton Port, Tasman District Councils, Port of Tauranga and Waka Kotahi – New Zealand Transport Agency. The Ministry for the Environment, Ministry of Health, Ministry of Transport, Department of Statistics, New Zealand have all funded and used the data from the Health and Air Pollution in New Zealand Study.

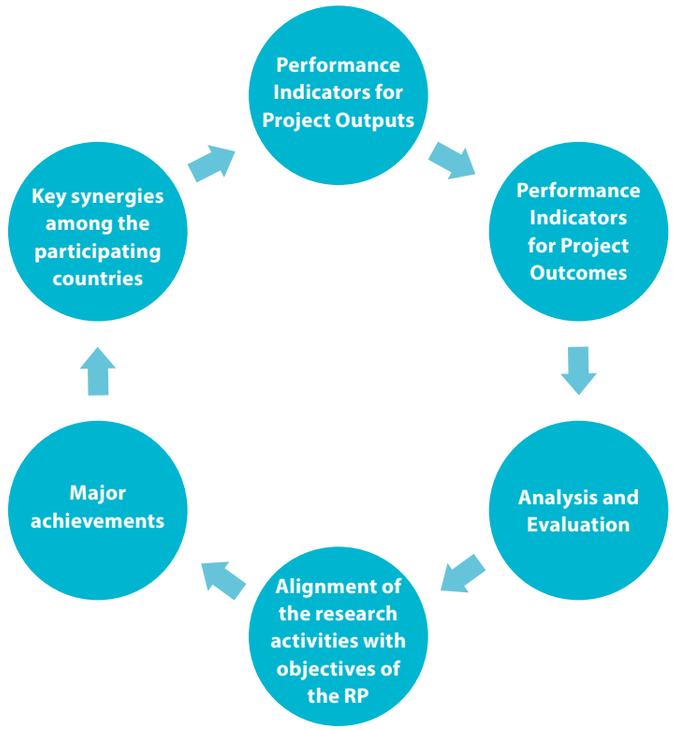
The long-term Asia-Pacific Aerosol Database (APAD) dataset was used by each Member State to determine the source fingerprint of air pollution for each site. The results were compiled in to the Asia-Pacific Source Fingerprint Database (ASFID), which are currently available for free download from the websites of the IAEA RCA (*www.rcaro.org*).

Annex : Project Evaluation approach

At the beginning of each phase of the RP, the participants defined and agreed upon major parameters such as overall and specific objectives, expected outputs and outcomes as well as performance indicators to assess quality of the project in the evaluation stage. Performance indicators for outputs and outcomes are quantitative (measurable) parameters which were defined based on the national work plans as well as anticipated (confirmed) contribution of all participating countries to the regional outputs and outcomes. They were used as a very useful managerial tool for monitoring progress and implementation of the research project and for identification of problems and delays which required intervention or corrective measures. Performance indicators were finally applied to assess the achievements after completion of the project.

Systematic Approach to the Evaluation of Research Project

The evaluation of this RP was assessed in both qualitative and quantitative ways: first, set (1) project outputs using performance indicators as defined in the project proposal (phase 1 and 2), define (2) project outcomes in two phases, execute (3) analysis and evaluation, assess (4) alignment of these research activities with the special objectives of this RP, summarize (5) major achievements, and finally consider (6) key synergies among the participating countries.



Overall assessment of outputs by using performance indicators

PERFORMANCE INDICATORS	CONTRIBUTION / COUNTRIES	
	Phase 1	**Phase 2**
No. of countries producing analytical results relevant to the project (target: 10) – ***both Phases***	AUL, BGD, INS, MON, MYA, NEP, SRL, MAL, CPR, ROK, NZE **In total: 11 countries**	AUL, CPR, INS, MAL, MON, NZE, PAK, THA, VIE **In total: 9 countries**
No. of database entries across all Government Party/Parties (GPs) (target: 2,000) – ***both Phases***	AUL, BGD, INS, MON, CPR, NZE (2302 pairs) **In total : around 2000 samples**	AUL (247 PM2.5), INS (226 pairs), MAL (218 fine and 218 coarse), MON (636 PM2.5 and elemental concentrations for 20 samples), NZE (2281 fine and 2281 coarse), THA (215 PM2.5 and 173 for K, Si and S), VIE (163 PM2.5 samples and 37 TSP samples) **In total : around 5800 sample**s
No. of countries with time series of identified industrial pollutants (target: 10) – ***both Phases***	AUL, BGD, INS, MON, MAL, NZE **In total: 6 countries**	AUL, CPR, INS, MAL, MON, NZE, PAK, THA, VIE In total: 9 countries
No. of countries with back-trajectories identifying transport from airborne pollutants (target: 50%) – ***both Phases***	AUL, BGD, INS, MAL, NZE **In total: 5 countries (45%)**	AUL, MAL, NZE, PAK, VIE **In total: 5 countries (50 %)**
No. of countries developed analytical methodologies and personnel trained as set out in national work plans (target: 100%) – ***Phase 1***, (target: 60%) – ***Phase 2***	AUL, BGD, INS, MON, MYA, NEP, SRL, MAL, CPR, ROK, NZE **In total: 11 countries (100%)**	AUL (4 persons), CPR (4 persons), INS (21 persons), MAL (2 persons), MON (10 persons), NZE (3 persons), PAK(4 persons), THA (5 persons), VIE (1 person) **In total: 9 countries (90%)**
No. of publications (P) and conferences (C), stakeholder meetings (SM) attended (target: 1 in each category in each country over 3 years) – ***both Phases***	AUL (12/15/0), BGD (13/2/0), INS (3/11/0), MON (0/2/2), MYA(0/0/1), NEP (1subm/3), SRL (0/1/5), MAL(0/2/3), CPR (2/2/1), ROK(3/0/0), NZE(7/5/12 plus 14 end-users reports) **In total: P – 41 (7 countries), C - 43 (9 countries), SM - 24 (6 countries**)	AUL (1/2/2 +24 commercial reports), CPR (2/0/0), INS (8/20/5), MAL (0/6/1), MON (0/1/4), NZE (7/10/12), PAK (1+2 in prep./2/4), THA (1/0/0), VIE (3/2/3) **In total: P – 24 (8 countries), C - 43 (7 countries), SM - 31 (7 countries)**
No. of countries which disseminate information to the stakeholders and government (target: 6 countries) – ***Phase 2***		AUL, INS, MAL, MON **In total: 4 countries**
No. of countries which determine industrial pollution (target: 8 countries) – ***Phase 2***		AUL, INS, MAL, MON, PAK, THA **In total: 6 countries**

PERFORMANCE INDICATORS	CONTRIBUTION / COUNTRIES	
	Phase 1	**Phase 2**
No. of countries which demonstrate confirmed intent by other organizations to take up data in support of development/strengthening Air Quality Management (target: 10 countries) – ***both Phases***	AUL, BGD (data submitted), INS, MON, NEP (Asia Pacific Network for Global Change, APN, Japan), SRL, MAL, CPR, NZE **In total: 9 countries**	AUL, INS, MAL, MON, NZE, VIE **In total: 6 counties**
No. of stakeholders, end users and researchers who take up the new knowledge related to pollution sources (target: total 30 across all countries) – ***both Phases***	AUL (5+), BGD (2+), INS (4), MON (1), MYA (1), NEP (1), SRL (3), MAL(3), CPR(1), ROK (1), NZE(7+) *Researchers who took up the new knowledge include, i.a., MSc students (18+) **In total: 46+ (11 countries**)	AUL (9), CPR (2), INS (15), MAL (3), MON (11), NZE (9), ROK (1), THA (5), VIE (3) *Researchers who took up the new knowledge include BSc, MSc and PhD students **In total: 58 (9 countries)**
No. of countries which demonstrate confirmed intent by industry and governmental authorities to consider development and/or implementation of mitigation strategies for reducing level and impact of pollution on environment (target: 4 countries) – ***Phase 2***		AUL, INS, MAL, MON, NZE, PAK, VIE **In total: 7 countries**

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