APINA

AIR POLLUTION INFORMATION NETWORK-AFRICA

Second Corrosion Workshop and CORNET meeting on the Development of Dose-Response Functions, Stock of Materials at Risk and Evaluation of Corrosion Trends

Wasawange Lodge, Livingstone, Zambia.
11th to 13th February 2008

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Executive Summary

The APINA and Malé Declaration progamme s on Imapcts of Air Pollution on Corrosion of Man Made Materials had a workshop on capacity building for development of dose-response functions, assessment of stock of materials at risk from corrosion as well as evaluation of corrosion trend. This meeting took place from 11th to 13th February 2008 in Livingstone, Zambia. The thematic areas examined were (i) Development of dose-response functions, (ii) Evaluation of stock of materials at risk and cost calculations, (iii) Trends of corrosion and pollution as well as (iv) Discussions on the Extension of the corrosion network.

Significant differences have been observed in the evaluation of mass loss for corroding materials when European generated dose-response (DR) functions are used on materials exposed in RAPIDC countries where tropical or sub-tropical conditions apply. This situation calls for development of appropriate DR functions and the Livingstone workshop shed some light on this aspect.

Assessment of corrosion levels in selected materials by itself is not very useful when its impacts are not highlighted appropriately especially for policy input purposes. One such way is to undertake a stock of materials at risk study and has a number of involving facets to it. Availability of accurate data on building constructions, materials used, population and other economic infrastructure combine to create a complex interplay of parameters.

Long term exposure cycles for materials are useful for evaluating accurate mass loss under given conditions where as short term cycles are important for monitoring trends in pollution levels. Trends are themselves impacted by policy and technological changes singly or combined. The sharing of experiences between regions undertaking similar work was important in further developing capacity for continued evaluation and monitoring of material degradation.

1.0 Introduction

The proceedings of the joint Air Pollution Information Network for Africa (APINA) and Malé Declaration program (i.e., Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia) Training Workshop and Corrosion Network program (CORNET) meeting held at Wasawange Lodge, Livingstone during 11th to 13th February 2008 are presented in this report. There were eighteen (18) participants including two resource persons from Corrosion and Metals Research Institute (KiMab), Sweden. In addition two persons assisted with secretarial and workshop/meeting logistics (see attached list).

The objectives of the workshop were to;

1. Transfer of knowledge on how to perform:
    a. Statistical evaluations
    b. Stock at risk studies
2. Follow-up on first workshop on sample evaluation
3. Presentation of results from long-term and trend exposures
4. Presentation of first results from the rapid urban assessment study performed in Kathmandu, Nepal
5. First step in development of dose-response functions for the investigated regions
6. Future developments of RAPIDC/Corrosion and CORNET.

The facilitation methods involved power point presentations and discussions within the whole group. The full titles of the presentations are appended to this report.

The Task Team Leader for Corrosion and local organiser for the meeting presented on behalf of the APINA network the status of the network and preparations for the commencement of Phase IV planned for April 2008. An insight into the various APINA activities being undertaken in the region was given specifically highlighting corrosion activities since 2002 to date with the coming on board of two new sites at Dar es Salaam, Tanzania and Maputo in Mozambique.

The Malé Declaration Secretariat (from UNEP Regional Resource Centre for Asia and the Pacific (RRCAP)) briefly mentioned the implementation of Malé Declaration since its Adoption in April 1998, its phases and components, ongoing Phase III in particular, national and regional networks, recent regional meetings, development of various manuals, and impact assessment of transboundary air pollution and case studies for rapid urban assessment, crop impact assessment, health impact and corrosion studies. Like APINA, Male has an active newsletter and other communication tools for their entire stakeholders.

2.0 Knowledge Base

The presentations were done largely according to suggested thematic areas; (i) Development of dose-response functions, (ii) Evaluation of stock of materials at risk and cost calculations, (iii) Trends of corrosion and pollution and (iv) Extension of corrosion network. Discussions followed each presentation immediately after.

2.1 Development of dose-response functions

2.1.1 Concept and application of DR functions

It should be tested if dose-response functions developed based on European experience can be applied and used to accurately assess corrosion effects in the tropical/sub-tropical regions of Africa and Asia. In general the response function will have the form;

$$K = f_{dry}(T, RH, [SO_2]) + f_{wet}(Rain[H^+])$$

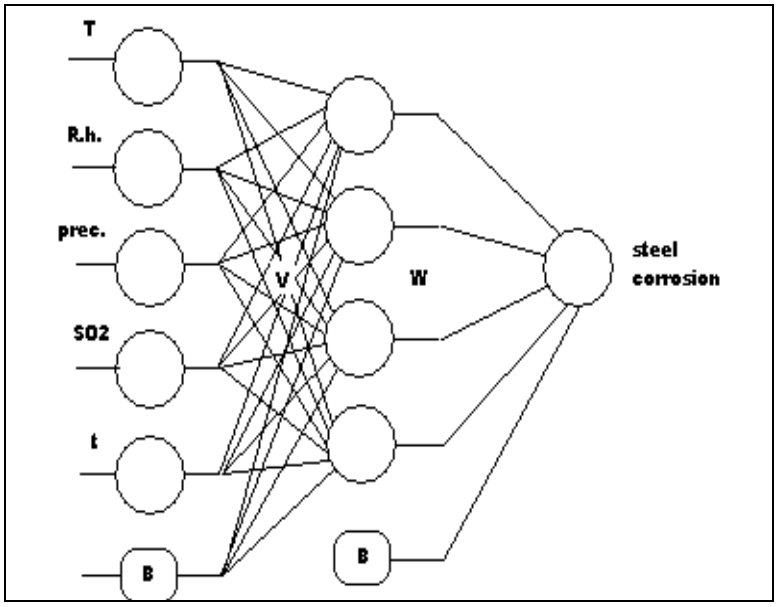
The corrosion rate or mass loss will depend on the magnitude and interplay of the above five major parameters of ambient temperature, relative humidity, sulphur dioxide concentration, precipitation and acidity. Local conditions at exposure site can greatly affect impact of polluting gases in terms of levels of concentrations as well as factors used on climatic parameters such as temperature, T. The European model DR functions when used on data collected from participating RAPIDC countries yielded significant differences in the corrosion responses of the materials tested in the programme. For instance the RAPIDC zinc corrosion values were only 78 % of the expected levels while copper and limestone were much higher at values of 141 % and 256 % respectively. It is

said that the influence of ozone (O_3) is very different in the two regions of Europe and the sub-tropics. This clearly demonstrated the need for development of new models of DR functions suitable in both situations of Europe and Asia. This will be achieved by using the STATGRAPHICS software.

2.1.2 Analysis of corrosion using neural networks

The concept is borrowed from biological modeling of systems such as functions of the human brain and has the advantages of dealing with the strong non-linearities in present in the atmosphere (complexicity of physical-chemical processes), being robust enough and ability to generalize, able to minimise errors as well as learning on the basis of inputs from the environment and ability to improve performance. A big disadvantage however is there isn't an exact model of the system ("black box") and this is the key problem.

The neural network looks as below showing inputs of corrosion parameters on the left and the output of corrosion on the right with the possibility of back propagation.



2.2 Evaluation of stock of materials at risk and cost calculations

Assessment of stock-at-risk is an important part of analyses of cost of damage caused by air pollution. Several methodologies have been used depending primarily on the geographical scale and data availability. In principle top-down and bottom-up methods and their combinations are used.

The **"bottom-up method"** counts individual buildings from maps and uses identikits and the **"top-down method"** is uses census data on the number of buildings of different types, a multiplication with the identikits gives the stock-at-risk of the investigated area. A **building identikit** is a typical description of the exterior surfaces of selected building types e.g. multi-storey buildings, detached houses, office blocks and so on.

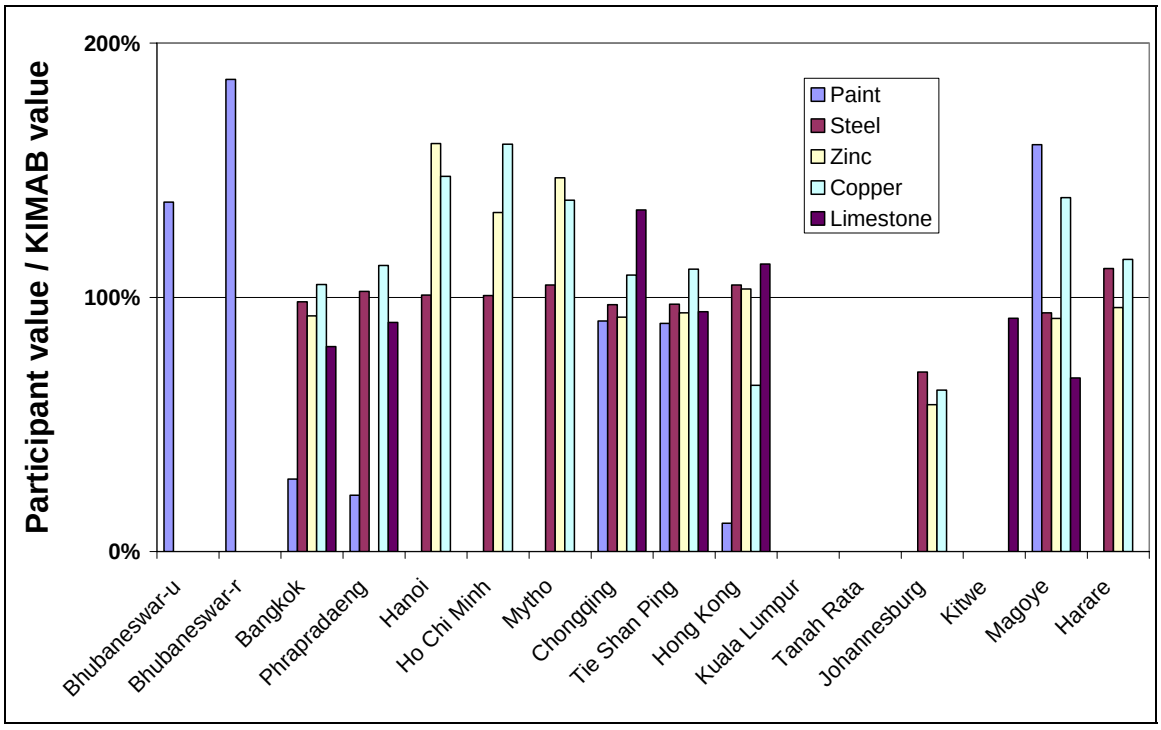
Kathmandu in Nepal has an ongoing exercise on stock at risk and during the 2007 assessment concluded that buildings and materials would last three times longer in clean environments and that the savings in costs of repairs is around US $1,700 per building per year in the same clean environments.

2.3 Trends of corrosion and pollution

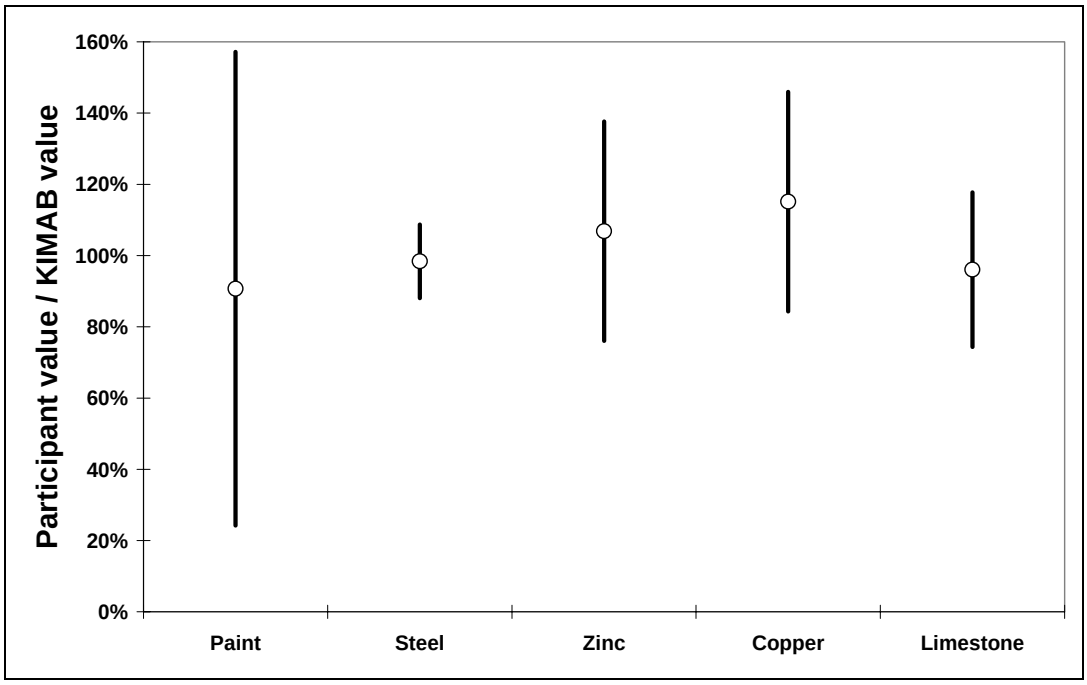
Sometime was spent discussing the trend results obtained by the participating RAPIDC countries (refer Kitwe workshop by APINA, February 2007) and the duplicate ones by KIMAB for all the sites.

2.3.1 Comparison of samples evaluated in individual countries and samples evaluated at KIMAB

The overall agreement between RAPIDC countries and KIMAB was good, taking into account all possible sources of error. The difference, both in absolute terms and the variation between evaluators, are exceptionally good for carbon steel, which was in the range of ± 10% while for zinc, copper and limestone the error was in the range of ± 40%. The error for paint coated steel was the largest, in the range of ± 70% (see figures below).



Comparison of analysis for all centres and samples in the RAPIDC countries



Error spread in the analysis for all types of samples for all centres in the RAPIDC countries

For minimising of errors it is recommended to appoint sub-centres responsible for the evaluation of individual materials rather than each participant making their own evaluation.

2.3.2 Model to predict corrosion trends at various sites

This is based on exposure time for each material and at a given site;

$ML = AT^n$ (Exponential Function)

Where ML – Weight or mass loss of material

T – Exposure time (year)

A, n – Coefficients that need to be determined

When T = 1, then $ML_1 = A$ (ML_1- material loss for one year)

When T = 2, then $ML_2 = ML_1 2^n$ (ML_2- cumulative material loss for two years)

Then $n = LN(ML_2/ML_1)/ LN(2)$ (LN – Natural Logarithm)

Given $ML_1$and ML_2 values at an exposure site, then n-value can be obtained for the site. The results are displayed in the following Table on next page. The average n values are computed using the Trimmean method and taking the 50 % level and the results become as shown here and so n = 0.60 for Carbon Steel, n = 0.92 for Zinc and n = 0.90 for Copper. Then,

$ML_2=ML_1 2^{0.60}$, $ML_4=ML_1 4^{0.60}$ for Carbon Steel

$ML_2=ML_1 2^{0.92}$, $ML_4=ML_1 4^{0.92}$ for Zinc

$ML_2=ML_1 2^{0.90}$, $ML_4=ML_1 4^{0.90}$ for Copper

The above prediction model and precision was acceptable for above materials and reasonably accurate only for year four (4Y) for Zinc and Copper.

Table 2.3: Calculated n values for RAPIDC sites for steel, zinc and copper.

Material	Carbon Steel (g/m^2)			Zinc (g/m^2)			Copper (g/m^2)		
Site	1Y	2Y	n	1Y	2Y	n	1Y	2Y	n
Bhubaneswar-u	157	252	0.68	4.27	8.61	1.01	8.28	15.22	0.88
Bhubaneswar-r	156	270	0.79	3.56	7.91	1.15	11.91	19.35	0.70
Bangkok	115	161	0.49	4.53	7.62	0.75	14.98	26.26	0.81
Phrapradaeng	281	417	0.57	5.68	11.30	0.99	17.09	28.61	0.74
Hanoi	182	279	0.62	6.09	11.59	0.93	5.38	11.37	1.08
Ho Chi Minh	164	214	0.39	6.87	11.25	0.71	8.00	15.07	0.91
Mytho	166	298	0.84	4.38	8.51	0.96	12.06	20.08	0.74
Chongqing	783	1201	0.62	9.04	19.85	1.13	24.17	46.04	0.93
Tie Shan Ping	492	769	0.65	11.63	24.76	1.09	17.84	36.49	1.03
Hong Kong	150	201	0.42	6.41	11.43	0.83	6.67	12.43	0.90
Kuala Lumpur	139	181	0.38	8.09	15.84	0.97	9.55	19.30	1.01
Tana Rata	50	90	0.84	7.51	10.98	0.55	10.50	19.97	0.93
Joburg	105	168	0.68	2.02	4.28	1.08	4.57	8.95	0.97
Kitwe	463	561	0.27	27.02	47.55	0.82	12.72	19.29	0.60
Magoye	27	70	1.40	1.96	3.33	0.76	5.04	10.17	1.01
Harare	193	267	0.47	3.44	6.31	0.87	4.06	7.57	0.90
			0.60			0.92			0.90

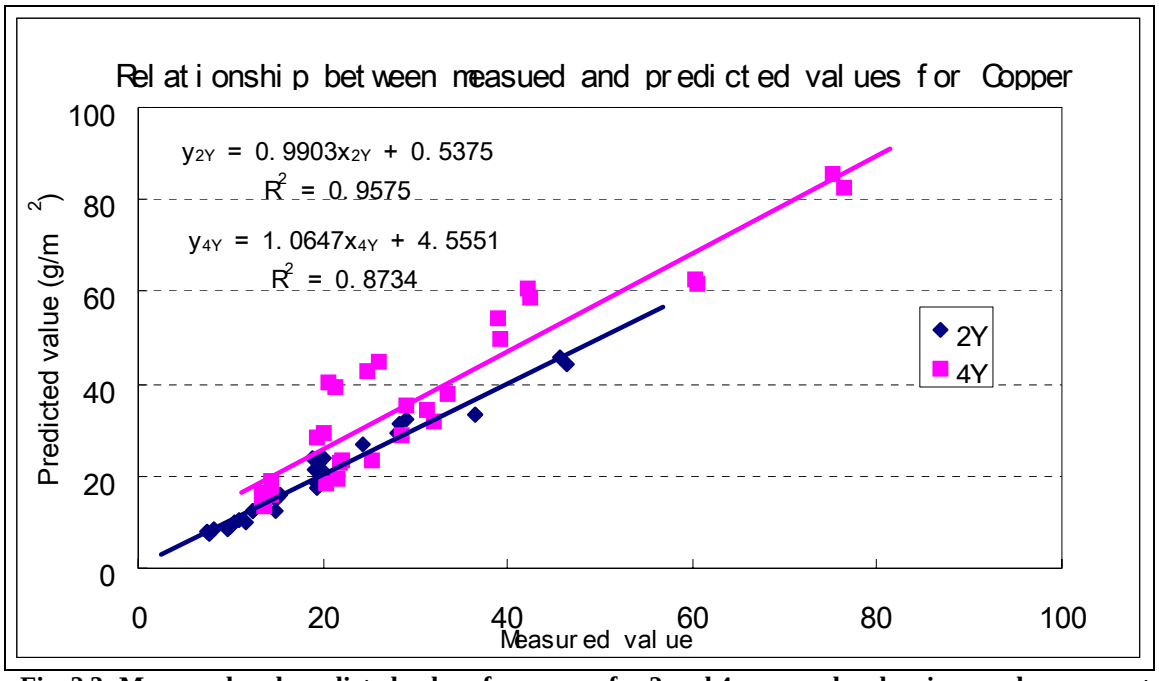


Fig. 2.3: Measured and predicted values for copper for 2 and 4 year cycles showing good agreement

2.3.3 Time and scope of next trend exposure

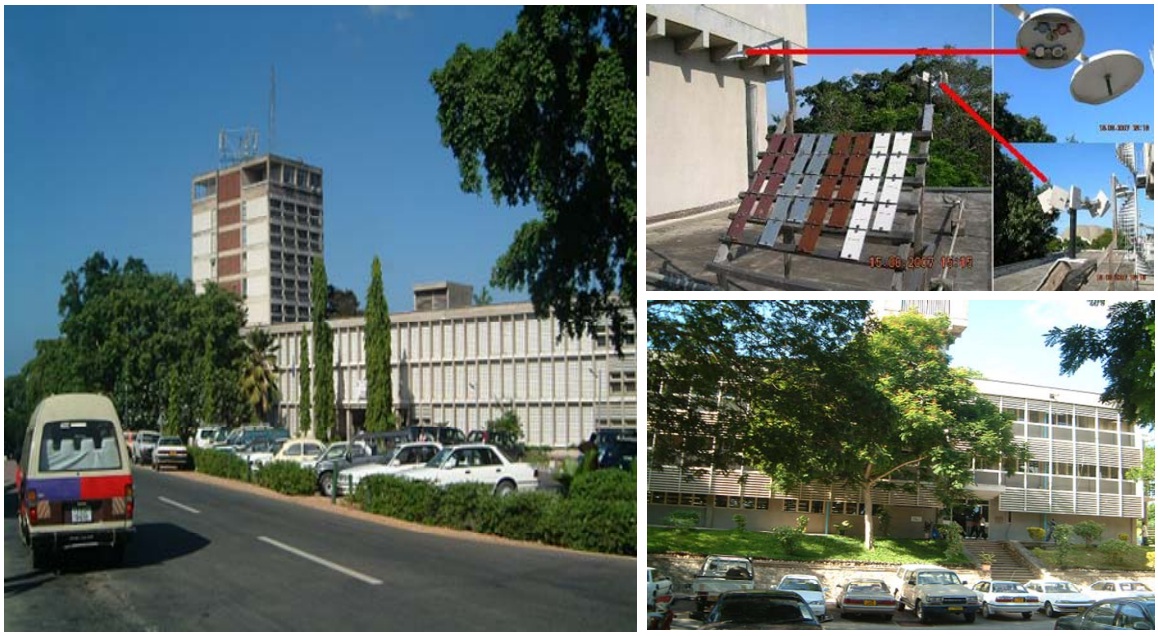
The time for mounting the next cycle of trend samples would be August/September 2009 and that would include the new sites that started exposures during August/September 2006 (Maputo and Dar-es-Salaam for APINA). By their nature trend exposures are supposed to be used to gauge any changes in pollution levels that may be linked to policy or legislation shifts in the individual countries. The old sites for APINA (RSA, Zambia and Zimbabwe) shall require rehabilitation during the coming Phase IV. Climatic and environmental data shall continue to be collected at all the sites.

During the period 2002-2006 the trends in pollution and corrosion were more or less constant although both corrosion and pollution continued to be high at some places. Even though the trends in corrosion of carbon steel were very small it was possible to relate trends in carbon steel to trends in SO_2 and/or pH and therefore continued trend exposures are important in order to verify future changes.

2.3.4 Extension of corrosion network (CORNET)

Discussions on exposures at new sites in India, Iran, Maldives, Mozambique, Nepal, Sri Lanka and Tanzania were made. In the case of the Mozambique and Tanzania sites, issues were raised regarding the use of background samplers for passive sampling and their role in getting accuracy of readings for pollutant gases. It was also stated that manufacturers of passive samplers normally have details on background readings which are also given on their websites.

Tanzania has in addition to the RAPIDC samples, exposed local roofing sheets as well as cement based blocks. The roofing sheets are galvanised steel and are inclined at 30 degrees to the horizontal compared to the 45 degrees used on the RAPIDC racks. That was said to be the normal practice with construction buildings in Tanzania.



The University of Dar es Salaam (UDSM) exposure site for Tanzania

3.0 Other Business, Concluding Remarks and Way Forward

3.1 Abstract for the Las Vegas Corrosion Congress

An abstract for the 17th International Corrosion Congress to be held in Las Vegas, Nevada, USA, during October 2008 had been finalized. In addition to presenting authors from KIMAB, all RAPIDC partners are co-authors of the paper. This would show case the results of the initial four year cycle in the RAPIDC countries in addition to ICP Materials. At that time, the 1st year results for the new RAPIDC sites would have been analysed and have a chance of being referred to in discussions at paper presentation.

3.2 RAPIDC Phase IV Activities

Phase IV proposal have been more or less finalized by both the Malé Declaration and APINA progamme. It was stated however that consideration should be given by individual countries to incorporate local materials for exposure as that was important in order to attract further funding.

3.3 Stock at Risk in Nepal

Other than studies done in European countries, Nepal has been the first country in the RAPIDC programme to undertake a stock at risk assessment. It was noted from discussions that the 'cost' component was not very well articulated by persons undertaking the 'technical' or 'scientific' part. The two were very much part of the same thing and should be handled thoroughly.

In Nepal for example (see picture below) it has been established (2007) that a typical building in a clean environment will have up to three times the lifespan of a comparable building in a polluted environment. Savings of up to $1,700 per year per building in repair costs were expected for buildings in clean environment from the above study.

Fig. 3.3: A building in Kathmandu assessed for stock at risk (2007)

It was suggested that if APINA countries wished to undertake a similar study, it would be best done side by side with the Rapid Urban Assessment (RUA) exercise such as currently taking place in Maputo, Mozambique. In addition to measuring levels of pollutants and collection of environmental data, provision must be made for the acquisition of other equipment such as laser instruments for distance measurements whose unit price is around US $1,000.

3.4 Networking between APINA and Male Countries

It was suggested that some resources during Phase IV be devoted by both programmes to support networking activities within RAPIDC as well as with other global for a such as the forthcoming ICP Materials and the Las Vegas Corrosion Congress in April and October 2008 respectively.

It was also suggested that more co-ordination of activities between Malé and APINA in order to avoid fragmented results and training events. Linkage between both Malé and APINA and Convention on Long-Range Transboundary Air Pollution (CLRTAP) should be further explored within Phase IV of RAPIDC. This should have a large chance for success as the Corrosion and Metals Research Institute also is the main research centre and Chair of ICP Materials under the LRTAP Convention.

3.5 Centres of Excellence for Evaluation

The APINA and Malé should decide which institutions or organizations were best suited for undertaking given types of material evaluations or tests so as to allow specialisations to develop and eliminate errors in reporting of results.

Appendix 1:

Corrosion Network (CORNET)

Malé Declaration on the Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia **&** **Air Pollution Information Network for Africa (APINA)**

Minutes of the 2nd Meeting of the Programme Task Force of CORNET and report from Corrosion Workshop on Dose-Response Functions and Stock at Risk

February 11-13, 2008, Wasawange Lodge, Livingstone, Zambia.

1. Opening of the meeting

   Chozi V.Lungu (School of Mines, University of Zambia), the leader of the corrosion group within APINA and local organiser of the meeting welcomed the participants on behalf of APINA.

   Naw Wah Wah Htoo (UNEP PRC.AP, Bangkok, Thailand) welcomed the participants on behalf of the Malé countries and explained briefly the organisation of the activities within the Malé Declaration. One of the focus areas for the future is to "strengthen knowledge on corrosion impact assessment".

   Johan Tidblad (Swerea KIMAB) opened the meeting, welcomed the participants and expressed his thanks to the organisers from APINA and form the Malé Declaration for organising and hosting the meeting.

2. Approval of Draft Agenda

The draft agenda distributed was approved.

3. Introduction

   Johan Tidblad presented the organisation and the programme of the workshop and the CORNET meeting. He pointed out that due to the close interrelation of both events, the agenda will not separate them in a chronological order. He stressed that the main aims of the workshop was to give the basis for development of dose-response functions and the aim and methodology of performing stock at risk inventories. The main aims of the CORNET meeting was to show the progress made within these two

areas since the last meeting, to present and discuss the results obtained in the 4-year RAPIDC exposure programme, the 1-year trend exposure programme and the future activities including possible start of exposure on new test sites.

Session I – Development of dose-response functions

4. Concept of dose response functions and their application (*Vladimir Kucera,KIMAB)*

   The overview presented the concept of development of DRF in both SO_2 dominated and multipollutant atmospheres and their applications for developing corrosion and pollution indicators, mapping corrosion risk, and calculating corrosion cost caused by pollution.

5. Presentation of used databases for evaluation (*Johan Tidblad)*

   The activities performed within CORNET and exposures since the start in 2002 have resulted in an extensive database containing corrosion data from 1, 2, and 4-years exposure of carbon steel, zinc, copper, painted steel and Portland limestone and pollution data from the 1^{st} and 4^{th} year exposure for the period 2002/03 to 2005/06. This database can be compared and combined with an in principal identical database obtained in the temperate climate zone by ICP Materials in the years 1997 to 2001.

6. Statistical analysis using regression analysis (*Johan Tidblad)*

   Analysis of CORNET data using ICP Materials DRF:s shows that these functions overestimate the corrosion of zinc and underestimate the corrosion of copper and limestone. This demonstrates the need of development of new DRF.s describing the data from the CORNET region. The next steps should lead to development of DRF:s valid for both regions and to an understanding of the reason for the differences.

7. Statistical analysis using neural networks (*Johan Tidblad, Maros Halama)*

   The neural networks seem to be a useful method for discovering hidden data dependencies as there are no prejudices involved. Unexpected/unrealistic functional behaviour might occur, for example negative corrosion values, but there are possibly ways to solve this. Dose-response functions can not easily be derived from the model results. Further efforts are planned with application of this method.

8. Statistical analyses performed by participants

   Development of Dose-Response Function and its Statistical Evaluation (*Zhao Dawei, Chongqing Institute of Environmental Science & Monitoring*)

Nonlinear Regression Analysis –NRA, a computation program in SPSS (Statistical Package for the Social Science) for Windows has been applied on the CORNET database using an iteration method. Additionally the T-test, a statistical test including Paired Sample Correlation- PSC and Paired Sample Test- PST has been used. For the CORNET database, tentative DRFs of the all 5 materials possess acceptable predicted precision, but only those of carbon steel and painted steel also possess simultaneously acceptable accuracy for the ICP Materials database.

8. Discussion on selection of dose-response functions

   It was agreed that in the continued statistical analysis several statistical approach should be applied. The importance of obtaining DRF:s explainable by physical-chemical principles was stressed.

Session II – Evaluation of stock of materials at risk and cost calculations

9. Overview of methods used for stock at risk assessment (*Vladimir Kucera*)

Assessment of stock-at-risk is an important part of analyses of cost of damage caused by air pollution. Several methodologies have been used depending primarily on the geographical scale and data availability. In principle top-down and bottom-up methods and their combinations are used. Classification of the building stock into categories and describing them by identikits giving the average total amount and share of different materials is often used. Performing stock-at-risk for CH objects is usually a difficult task due to the great variability of the monuments.

10. Exposure of corrosion kits in Kathmandu, Nepal (*Bidya Banmali Pradhan, ICIMOD*)

    The 9 sites where the kits have been exposed in Kathmandu valley (November 2006/November 2007) were presented including photos illustrating the development of corrosion attack on the different materials. A complete database of pollution parameters obtained by passive sampling at the sites was presented. The exposure of an additional kit on Durbar Square, Bhaktapur (a World Heritage site) was started in November 2007.

11. First results from exposure of corrosion kits (*Vladimir Kucera*)

    There are considerable variations in corrosion rates among the nine sites in Kathmandu valley .The variations are the largest for carbon steel and SO_2

concentration, more than a factor of ten when comparing the sites with the highest and the lowest corrosion. For zinc and limestone the variation is smaller, about a factor of three. The results will be used in connection with the rapid urban assessment performed by ICIMOD in co-operation with IVL where measurements are performed at about 50 sites together with an emission inventory.

12. Present status of stock at risk study in Kathmandu (*Bidya Banmali Pradhan*)

A stock at risk training seminary was performed in October/November 2007 during the visit of *J.Tidblad and V.Kucera* to ICIMOD consisting of lectures and discussions with participants from different authorities including the Technical Department of Kathmandu and archaeological and cultural heritage authorities. During the second day of the seminary a practical stock at risk study was performed on a heritage building on Patan Durbar Square using a laser equipment and a questionnaire prepared by KIMAB. In a final discussion the participants expressed their interest and their possibilities to participate in the stock at risk study. Later during the KIMAB:s visit a plan for the study was prepared consisting of the stock at risk of buildings in Kathmandu using two polygons (wards) for the inventory of amounts of selected types of buildings. The results will be used for allocating the amounts of different materials per capita and subsequently for calculation of stock at risk in all the other polygons based on the population census. A principal plan and results from the first phase of the study were presented.

Session III Extension of corrosion network

13. Evaluation of corrosion samples in individual countries

- India: *S.N. Das, Institute of Minerals&Materials Technology, Bhubaneswar*)

The results of evaluation of specimens were presented. There is a strong interest and need of performing and continuing corrosion exposure as most of the thermal power plants are located in Orissa and its periphery and the wind trajectories during monsoon pass through Bhubaneswar into Bay of Bengal carrying the pollutants. In consequence the acidity of both rain and particles is increasing. Capability for exposure and evaluation has been developed and there is a possibility to run exposure studies in

parallel to other air pollution studies including precipitation chemistry and aerosol chemistry. There is an interest in exposing rapid kits on objects of cultural heritage.

- China : Trends of atmospheric corrosion and pollution (*Zhao Dawei*)

Results from seven 1-year exposures of C-steel in Chongqing in the period 1989-2006 show that the corrosion rate has decreased considerably, from 220 to 80 microns/year. The corrosion rate is, however, still high. The CORNET database has been evaluated using the power function for time development and reasonable exponents n have been obtained for C-steel , zinc and copper. The equations have been used for prediction of 4-years values from 1 and 2-years values and an acceptable accuracy has been obtained for zinc and copper.

- APINA (South Africa, Zambia, Ziombabwe and the new sites in Tanzania and Mozambique): Kitwe workshop and exposure of standard materials and pollutants passive sampling; a new site (*Albert Mmari*)

An APINA corrosion workshop was held in Kitwe, February 2007. The purpose of the workshop was to analyze one year trend samples from the four sites in South Africa, Zambia and Zimbabwe so as to build capacity in the task team on laboratory analysis of exposed samples.

The rational for the choice of the site in the University of Dar es Salaam was presented as well as results obtained so far from the exposure which started in 2006. Passive samplers from Italy have been used simultaneously with the IVL samplers giving similar results which confirms the reliability of the method.

14. Influences of Environmental Factors on Atmospheric Corrosion of Materials (*Zhao Dawei*)

The results obtained in the CORNET network have been analysed in the Chongqing Institute of Environmental Science & Monitoring using two statistical methods: GRA – Grey Relational Analysis and FR – Fuzy Ranking & FCA- Fuzy Cluster Analysis. They permit as a final step a ranking of the effects of environmental parameters on corrosion. In a following discussion it was concluded that these method could be useful as a compliment to other statistical methods presented.

15. Comparison of samples evaluated in individual countries and samples evaluated at KIMAB (*Johan Tidblad)*

The main reasons for arriving at incorrect values for painted specimens, metal specimens and stone samples were analysed. The overall agreement is good, taking into account all possible sources of error. The difference, both in absolute terms and the variation between evaluators, are exceptionally good for carbon steel, in the range of 10%.For zinc, copper and limestone the error is in the range of 40%.The error for paint coated steel is largest, in the range of 70%. For minimising of errors it is recommended to appoint sub-centres responsible for the evaluation of individual materials rather than each participant making their own evaluation. In the following discussion it was concluded that the need of creation of sub-centres for preparation and evaluation of specimens should be stressed and forwarded to Malé and APINA managements.

IV. Trends of corrosion and pollution

15.Results from trend exposure (*Johan Tidblad*)

The two 1-year exposures performed during the period 2002-2006 have shown that the trends in pollution and corrosion are more or less constant, both corrosion and pollution continues to be high at some places. Even though the trends in corrosion of carbon steel, SO_2 and pH are very small it is possible to relate trends in carbon steel to trends in SO_2 and/or pH. Continued trend exposures are important in order to verify future changes.

16.Discussion of time and scope of next trend exposure

An extensive discussion stressed the importance of continuing the trend exposure which is an important part of the investigations of the effects of pollutants on materials and the results can also be used for analyses of effects of climate changes on materials. The trend exposure is also an opportunity for the capacity building in the participating countries and for focusing on objects of cultural heritage. As a conclusion it was proposed to start the new trend exposure in 2009. This will coincide with the 4^{th} year of exposure on the test sites, where exposure started in 2006.

17. Description of exposure at new sites

- Iran: The rack is situated on the roof of a 15m high building situated between two highways in a distance of 100 and 800 meters respectively. The corrosion data are not available yet as the specimens have been sent to IVL.
- India: Exposure has started in November 2006 in Agra (Taj Mahal). The rainfall data are obtained from the Meteorological Office (amount), while the chemical analysis is performed in the laboratory of the Central Pollution Control Board, Project Office in Agra.
- Nepal: Exposure of the main rack has started in ICIMOD in October 2006 on the roof of their building. An exposure of a rapid kit was started in Durban Square in Bakhtapur in November 2007.
- Sri Lanka: Exposure has started in November 2006 on the roof of the building of the Central Environmental Authority in Battaramulla.
- Maldives: This is the latest started site, the exposure commenced in January 2008 on the Hanimadhoo Island in the area of a meteorological station, where other advanced physical and chemical measurements are performed.
- Tanzania and Mozambique: see p 13 above.

18. First results from exposure on new sites (*Johan Tidblad*)

So far the pollution data from almost all sites are available and an overview of data on gaseous pollutants and particles obtained by IVL passive samplers was presented. It was pointed out that also soiling data are collected and will be used in the evaluation and reporting.

From the site in Teheran only two sets of passive samplers have apparently arrived to IVL. KIMAB will find out if there could be an admixture with the other Iranian site.

19. Protocol for collection of environmental data by individual participants

Johan Tidblad stressed that the following four parameters – temperature, relative humidity, rain amount and pH – are needed from all sites. A round table inquiry revealed that no problems are expected from the new countries. A form for reporting the data was required. *Johan Tidblad* concluded that the situation looks very promising and promised that KIMAB will distribute a form for reporting.

20. Discussion on extension of CORNET

Malé Declaration :

- Pakistan is interested in participation and Islamabad and Karachi were mentioned as possible places where the site could be established. The representative of Pakistan, Mahmood Sajid, promised to send pollution data to KIMAB for selection of the most appropriate site.
- Bhutan is also a potential candidate, the final decision will depend on the new administration.

APINA :

The policy dialog in the end of March this year will discuss the Phase 4 of the RAPIDC programme and is thus an appropriate forum to treat the extension. At present Botswana is a candidate for joining the programme. *Albert Mmari* reported that Kenya and Namibia have shown an interest to participate on an informal level. *Chozi Lungo* stressed that the possibility to participate depends also on the activity of the national focal points.

V. Other business

21. Information on models and calculations on health effects due to air pollution (*Bidyia Banmali Pradhan*)

A brief overview was given on a detailed study performed in collaboration with IVL within RAPIDC in Kathmandu. Using emission factors for vehicles, cooking and other activities the total emissions of SO_2, NO_2, PM_{10} can be calculated from every grid in the network. A comparison of the current baseline with targeted baselines enables calculations which effects different measures will have in the individual grids and calculate the cost. A similar procedure could possibly also be done for materials. The following discussion concerned the methodology of such study. *Vladimir Kucera* stressed the importance of combining the investigations of pollution on health and on materials. This is cost efficient and will strengthen the motivation for performing corrosion studies including cost-benefit analyses.

22. Contribution to the 17th International Corrosion Congress , October 2008, Las Vegas

Johan Tidblad presented an abstract of a common paper which will describe the CORNET activities and the results obtained in the network. One representative of

each participating country will be co-author of the paper and all organisations performing the exposure on the sites will be acknowledged. KIMAB will prepare a draft of the paper and distribute it for comments to the members of CORNET before submission.

23. Discussion on scope of corrosion activities in Phase 4 of RAPIDC including co-ordination of

APINA and Malé activities

Naw Wah Wah Htoo reported that it has already been approved to submit a project proposal for the 4th Phase of RAPIDC to SIDA. The proposal will also include how much the individual countries are prepared to contribute to the financing. Corrosion will be included even if so far no details have been discussed. One aim is also to appoint a regional centre for corrosion. The goal is to present and discuss the proposal in the regional policy dialog in April 2008.

Chozi Lungo reported that the views of the APINA stakeholders were expressed at a meeting in October 2007. The intention is to continue the expansion of monitoring activity and perform stock-at-risk studies. There is a need to build the local policy interest and the preparedness also to contribute financially. A dialogue exists between Malé and APINA concerning a common planning especially on materials and crop activities.

The ownership of the intellectual property of the results was discussed. It was stressed that SIDA who is financing the project has the right to the results. This concerns both the corrosion data and passive samplers. The question with environmental data is more complicated as they have in some cases been collected and supplied by different organisations. It was proposed to deal with the results in a similar way as with ICP Materials results in Europe. This means that the results are first available for the CORNET members for common analyses and publication acknowledging all organisations participating in the work. Thereafter will the results be publicly available. Publication of the own results obtained in individual countries is, however, possible even before the common analyses are published as that can be required by domestic grant organisations.

Naw Wah Wah Htoo pointed out that SIDA is now interested in supporting activities dealing with climate change. To include this in the Phase 4 could be beneficial. In the following discussion *Vladimir Kucera* claimed that it is possible to show the need of studies on climate effects for further understanding and development of DRF:s for corrosion as they obviously differ between temperate and warm regions. These studies would thus also be important for assessment of effects of climate change on corrosion which is at present a priority in Europe within 7FP especially in connection with objects of cultural heritage.

Mr Foax (South Africa) stressed the need of increasing the awareness of the public on APINA and Malé activities. Measures in this direction are urgent. One possibility will also be the paper and presentation at the 17th International Corrosion Congress.

There is an interest in co-operation between the activities of the LRTAP Convention and the Malé Declaration as expressed in the exchange of letters between *Mr Keith Bull (LRTAP) and Mr.Surendra Shrestha(UNEP)* which were available. *Johan Tidblad* pointed out that the co-operation between the activities of the LRTAP Convention in Europe and Malé Declaration &APINA could be realised e.g. by invitation of representatives of Malé & APINA to ICP Materials meetings or even by organising a common meeting of the organisations.

24. Closing and date of next CORNET meeting

The next CORNET meeting will be held in the autumn of 2009 preferably in Nepal or in Hanoi (both subject to confirmation).

Johan Tidblad expressed thanks to all participants for joining the meeting, for their presentations and for the very fruitful discussions. A special thank was directed to APINA for hosting the meeting and especially to *Chozi Lungo* for the excellent organisation and kind hospitality

Appendix 2: List of Participants

APINA and Malé Declaration 2nd Corrosion Workshop and CORNET meeting on development of dose-response functions, stock of materials at risk, and evaluation of corrosion trends,
11th to 13th February 2008, Livingstone, Zambia

Asia	
Bhutan 1. Mr. Tashi Wangdi, Chemist/ Head of the Environment Unit, Bhutan Ferro and Alloy Co. Ltd, Phuntsholing Email: tashiwangdi@druknet.bt, Mobile: 00975- 17633596	**China** 2. Dr. Zhao Dawei Chongqing Institute of Environmental Science and Monitoring 37#, Jia Ling VL G-1, Jiang Bei District, Chongqing, Post Code: 400020, China Email: zhaodawei@cta.cq.cn
India 3. Dr.Dipankar Saha Scientist and In-charge, Central Pollution Control Board, Project office, 4-Dholpur House (near Chhipitola Xing), M. G. Road, Agra-282 001, India Tel.:91-562-2421548 Fax: 91-562-2421568, Cell No: 091-94-122 60942 Email : cpcbagra@rediffmail.com and cc_lab@dataone.in, mailcpcb@gmail.com	4. Dr. S.N. Das Scientist F & Deputy Director Regional Research Laboratory (CSIR) Govt. of India Bhubaneswar 751013 INDIA Tel: 91-674-2581636 (540 extn.) Email: sn_das@yahoo.com
Iran 5. Mr. Masood Zandi, Air Pollution Research Bureau-DOE Environmental Research Center, Hemmat Highway Pardisan Park Tehran, Islamic Republic of Iran Tel (O): 98-21-8267996, Fax (O): 98-21-8269920, Email: Zandi740@yahoo.com	**Maldives** 6. Mr. Ahmed Muslim, Assistant Climatologist Department of Meteorology, Orchid Building, Orchid magu Male', MALDIVES Tel.: 960 3326341 Mobile: 960 7773407 Fax: 960 3320021 Email: ahmedmuslim@hotmail.com

Nepal 7. Ms. Bidya Banmali Pradhan Environment Officer, MENRIS, International Centre for Integrated Mountain Development (ICIMOD), P.O. Box 3226, Kathmandu, Nepal Tel (O): 977-1-5525313 ext. 566; (R): 977-1-4253044, Fax: 977-1-5524509/5536747 Email: bbanmali@icimod.org	**Pakistan** 8. Mr. Sajid Mahmood Laboratory Assistant Pakistan Environmental Protection Agency (Pak-EPA) House #311, Main Margala road, Sector F-11/3, Islamabad 44000, Pakistan Tel: +92-51-9235142, Fax: +92-51-9267622 Mobile: +92-51-300-5066011 Email: searchline2001@yahoo.com
Sri Lanka 9. Mr. K.T.C.Ariyawansa Senior Environmental Officer Central Environmental Authority 104, Robert Gunawardana Mawatha Battaramulla, Sri Lanka Sri Lanka Tel: (O) 94-11-2278872 Email: champaka@cea.lk	**Vietnam** 10. Dr. Le Thi Hong Lien Atmospheric Corrosion Group, Institute of Materials Science, Vietnamese Academy of Science and Technnology. 18 Hoang Quoc Viet, Cau Giay, Hanoi E-mail: honglien@ims.vast.ac.vn
Africa	
South Africa 11. L Jay Foax Knowledge Applicator (metallurgy & Corrosion) Council for Scientific and Industrial Research (CSIR) Private Bag X28 Aucilland Park 2006 Johannesburg, South Africa Tel: +27118534567 Fax +27117266418 E-mail: ljfoax@csir.co.za	**Mozambique** 12. Lazaro Chissico Edvardo Mondlane University Department of Physics Private Address: B. Coop – RVA Jose. A. De Almeida No. 58 R/C ESQ Contact: +258-82-4993290 Maputo – Mozambique E-mail: malaba@vem.mz

Tanzania 13. Albert Geoffrey Mmari University of Dar-es-Salaam Physics Department P. O. Box 35063 Dar-es-Salaam, Tanzania Tel: +255 754 281 618 E-mail: Albert_Mamri@yahoo.com	**Zambabwe** 14. Godfrey Dombo University of Zimbabwe Department of Metallurgical Engineering P. O. Box MP 167 Mount Pleasant Harare, Zimbabwe Tel: +263 -4 – 303280 E-mail: gtdombo@yahoo.co.uk
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Resource Persons 17. Dr. Vladimir Kucera Scientific Consultant (Corrosion) Swerea/KIMAB AB P.O. Box 55970, SE-102 16 Stockholm, Sweden, Visitors: Drottning Kristinas vag 48 Phone: 46(0) 8 440 48 00 Direct: 46(0)86741725 Email: vladimir.kucera@kimab.com, www.swereakimab.se	18. Johan Tidblad Infrastructure Department (Corrosion) Swerea/KIMAB AB P.O. Box 55970, SE-102 16 Stockholm, Sweden, Visitors: Drottning Kristinas vag 48 Phone: 46(0) 8 440 48 00 Direct: 46(0)8674 17 33 Mobile: 46(0) 73 512 56 82 Email: vladimir.kucera@kimab.com, www.swereakimab.se
UNEP RRC.AP 19. Naw Wah Wah Htoo Programme Officer, UNEP RRC.AP, Asian Institute of Technology P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand Fax: 662 516 2125, Tel: 662 524 6234, Email: wahwah@rrcap.unep.org	

Appendix 3: Workshop Programme

APINA and Male Declaration 2nd Corrosion Workshop and CORNET Meeting
11-13 FEBRUARY 2008
LIVINGSTONE, ZAMBIA

Monday, 11th February 2008		
07.30	Registration	
	SESSION I –DEVELOPMENT OF DOSE-RESPONSE FUNCTIONS	
08.30	Welcome Opening Speech	APINA Corrosion Task Team Leader APINA Coordinator
08.45	Concept of dose-response functions and their applications	
09.30	Presentation of used databases for evaluation	Johan Tidblad
10.00	Statistical analysis using regression analysis	Johan Tidblad
10.30	**GROUP PHOTO/HEALTH BREAK**	
11.00	Statistical analysis using neural networks	Johan Tidblad
11.45	Statistical analyses performed by participants	Selected participants
12.30	Discussion on selection of dose-response functions	All
13.00	**LUNCH BREAK**	

	SESSION II – EVALUATION OF STOCK OF MATERIALS AT RISK AND COST CALCULATIONS	
14.00	Overview of methods used for stock at risk assessment	Vladimir Kucera
14.45	Present status of stock at risk study in Kathmandu, Nepal	Bidya Banmali Pradhan
15.30	**HEALTH BREAK**	
16.00	First results from exposure of corrosion kits	Johan Tidblad/Vladimir Kucera
16.45	Exposure of corrosion kits in Kathmandu, Nepal	Bidya Banmali Pradhan
17.30	**END OF DAY**	

Tuesday, 12th February 2008		
	SESSION II – EVALUATION OF STOCK OF MATERIALS AT RISK AND COST CALCULATIONS	
08.30	First results from exposure of corrosion kits	Johan Tidblad/Vladimir Kucera
09.30	Discussion on applicability of used methodologies for other regions	All
10.30	**HEALTH BREAK**	
	SESSION II – TRENDS OF CORROSION AND POLLUTION	
11.00	Evaluation of corrosion samples in individual countries	Representatives from India, China/Chongqing and Hong Kong, Malaysia, Vietnam, Thailand, South Africa, Zambia and Zimbabwe
12.30	**LUNCH BREAK**	
14.00	Comparison of samples evaluated in individual countries and samples evaluated at KIMAB	Johan Tidblad
14.45	Results from trend exposure	Johan Tidblad
15.30	**HEALTH BREAK**	
16.00	Discussion of time and scope of next trend exposure	All
17.00	**END OF DAY**	

Wednesday, February 13th 2008		
SESSION III – EXTENSION OF CORROSION NETWORK		
08.00	Description of exposures at new sites	Representatives from Iran, India, Nepal, Sri Lanka and Maldives
09.00	First results from exposure at new sites	Johan Tidblad / Vladimir Kucera
09.30	Protocol for collection of environmental data by individual participants	Johan Tidblad
10.00	Discussion of extension of CORNET	All
10.30	**TEA BREAK**	
	SESSION IV – OTHER BUSINESS	
11.00	Contribution to 17th International Corrosion Congress, 2008, Las Vegas	All
11.30	Discussion of scope of corrosion activities in phase IV of RAPIDC including co-ordination of APINA and Male activities.	All
12.00	Other business from members	All
12.30	Closing and date of next CORNET meeting	
13.00	**LUNCH. FREE AFTERNOON FOR VISITS TO PLACES OF INTEREST AND DINNER IN EVENING**	