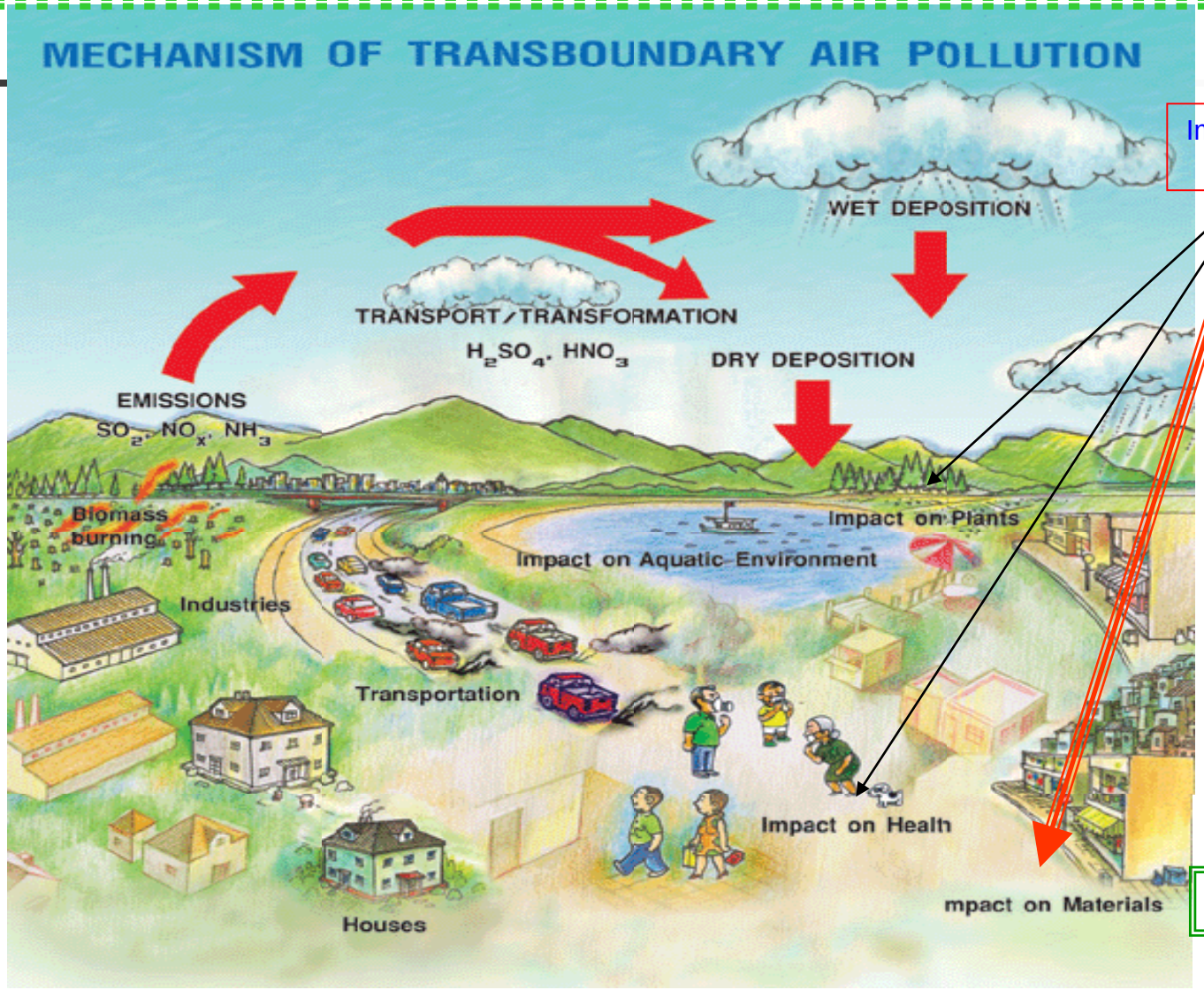
WELCOME

THE FIFTH REGIONAL STAKEHOLDERS CUM REGIONAL COORDINATION MEETING UNDER MALE DECLERATION ON CONTROL AND PREVENTION OF AIR POLLUTION & ITS LIKELY TRANS-BOUNDARY EFFECTS FOR SOUTH ASIA

VENUE: COLOMBO, SRI LANKA
ORGANIZED BY: UNEP
DATE: AUGUST 19-20, 2008

PREVENTION & CONTROL OF TRANS-BOUNDARY AIR POLLUTION



Impact Assessment Studies

Corrosion

IMPACT ASSESSMENT :CORROSION

AGENDA

1. Introduction (Dr Saha)
2. Background & Methodology (Dr Saha)
3. CORNET investigations (Dr Saha)
   i. Initial studies (as were started in 2002)
   ii. Extended studies (as initiated in 2006, some of the stations are under Male' Declaration)
4. Male Declaration Sites
   i. India Corrosion site (Dr Saha)
   ii. Iran site (Mr Zandi)
   iii. Sri Lanka site (Ms. Warnika)
   iv. Maldives site (Mr. Muhusin)
   v. Nepal site (Ms.Bidya)
5. Conclusion and data analysis (Dr. Saha)
6. Discussion

IMPACT ASSESSMENT :CORROSION

INTRODUCTION & BACKGROUND

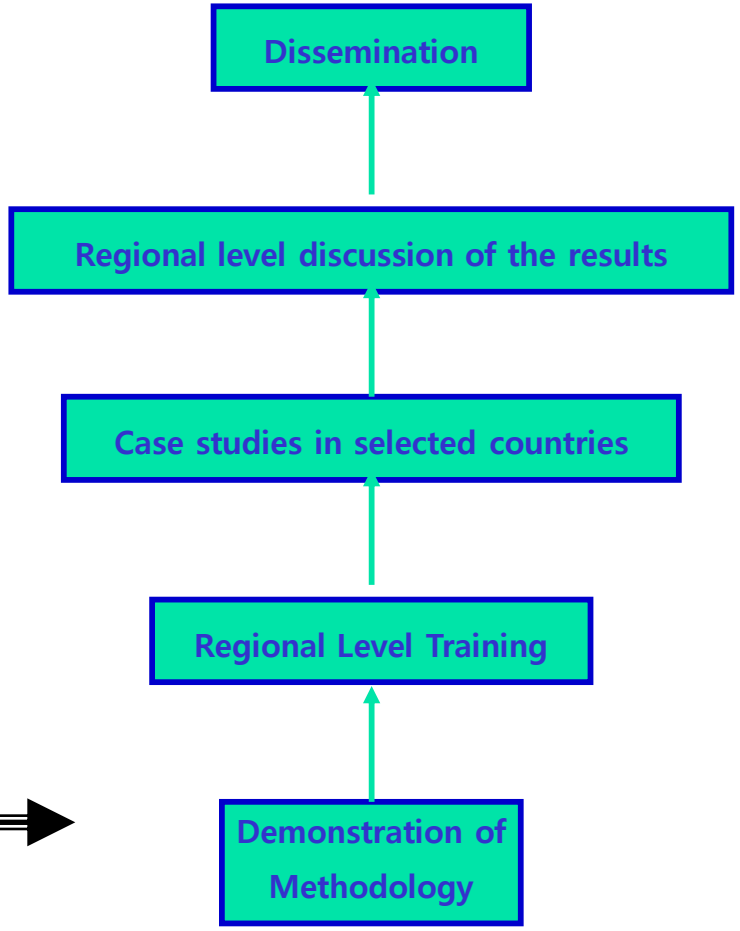
DECLERATION ASPECT 4:
CAPACITY BUILDING ON IMPACT ASSESSMENT

OBJECTIVE: Enhance the analytical and impact assessment capability at the national level through integration of findings from local pollution studies and conducting assessment studies

AREAS OF CONCERN:

- STRENGTHEN KNOWLEDGE ON HUMAN HEALTH IMPACT ASSESSMENT
- STRENGTHEN KNOWLEDGE ON CROPS IMPACT ASSESSMENT
- STRENGTHEN KNOWLEDGE ON CORROSION IMPACT ASSESSMENT

METHODOLOGY USED



PROGRESS
IMPACT ASSESSMENT: ISSUE IS CORROSION

Regional Training on Corrosion Impact Assessment;

October 2006, RRCAP, Bangkok

REGIONAL TRAINING: DEMONSTRATION OF METHODOLOGY (OCTOBER, 2006)

- BASIC THEORETICAL CONCEPTS
- TECHNICAL HANDS-ON TRAINING
- DISCUSSION ON STANDARDS
- DEMOSTRATION ON CORROSION ATTACKS ON A WIDE RANGE OF MATERIALS (CARBON STEEL, PAINTED STEEL, COPPER, ZINC AND STONES
- DATA ANALYSES OF EARLIER STUDIES

"Regional Air Pollution in Developing Countries" (RAPIDC CORNET: Information)

- *This project is the pilot project on corrosion network in the world and the activity is partly funded by Swedish International Development Co-operation Agency (SIDA)*
- *The Program is managed on SIDA's behalf by the Stockholm Environment Institute (SEI) and the corrosion project is coordinated by Corrosion and Metal Research Institute, Sweden (Swerea KIMAB AB).*
- *The program is called "Regional Air Pollution in Developing Countries" (RAPIDC).*
  - *Study is being carried out 6 sites in India (2), Vietnam (3), Thailand (2), Malaysia (2), and China (2), Hong Kong(1) [total 12 in Asia] and at South Africa (1), Zambia (2) and Zimbabwe (1) [Total 4 in Africa].*
  - *Additional network stations established in 2006 includes five new test sites in Asia (Tajmahal, Iran, Nepal, Sri Lanka and Maldives) and two new test sites in Africa (Mozambique and Tanzania).*
  - *Exposure of standard materials viz. carbon steel, painted steel, zinc, copper & limestone At each test site, the environment is characterized by SO2, NO2, HNO3, O3, particles, amount and pH of precipitation, temperature and relative humidity.*
- *The study includes*
  - *Corrosion attack after:*
    - *One year (2002-2003),*
    - *Two Year (2002-2004) and*
    - *Four year (2002-2006) years of exposure*
  - *Correlations of Air Pollution, Precipitation and Corrosion*
  - *Economics of material loss*

CORNET investigations
Initial studies (Started in 2002)

Country	Test site name	Responsible organisation	Start
India	Bhubaneswar-u	Regional Research Laboratory	25 May 2002
India	Bhubaneswar-r	Regional Research Laboratory	25 May 2002
Thailand	Bangkok	Thailand Institute of Scientific and Technological Research	10 June 2002
Thailand	Phrapradaeng	Thailand Institute of Scientific and Technological Research	11 June 2002
Vietnam	Hanoi	Institute of Materials Science	23 July 2002
Vietnam	Ho Chi Minh	Ho Chi Minh Branch of the Institute of Materials Science	26 July 2002
Vietnam	Mytho	Ho Chi Minh Branch of the Institute of Materials Science	27 July 2002
China	Chongqing	Chongqing Institute of Environmental Science and Monitoring	20 July 2002
China	Tie Shan Ping	Chongqing Institute of Environmental Science and Monitoring	20 July 2002
China	Hong Kong	Environmental Protection Department	18 July 2002
Malaysia	Kuala Lumpur	Malaysian Meteorological Service	13 June 2002
Malaysia	Tanah Rata	Malaysian Meteorological Service	14 June 2002
South Africa	Johannesburg	Council for Scientific and Industrial Research	21 August 2002
Zambia	Kitwe	University of Zambia	27 August 2002
Zambia	Magoye	University of Zambia	25 August 2002
Zimbabwe	Harare	University of Zimbabwe	30 August 2002

STANDARD METHODOLOGY USED

Sample Preparation and Evaluation of Corrosion Attack

- Use of Standard Materials [all w*ere cut to dimensions 100 x 150 mm2*]:
  - *Carbon steel (Dc 04, SS – EN 10 130),*
  - *Zinc (Z1 – DIN EN 1179),*
  - *Copper (Cu DHP, SS 5015) and*
  - *Painted steel.*

- The thickness of all flat samples was 1 mm except for steel, which had a thickness of 2 mm. The painted steel had two layers of alkyd (90 µm), the first consisting of a 50 µm alkyd based primer and the second of a 40 µm and glossy acrylic modified alkyd topcoat.

- Uniformity in exposure period at all locations: A set of three identical samples was prepared and exposed i.e. at the start of exposure. Nine samples were exposed for each material [for four year study period]

- Uniform conditioning of samples at both pre and post exposure of samples (viz. oven-drying, room-cooling , weighing etc.)

- The corrosion attack of the metal samples was evaluated with 10 minutes consecutive pickling using Clarke's solution for steel, 250 g glycine and distilled water to make 1000 ml saturated solution for zinc and 50 g amidosulfonic acid and distilled water to make 1000 ml for copper. Painted steel was evaluated by visual examination of the spread of corrosion attack in both directions from the 1 mm cut but expressed as the average spread in one direction, excluding the width of the cut.

Standard METHODOLOGY Used

(Contd.)

Corrosion of Stone Samples

- *Uniform Portland limestone specimens of dimensions 50 x 50 x 8 mm3* were obtained from the Building Research Establishment Ltd, United Kingdom, where also the corrosion attack was evaluated as mass change during exposure. The mass change was then recalculated to surface recession.

Characterization of the Environment

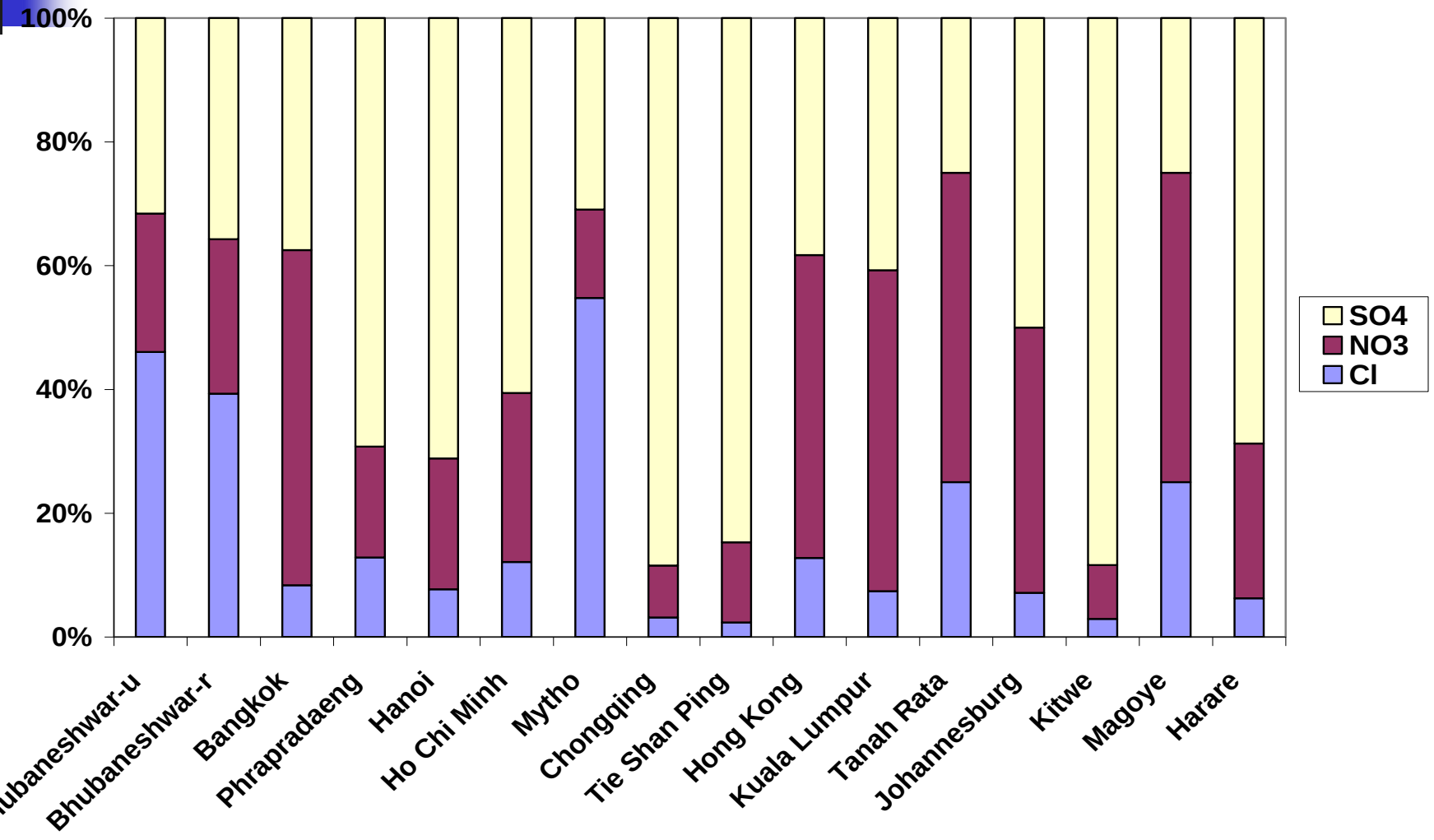
- Passive sampling was performed on all sites for the gaseous pollutants SO2, NO2, O3 and HNO3 and for particulate matter. Sampling was performed on a bi-monthly basis i.e., samplers were exchanged each second month.
- Complementary data on temperature, relative humidity, amount of rain and its pH were collected by the partners at a nearby monitoring station.

"REGIONAL AIR POLLUTION IN DEVELOPING COUNTRIES" (RAPIDC: DATA ON CORROSION)

Corrosion attack after 2 (2002-2004) years of exposure of painted steel (spread from cut), carbon steel, zinc, copper and limestone

Name	Painted steel	Steel	Zinc	Copper	Limestone
	mMm	g m^{-2}	g m^{-2}	g m^{-2}	µm
Bhubaneswar-u	2.1	252	8.6	15.2	24.3
Bhubaneswar-r	1.2	270	7.9	19.4	17.3
Bangkok	0.6	161	7.6	26.3	25.4
Phrapradaeng	1.7	417	11.3	28.6	47.9
Hanoi	1.4	279	11.6	11.4	27.6
Ho Chi Minh	0.8	214	11.3	15.1	20.0
Mytho	2.3	298	8.5	20.1	9.9
Chongqing	8.2	1201	19.9	46.0	75.6
Tie Shan Ping	6.7	769	24.8	36.5	55.6
Hong Kong	0.7	201	11.4	12.4	25.3
Kuala Lumpur	0.9	181	15.8	19.3	35.9
Tanah Rata	0.8	90	11.0	20.0	15.8
Johannesburg	0.6	168	4.3	9.0	-
Kitwe	4.0	561	47.5	19.3	61.2
Magoye	0.6	70	3.3	10.2	9.7
Harare	1.5	267	6.3	7.6	14.5

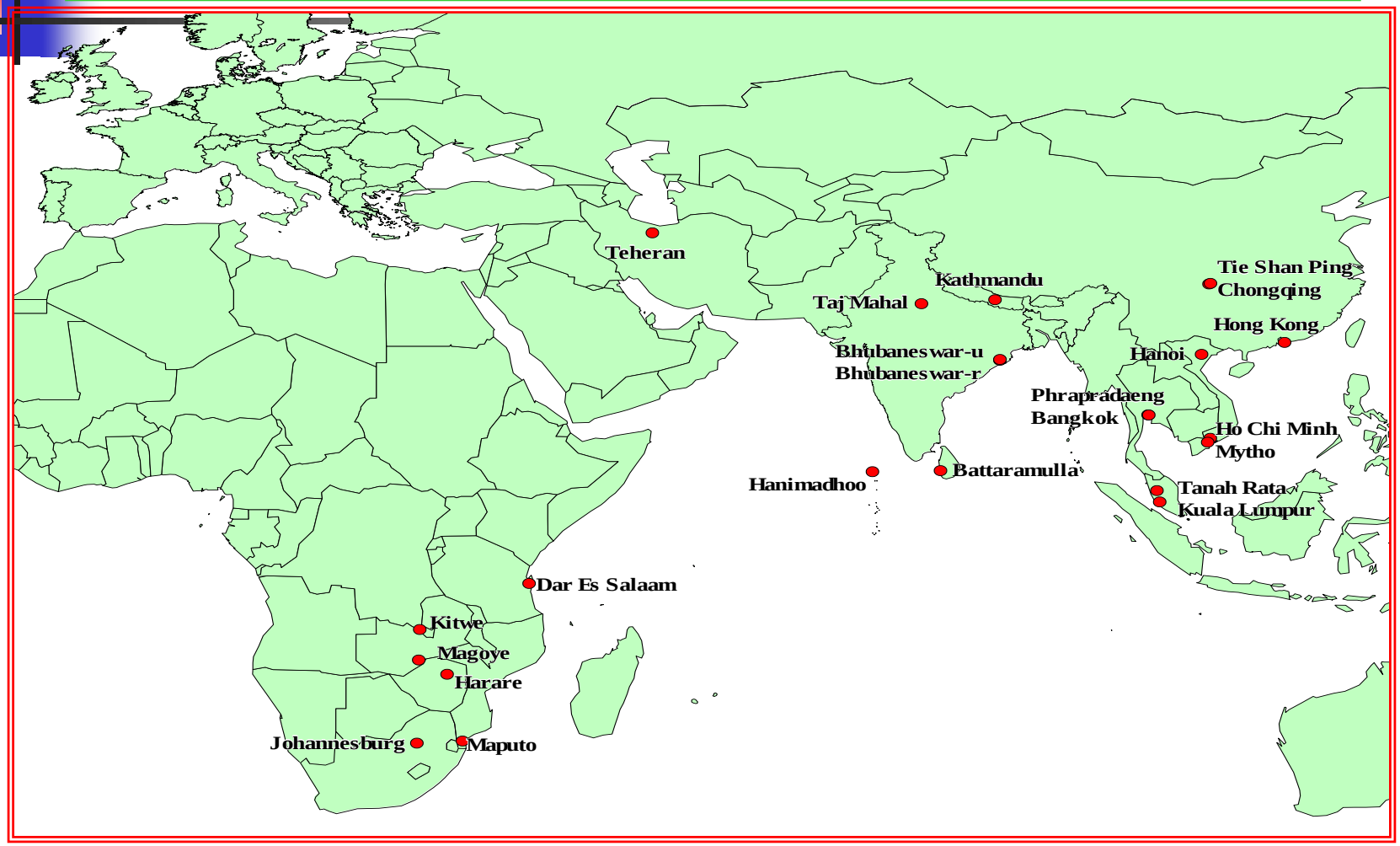
Soluble Anions in Particulate: SO_4^{2-}, NO_3^-, Cl^-



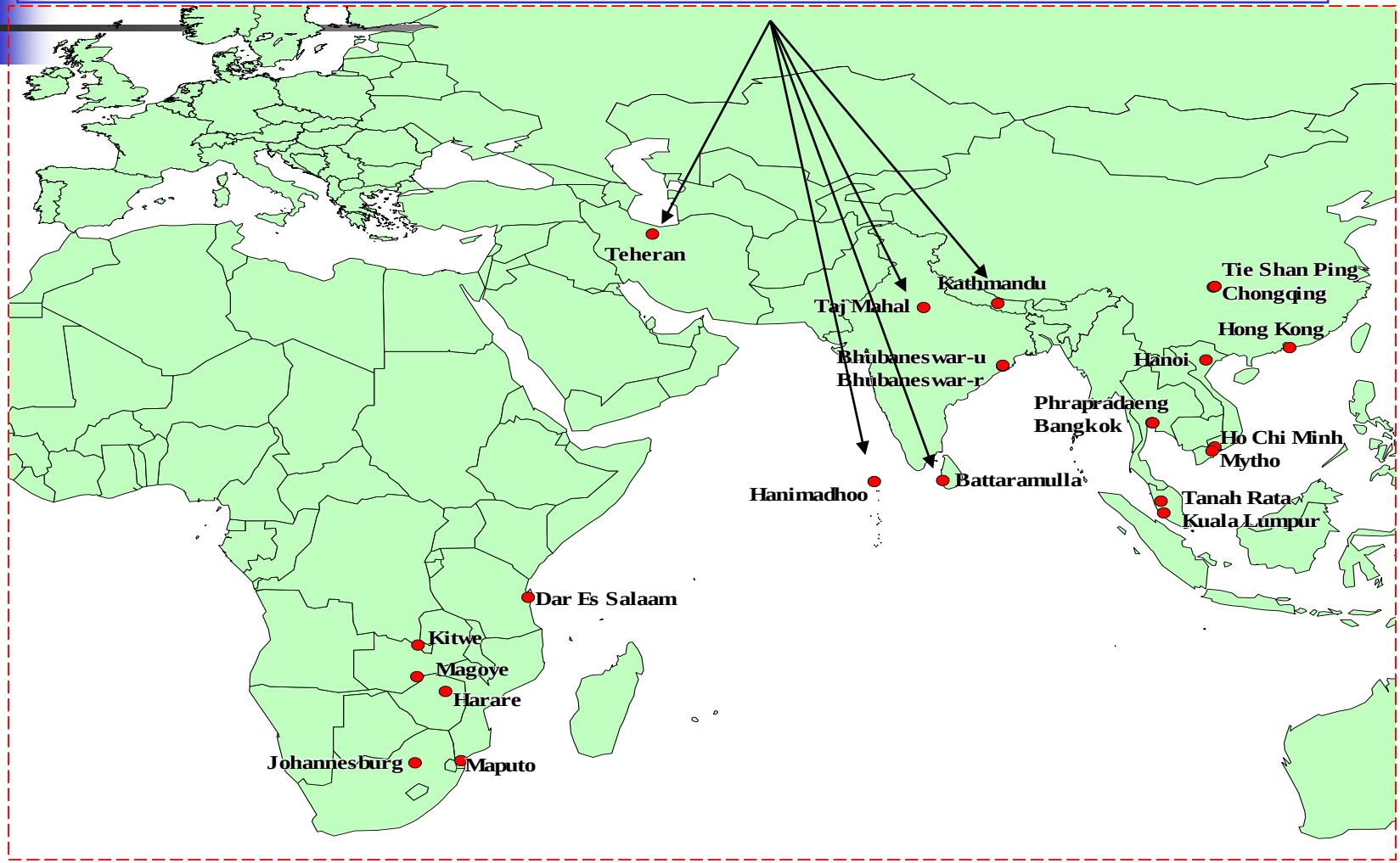
CORNET investigations
Extended studies (Started in 2006)

Country	Test site name	Responsible organisation	Start
India	Taj Mahal	Central Pollution Control Board	25 November 2006
Iran	Teheran	Environmental Research Centre	20 November 2006
Sri Lanka	Battaramulla	Central Environmental Authority	27 November 2006
Nepal	Kathmandu	International Centre for Integrated Mountain Development	14 November 2006
Maldives	Hanimadhoo	Department of Meteorology	23 January 2008
Mozambique	Maputo	Eduardo Mondlane University	8 September 2006
Tanzania	Dar Es Salaam	University of Dar es Salaam	15 September 2006

CORNET Stations
Asia & Africa : as on date (total 16+05=21)

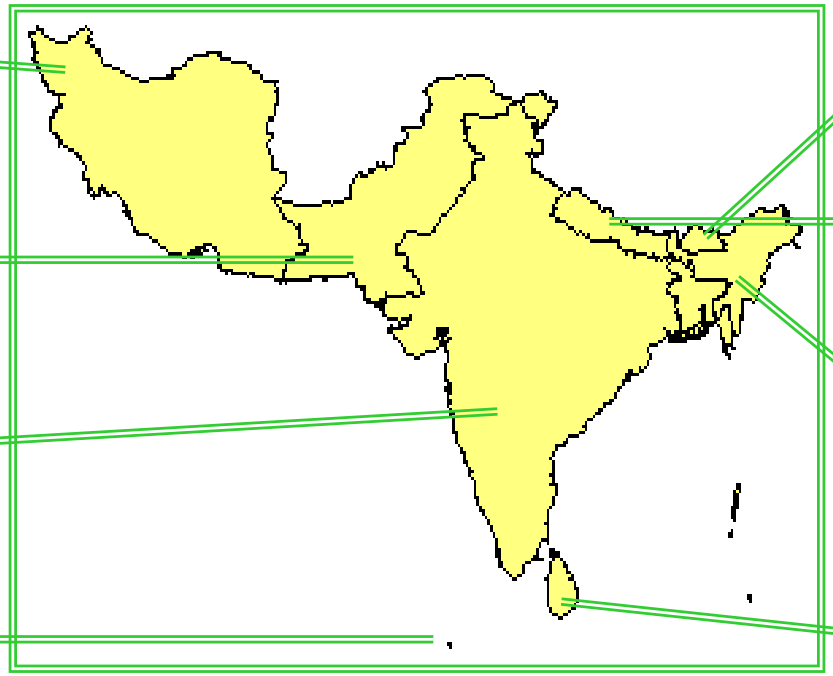


TEST SITES : MALE` DECLERATION-2006



CORROSION STUDY SITES (MALE´ COUNTRIES)

(x)-Station is yet to establish; (√)-Operational Stations



Iran (√-1)

Pakistan (x)

India (√-1)

Maldives (√-1)

Bhutan (x)

Nepal (√-1+9)

Bangladesh (x)

Sri Lanka (√-1)

All are main racks, except Nepal with 9 mini racks

ESTABLISGMENT OF CORROSION STUDY RACKS

Study Locations (November 2006):

- Agra, India
- Tehran, Iran
- Kathmandu, Nepal
- Colombo, Sri Lanka

Study Locations (January 2007):

- Maldives

Corrosion monitoring rack installed at Agra, India & at Kathmandu, Nepal

CASE STUDY SITE: AGRA, INDIA

BACKGROUND: SITE SELECTION

- For establishment of station for corrosion study, the issues of concern are:
  - Preferably be accompanied with air monitoring station & meteorological station,
  - Free flow of air,
  - Rack to be placed south facing (45^0 inclined) in tropical countries (best possible exposed to sun and wind),
  - Should be exposed for 2-years (4-years) without any disturbance,
  - Rack should be free from theft or any other disturbances

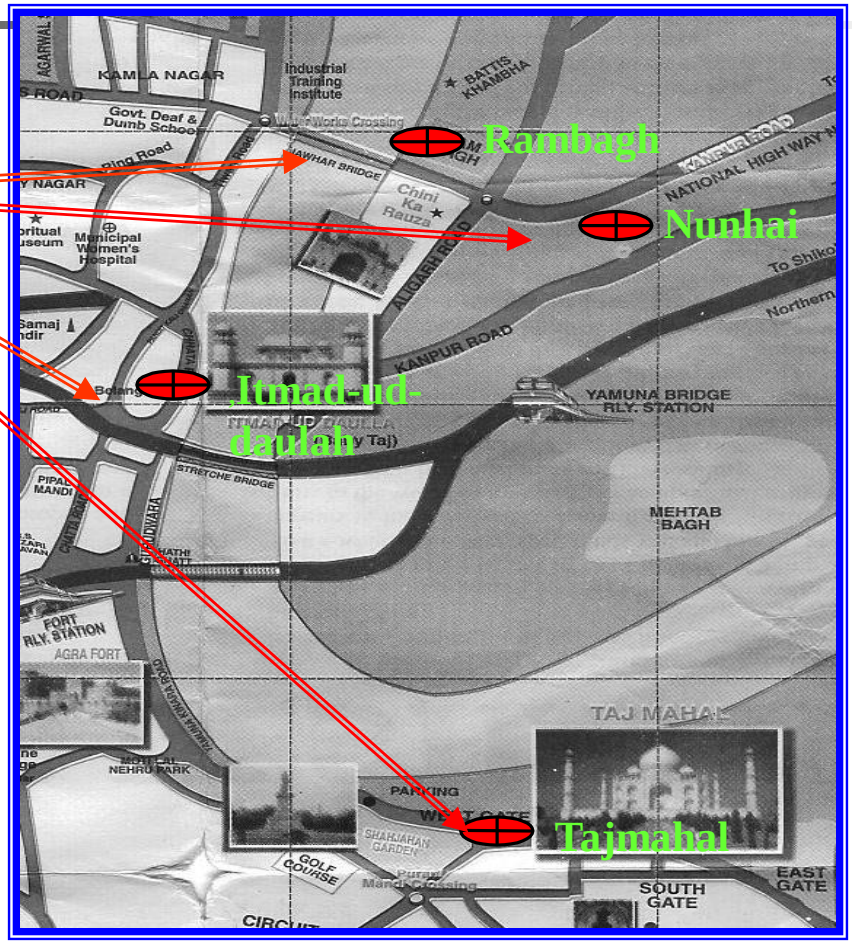
- It was decided that the corrosion study rack to be installed at Agra during November 06. After inspection of all air quality monitoring stations being operated by CPCB at Agra, [CPCB Officer & Mr. Vladimir Kucera of Corrosion and Metal Research Institute (KiMAB), Sweden] it was decided to install the corrosion rack at Tajmahal complex.
- Mr. M.Iyngararasan, UNEP suggested to use local samples for corrosion study at Agra. The issue was also discussed with Mr. Vladimir Kucera and a series of local stone samples were also forwarded.

TAJMAHAL, INDIA: GEOGRAPHIC LOCATION

[Geographic Location : N 270 10' 18.12"; E780 02' 26.52"]

CPCB OPERATED AAQM STATIONS IN AGRA, INDIA

AAQMS



AGRA CITY

- Geographic Location [27 ^{0} 10 ′ N , 78 ^{0} 05 ′ E]
- North Centrally located in India, about 200 km south of Delhi
- Two-thirds of its peripherals (SE, W, NW) are bounded by the Thar Desert
- Semi-arid with extreme climatic condition
- Indo-Gangetic plain with dry river bed since 2000-01 (particularly after construction of barrage at Gokul, Mathura)
- Water scarce city, ground water is alkaline
- Alkaline loose top-soil with predominance of Na^+, and Cl^- ions (least or no grass or bushes), least foliage trees (i.e. absence of natural barrier)
- Highly Industrial (coke/coal industrial units) in the recent past, however pollution has significantly reduced due to:
  - Interference by MoEF including formation of Taj-Trapezium Authority
  - Initiation of strict regulatory measures by CPCB and
  - Compliance of Hon'ble Supreme Court Orders /directions
- PM_{10} soluble fraction composed of Na^+, NH_4^+ , Cl^-(mostly local in origin), Ca^{++}, Mg^{++} (mostly transported), SO_4^{--} and NO_3 ions
- Rainwater pH varies between 6.7 to 6.9

CORROSION RACK UNDER THE BACKDROP OF TAJMAHAL, INDIA

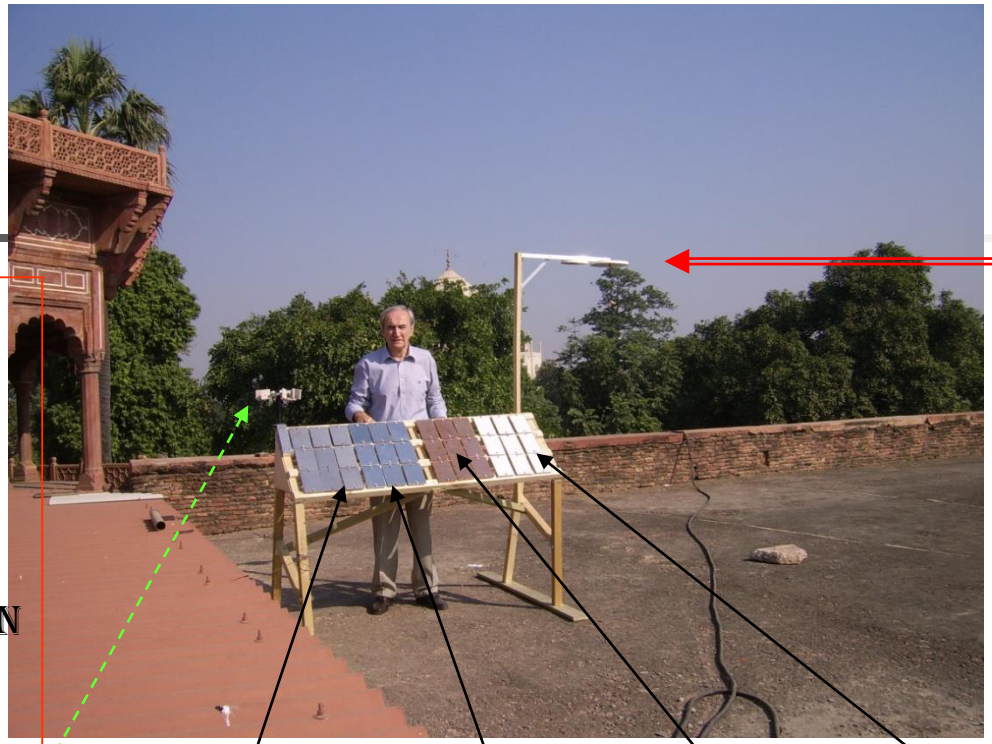
Date of Installation: 2006-11-25
Geographic Location : N 27° 10′ 18.12″; E78° 02′ 26.52″
Regional Air Pollution in Developing Countries (RAPIDC) Station No. 21

STANDARD STUDY MATERIALS USED AT TAJMAHAL

- Under this activity Copper, Zinc, Painted Steel, Carbon Steel and Stone samples (three sets of three each i.e. total nine samples) are being exposed
- Exposure for the 'one year' completed in November 2007 and one set of each material (03 samples each) are being analyzed, while 'two year' exposure to be completed in November 2008 and 'four year' exposure shall complete in November 2010.
- first year exposed data for corrosion evaluation has been analyzed at KiMAB, SWEDEN

AIR QUALITY MONITORING STATION AT TAJMAHAL

PARAMETERS:
PM_{100}, PM_{10}, & $PM_{2.5}$;
SO_2 & NO_2
METEOROLOGICAL;
CHEMICAL CHARACTERIZATION OF PARTICULATES



Diffuser samples are also were exposed regularly during Nov 2006 to December 2007 for monitoring of ambient HNO_3, SO_2, NO_2, O_3 and particulate deposition

Stone samples, Carbon Steel, Painted Steel, Copper and Zinc

Standard Material Exposure at Tajmahal

PASSIVE SAMPLES USED AT THE SITE

- THE PASSIVE DIFFUSER SAMPLES ARE ALSO WERE EXPOSED REGULARLY DURING NOV 2006 TO DECEMBER 2007 FOR MONITORING OF AMBIENT HNO_3, SO_2, NO_2, O_3 AND PARTICULATE DEPOSITION AT THE SITE
- ALL EXPOSED SAMPLES (TOTAL SIX SETS) WERE FORWARDED ON REGULAR INTERVALS (EVERY TWO MONTHS WITH TEMPERATURE & HUMIDITY DATA) TO CORROSION & METAL RESEARCH INSTITUTE, SWEDEN FOR ANALYSES
- DATA ARE BEING ANALYZED
- STUDY DISCONTINUED

Corrosion Study Description: **Iran**

- The site is located on the roof of the Environmental Research Center building (E :51° 21' 44.7"; N :35° 46' 25.8") in the Pardisan ECO Park, north-west of Tehran between Hemmat and Hakim highways.
- Installed in November 2006.

Exposed Materials: Iran

- Metals including Zinc, Copper, Carbon Steel, Painted Steel

- Passive samplers:HNO_3, O_3, SO_2, NO_2 and Cylindrical Teflon for particulate measurement.

Corrosion Study Site: **Maldives**

- Its Geographic Location is 6.78^0 N and 73. 18^0 E and altitude is ~2 m.
- The corrosion rack is placed on 23rd of January 2008 at the Hanimaadhoo Island in the northern most atoll of Maldives located about 400 km to the north of the country's capital, Male'.

Samples Exposed : Maldives

- Exposure of materials : Iron, Zinc, Cupper, Painted steel and Limestone. [First portion will be sent after one year, and the next after 2 years and the last after 4 years].
- Exposing diffusive samplers :HNO_3, O_3, SO_2, NO_2 and Cylindrical Teflon for particulate measurement, each of those are exposed for 2 months, and sent to IVL for analysis.

Corrosion Study Site: Sri Lanka

- Site no 23 Battaramulla (E-079° 55’ 35.2” : N- 6°54’ 02.4”)(premises of Central Environmental Authority) – Sub urban area with low level of air pollutants lies 10km(Arial distance) east of Colombo Fort at the Ambient air quality monitoring station.
- The surrounding consist mainly of Wet lands residents and government offices with moderate traffic intensity. The rack is placed on the roof garden of 3rd floor (16 meters above from the ground)of Central Environmental Authority building .
- Exposed Materials are Carbon steel, Painted steel, Copper, Zinc and Limestone.
- The first exposure started in 27th November 2006.

Corrosion Rack at Sri Lanka

Study site: Nepal

Corrosion monitoring rack installed at Kathmandu, Nepal

Main Rack

Mini Rack

Study at Nepal

Two types of racks with standard materials were exposed for this study.

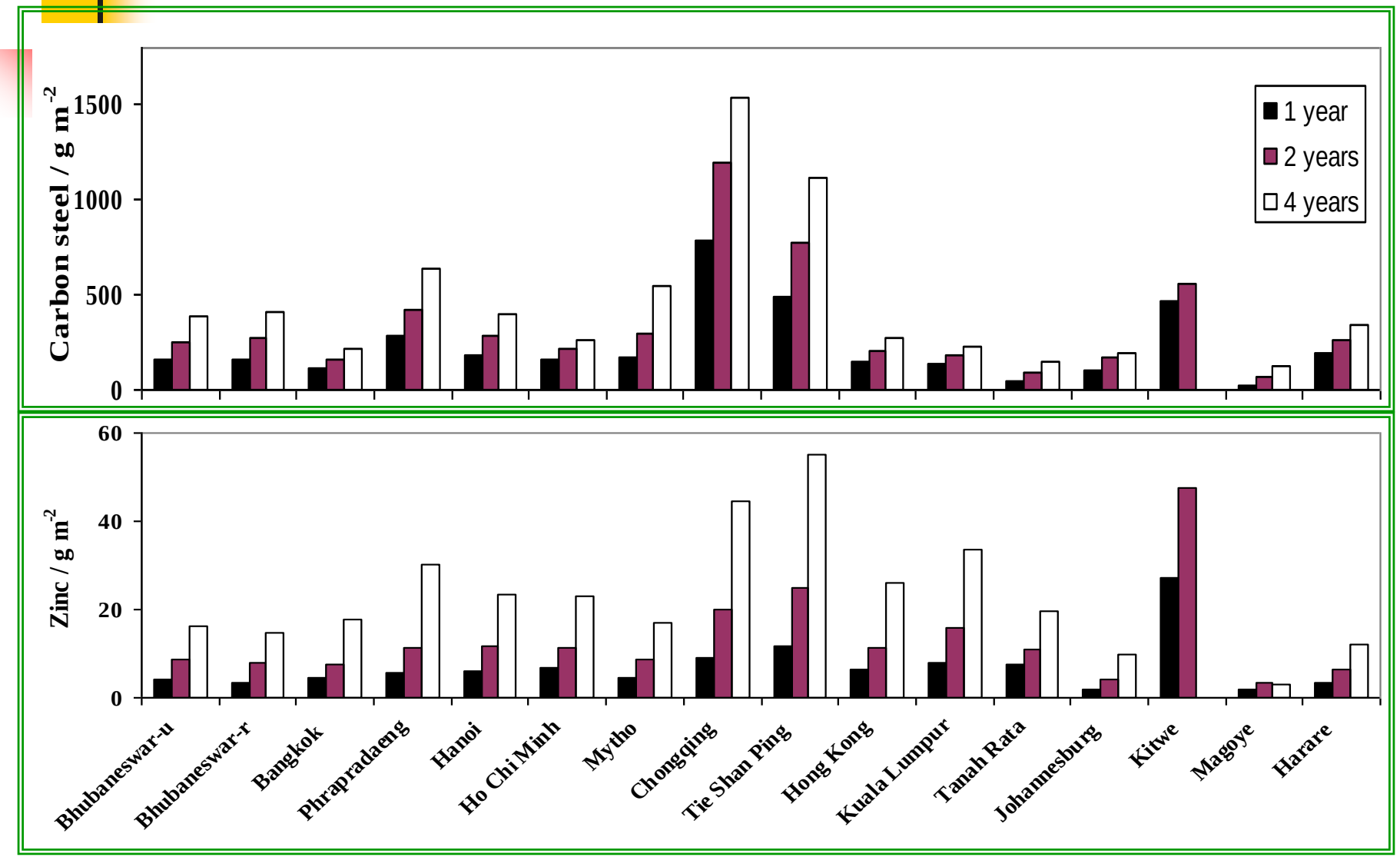
- The main rack which contains materials like carbon steel, zinc, copper, painted steel and limestone are exposed at ICIMOD head Quarter for four years period. The materials will be taken out from the racks at one year, two year and finally in the fourth year to access the rate of corrosion due to air pollution.
- The mini racks which contains only carbon steel, zinc and limestone (figure 2), are exposed for one year at nine different locations including cultural heritage sites. Passive samples like SO2, NO2, O3, HNO3 and PM (particulate matter) is also exposed in all the sites

2nd CORNET meeting and workshop on dose-response functions and stock of materials at risk, Zambia (February 2008)

Organization of 2nd CORNET meeting and workshop on dose-response functions and stock of materials at risk, Zambia (February 2008)

- Transfer of knowledge on how to perform:
  - Statistical evaluations
  - Stock at risk studies
- Follow-up on first workshop on sample evaluation
- Presentation of results from long-term and trend exposures
- Presentation of first results from the rapid urban assessment study performed in Kathmandu, Nepal
- Discussion and demonstration of Passive Sampling Results, Data interpretation and First step in development of dose-response functions for the investigated regions
- Future developments of RAPIDC/Corrosion and CORNET

CORROSION OF CARBON STEEL AND ZINC AFTER 1, 2 AND 4 YEARS OF EXPOSURE.



RANK CORRELATIONS
AIR POLLUTION AND CORROSION

Significant (95%) rank correlations between pollution and corrosion data

Materials	SO_2	HNO_3	-pH
Paint coated steel	0.42		0.33
Carbon steel	0.73		0.40
Zinc	0.45	0.22	0.61
Copper	0.28		0.30
Limestone	0.49	0.40	0.53

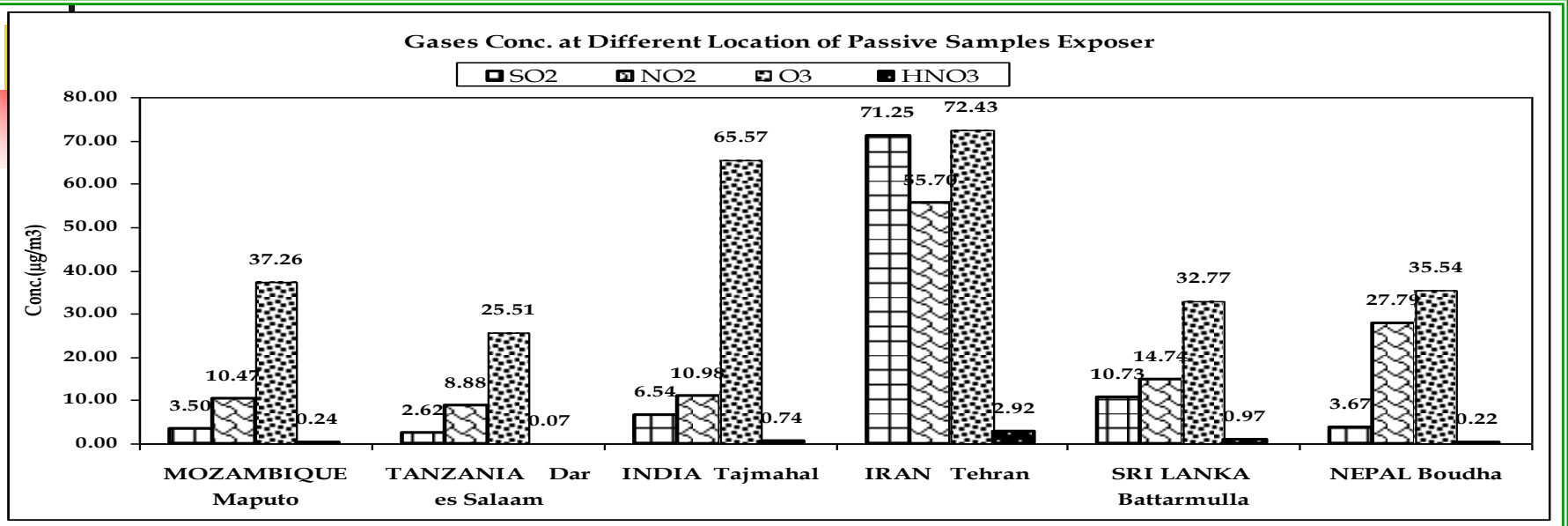
DATA COMPARISON WITH EUROPEAN CONDITIONS

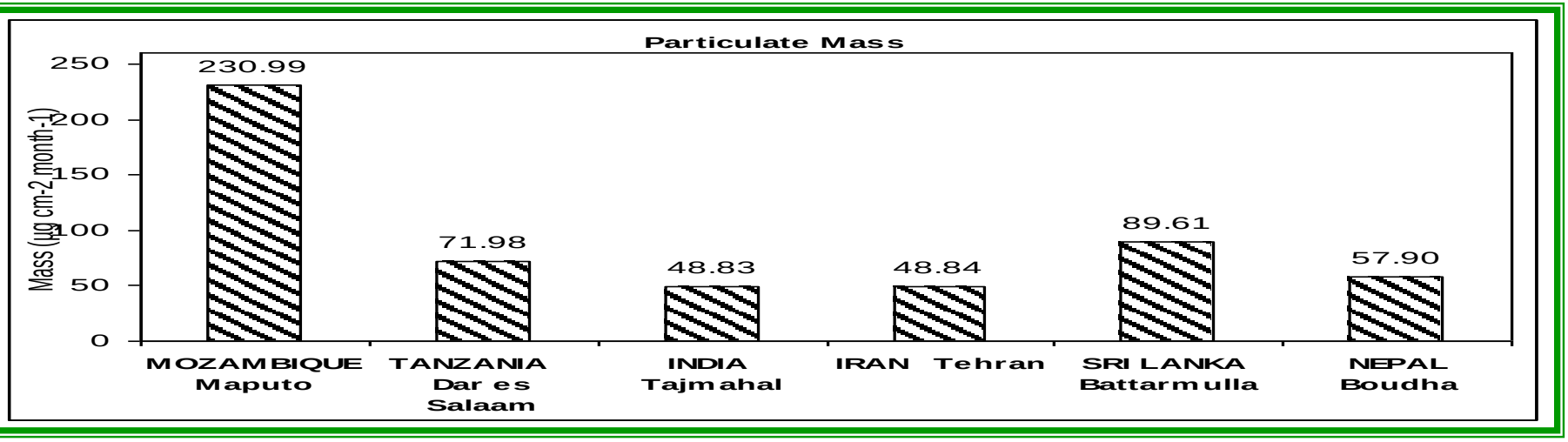
- Attempts has been made compare the present data to similar data obtained in Europe.
- The most important pollution parameters (dry deposition of SO2, acid rain and for some materials possible HNO3) seem to be the same in subtropical/tropical climates as well as in temperate climate.
- Data from the "International Co-operative Programme on effects on Materials including historic and cultural monuments" (ICP Materials)5 is used since the program uses identical methodology in almost every aspect.
  - Two types of comparisons have been made, the first to compare the corrosion data as it is, in order to answer the question if the corrosion problems in Asia/Africa poses a greater threat than in Europe.
  - The second is a lightly more sophisticated comparison aiming at answer the question if dose-response functions developed in Europe can be used to predict corrosion attack in Asia/Africa.

CORROSION LEVELS IN EUROPE AND ASIA/AFRICA.

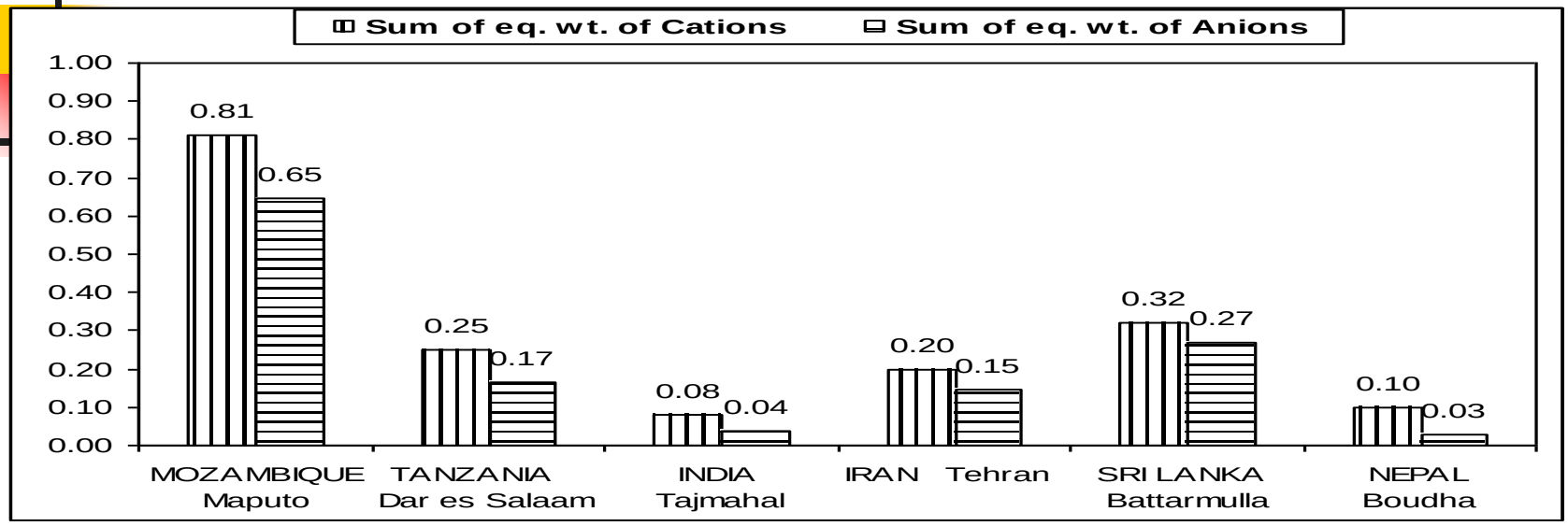
1. The median value was noted to be is slightly lower in Asia/Africa in case of Zinc, while
2. The median value was noted to be slightly higher in in Asia/Africa for both copper and carbon steel.
3. The median is about the same but there are some extreme values in Asia/Africa but not in Europe for painted steel, .
4. Limestone shows the highest difference with significant higher values in Asia/Africa, the median was found to be about three times higher.

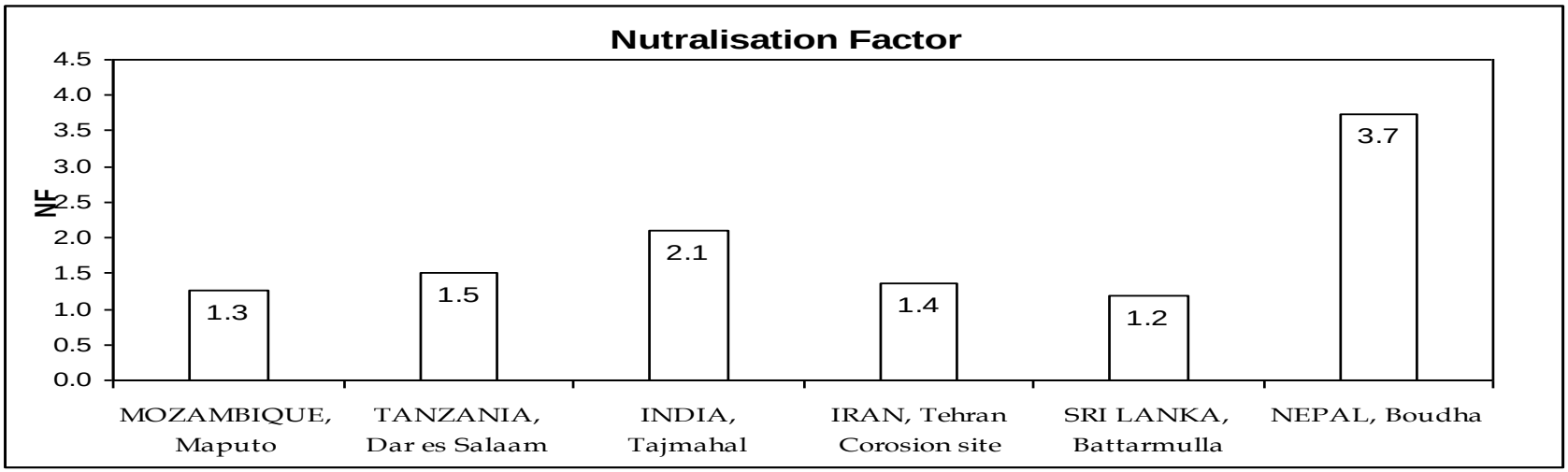
AIR POLLUTION PROFILE: NEW SITES





AIR POLLUTION PROFILE: NEW SITES





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IVL [SWEDISH ENVIRONMENTAL RESEARCH INSTITUTE]

SIDA [SWEDISH INTERNATIONAL DEVELOPMENT CO-OPERATION AGENCY]

ALL PARTICIPATING ORGANIZATIONS IN AFRICA AND ASIA AND ITS RESPECTED RESOURCES PERSON

UNEP

THANKS