Quality Audit at RIVM, 19 – 21 March 2001

Formal Statement

The audit conducted at RIVM in March 2001 was a 'dry run', made so that the proposed audit procedures could be considered and refined. Following the audit, the checklist items changed somewhat, and a new format was adopted for the presentation of the results. For this reason, a few items in the current checklist have not been fully assessed. During the present audit, it was not possible to observe the full calibration procedure for either instrument. A second visit to RIVM is planned for the spring of 2003.

Overview

The Laboratory of Radiation Research at the Dutch National Institute of Public Health and the Environment (RIVM) is responsible for providing assessments of present and future risks to public health and the environment from terrestrial UV radiation (UVR). The assessments are used for governmental policy-making and the supervision of public health. To this end, the work at RIVM is tailored to the continuous long-term monitoring of spectral UV irradiance in the Netherlands, which can be used to construct monthly and annual doses of effective UVR and thence to track any systematic changes in the local UV climate.

Spectral measurements have been made at the RIVM site in De Bilt (52.12° N 5.19° S) since January 1996. RIVM operates a Dilor spectroradiometer, housed in a movable container with a permanent site in the RIVM grounds (Figure 1). The horizon at the site lies mostly between 5 and 15 degrees altitude, with some nearby trees in the Northwest (Figure 2). The local surroundings are flat, with a mix of urban, woodland and agricultural cover.

The spectroradiometer records global spectral irradiance from 285 to 380 nm in steps of 0.5 nm (FWHM 0.3 nm). A complete scan takes about 9 minutes. Measurements are made continuously every 12 minutes from before sunrise until after sunset, 7 days a week, with breaks for calibration and maintenance. Occasionally, there are extended breaks (one or two weeks) when the instrument takes part in campaigns away from the RIVM site.

In addition to the spectroradiometer, two pyranometers and two biometers take measurements every minute, returning average values per scan.

A new spectroradiometer (also a Dilor) and calibration facility have recently been installed within a rooftop laboratory. This instrument is currently undergoing tests, making synchronised scans with the operational spectroradiometer. Once everything is functioning satisfactorily, the new instrument will operate continuously, and the existing Dilor will be moved to a local meteorological site. The older instrument will continue to take part in campaigns.

There are four full-time staff who work with the UV instruments and data. Between them, they dedicate approximately 5 days a week to routine maintenance, calibration, data collection and data analysis. Their experience in UV measurements goes back more than 10 years. New staff work alongside existing personnel for at least 3 months before taking over responsibility for any aspect of the UV-related work.

The operation at RIVM is highly organised and professional. Data are stored on a dedicated and centrally maintained server. The data files are held in a well-structured file system, with good records of all earlier versions and updates. Documents are also stored centrally on the data server, with clear and robust version control. All documentation and data files are immediately to hand.

RIVM was able to present a detailed and comprehensive description of the measurement and data analysis procedures, together with the results of their customary application. All aspects of the routine calibration, measurement and data analysis procedures are carefully documented and carried out according to well-defined and validated protocols. RIVM clearly have the resources, experience and motivation to achieve their objectives for data collection and analysis.

All procedures relating to data measurement and analysis are demonstrably repeatable and reproducible. Periodic internal audits ensure that the written protocols are followed. The measurement and collection of data are carried out diligently and to a high standard.

Despite some long-standing and continuing problems with the calibration of the mobile spectroradiometer using a 1 kW lamp, the on-going analysis and re-assessment of existing data suggest that difficulties in measuring changes in the instrument's sensitivity have been surmounted and that the extended data record is credible. While the calibration procedures were not examined in any detail on this visit, it is clear that some improvements could be made in the area of lamp husbandry.

The UV group at RIVM has access to superb resources and benefits greatly from the infrastructure and facilities available at RIVM. The mobile UV measuring station is well equipped and has proven to be exceptionally stable in operation. The new rooftop facility provides everything that is required for successful UV measurement, including instrumentation permanently mounted on an optical bench. The group also profits from the excellent knowledge and skills of the personnel. Two members of the group have more than a decade of experience. The technician responsible for the day-to-day maintenance and calibration of the spectroradiometer has more than six years experience.

RIVM have calculated the uncertainties in yearly doses of effective UV radiation, including detailed studies into the consequences of missing data. By supplementing spectral measurements with data from RB meters and model calculations, RIVM show that even large gaps in the data series can be accurately compensated for. (Typically, a loss of 10% of spectral data adds only 0.5% uncertainty to the yearly total). At the time of the audit, there was no uncertainty analysis for spectral UV irradiance or integrated irradiance, although RIVM plans to make such an analysis in the future. The provision of an uncertainty budget would add value to the data.

Figures

Figure 1. Mobile container housing RIVM Dilor spectroradiometer (looking North)

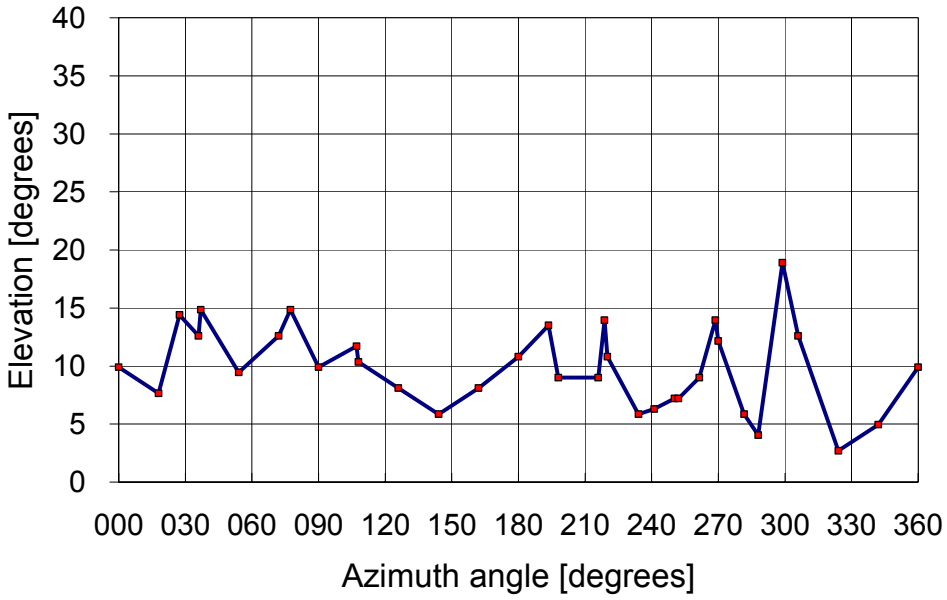


Figure 2. Horizon at RIVM site (North: 000/360, East: 090)

Summary

- The measuring site is highly representative of the local environment.

- The measurements made at the site are representative of the local conditions, although there are occasional breaks in the data series for one or two weeks when the spectroradiometer takes part in off-site campaigns. A new, permanent instrument, currently being commissioned, will soon obviate this limitation.

- The general standard of documentation and record keeping is exemplary. Much use is made of a Professional Quality Management Resource System, a document database which gives centralised storage and version control (earlier versions of documents and protocols are retained, together with record of dates for changes in any procedure). Every member of staff is able to find relevant documents within a matter of seconds.

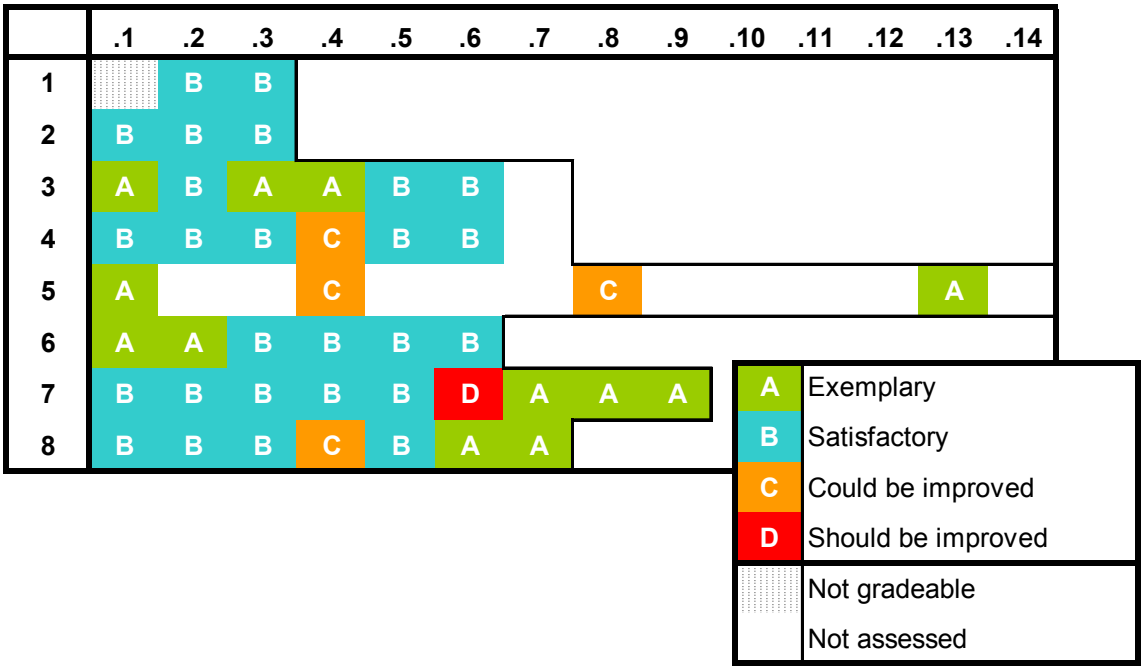
- All procedures relating to data measurement and analysis are demonstrably repeatable and reproducible and performed to a very high standard. Calibration and data collection procedures are rigorously documented. A periodic internal audit conducted by RIVM ensures that written protocols are followed.

- The facilities and resources available are sufficient for the site objectives to be fulfilled. The instrumentation, man-power and experience available to the Laboratory of Radiation Research at RIVM permits measurements to be made to a consistently high standard. The infrastructure of RIVM is a particular advantage, providing resources for a centralised documentation system, secure data storage and internal audits.

- The analysis of uncertainty in the yearly sums of erythemal UV irradiance is defendable. At present, there is no uncertainty analysis made for spectral irradiance, weighted irradiance or daily doses.

- The measurement and collection of data are carried out diligently and to a high standard.

Graded results



1. Resources and mission statement

1.1. The site mission statement: To undertake continuous long-term monitoring of spectral UV irradiance, which can be used to construct monthly and annual doses of effective UVR and thence to track any systematic changes in the local UV climate. To submit spectral and auxiliary data to the European UV Database.

1.2. One Dilor spectroradiometer (recording approximately 5 spectra/hour), two pyranometers and two biometers (recording once a minute and returning average values per scan) in mobile container. A new, stationary Dilor was being commissioned at the time of the audit.

1.3. At RIVM there are 4 members of staff involved with the regular measurement and analysis of UV irradiance, contributing the equivalent of about 18 person-months a year in total.

2. Location

2.1. Coordinates for longitude and latitude are available from GPS readings; the altitude is taken from a map reading.

2.2. The horizon has been measured using a theodolite; values are available in spreadsheet file; tall and close objects are described; distances are not given; no estimate of the influence of horizon on measurements of global irradiance has been made.

2.3. The measuring site is highly representative of the local environment. Local surroundings are very flat, with a mix of urban, woodland and agricultural cover at scales of 1 to 10 km and beyond.

3. Operational matters

3.1. All aspects of the site operation are rigorously documented in a systematic fashion. Full details of operational protocols are readily available. The itemised recipes for conducting calibrations, etc., are a joy to behold. Fortnightly meetings are held to discuss operational and procedural matters.

3.2. Sufficient manpower is available for the routine maintenance, calibration, data collection and data analysis tasks; The equivalent of one permanent post is dedicated to these tasks.

3.3. All staff concerned with operation of instruments and data analysis are highly qualified, with a minimum of 4 years experience.

3.4. Staff changes are infrequent. The last change occurred in 1999.

3.5. New staff work alongside existing personnel for at least 2 or 3 months before taking responsibility for tasks.

3.6. New calibration procedures were introduced following the SUSPEN campaign in 1998. Extra quality control procedures have been introduced following the development of the SHICrivm code in 1999.

3.7. The adoption of the WMO/GAW guidelines on site quality control is planned.

4. Instrumentation

4.1. The spectroradiometer and pyranometer have thorough and comprehensive user manuals, which include such details as a description of the instrument and its parts, information on all connections, an explanation of what the instrument is used for. Details of the instrument characteristics are also carefully documented and readily available, although some records were not up to date.

4.2. The spectroradiometer, pyranometer and biometers used for continuous monitoring are adequate for the fulfilment of the RIVM objectives; The occasional breaks in the data record, due to the instruments being taken off-site for remote campaigns, are not ideal, but the forthcoming introduction of a new, permanent spectroradiometer and associated broadband metres will considerably enhance the potential of the site. The addition of a PAR meter, or the equivalent, would enhance the value of the UV irradiance data for biological studies.

4.3. The slit function has been measured in 1997 and March 1999, and the angular response in 1997. The coarse properties of the slit function are verified indirectly through the routine application of the SHICrivm algorithm.

4.4. There is no measurement of the azimuthal dependence of the angular response. Uncertainties in the measurement and specification of the angular response are not estimated.

4.5. There is no periodic practical measurement of the wavelength dependence of the slit function, but the basic properties of the slit function are verified indirectly through the routine application of the SHICrivm algorithm.

4.6. Instruments are maintained as and when required.

4.7. Calibration of non-spectral instruments – not examined;

5. Calibrations

5.1. The standard forms used to record details of each calibration are a lesson in organisation. These are kept in addition to lab book summaries. The itemised

recipes for conducting calibrations, which include a list of pre-requisites and an introductory description of the calibration and all details of the apparatus and software used, are a joy to behold.

5.2. Standard calibration procedures – not examined;

5.3. One 1 kW lamp has exceeded the 50 hour certificate limit on burn time. 2 multimeters are each certified for 2 years. Both were last calibrated in 2001 (before this there were gaps of 6 and 8 years). Shunts, last calibrated in 1992 and 1996, are due to be calibrated later this year. The shunts and mulitmeters have not been compared.

5.4. All RIVM lamps have Optronic certificates. A future comparison of these lamps with a NIST- of PTB-traceable lamp is planned.

5.5. Lamp husbandry – not examined;

5.6. Source and age of lamps – not examined;

5.7. Level of agreement between lamps (internal consistency) – not examined;

5.8. No procedures are in place for the routine determination of lamp drift;

5.9. There is a monthly check on the instrument stability *in situ* with 200 W lamp; 1 kW calibrations are performed when there is significant instrument drift (typically once or twice a year).

5.10. Typical instrument drift between calibrations is less than 2%;

5.11. Evidence that the calibration is reliable at the quoted level of accuracy – not examined;

5.12. Level of repeatability/consistency in calibration regime – not examined;

5.13. The SHICrivm algorithm is applied to all data to determine any wavelength shift and apply appropriate corrections. Errors in the wavelength scale rarely exceed ±0.5 nm. In addition, wavelength calibrations are routinely performed with a mercury lamp. Monthly and yearly summaries of the detailed statistics are routinely generated, allowing for easy identification of both sudden change and slow drift in the instrument characteristics.

5.14. RIVM hopes to make an evaluation with the JRC calibration equipment in the near future;

6. Measurement regime

6.1. All aspects of the routine and exceptional measurement regime are clearly and rigorously documented;

6.2. There are detailed and comprehensive operating procedures for the routine measurement procedure;

6.3. Global spectral irradiance data are recorded continuously every day from before sunrise until after sunset. These data are supplemented with pyranometer and UV biometer measurements.

6.4. Global spectral irradiance is recorded from 285 to 380 nm in steps of 0.5 nm (FWHM 0.3 nm). A complete scan takes about 10 minutes.

6.5. Typical breaks in routine measurement of about 1 hour/week for backups, cleaning, etc., and an additional 2 hours/month for stability checks.

6.6. All aspects of the routine measurement regime are demonstrably repeatable.

7. Data Analysis

7.1. Data analysis procedures are well documented, although not at the standard of the measurement and calibration protocols. There are plans to place the analysis documentation at the same level as that for the measurement and calibration procedures. The methods used for resolving the effects of wave-

length shifts and slit width and for correcting for cosine errors have been published.

7.2. The present data analysis algorithm has been fixed since 1997. Any adaptations are applied retrospectively to the entire data set.

7.3. Wavelength errors are routinely analysed using the SHICrivm algorithm. Temperature-induced errors are determined. There is no estimate of the average or seasonal error introduced by dust on diffuser dome between weekly cleaning. There is no estimate of the influence of the local horizon on measurements, although any effect is expected to be small.

7.4. Cosine errors are routinely corrected for using pyranometer data, an estimate of the aerosol loading, a knowledge of the SZA and the instrument's angular response function (the typical correction is 6%). Wavelengths are shifted to a uniform grid, using an extraterrestrial spectrum and ozone structure for interpolation. There is no systematic correction for lamp-drift errors. Future plans include the identification and removal of spikes.

7.5. A combination of pyranometer data, ozone data and RT models are used to estimate missing values of daily doses. Pyranometer data are used when making the cosine correction.

7.6. At the time of the audit, no detailed uncertainty analysis was available for measurements of spectral UV irradiance or daily doses. Plans are afoot to estimate the uncertainty according to the procedure described in the WMO/GAW guidelines for site quality control or to prepare a more detailed uncertainty budget along the lines of that described in Bernhard and Seckmeyer (1999).

7.7. Careful and sophisticated estimates are made of the uncertainties in the values of yearly doses of effect UV radiation, including the effect of substituting modelled values for missing data [published].

7.8. Any changes to the irradiance scale are applied retrospectively to the entire data set. All previous versions of data are available from backup copies, with most available on-line. Datasets are labelled alphabetically according to version. At the time of the audit, the present data version was level '_d'. Suspect data are not removed from the dataset, but all problems or exceptional circumstances are described in monthly and yearly summaries.

7.9. Data are stored on a central server, with full automatic backup. The directory structure is clear and unambiguous. The most recent dataset is available on-line, together with all ancillary information and auxiliary data. The data version number is included in the header information of each data file.

8. Quality management

8.1. There is complete documentation of all quality control procedures, including the SHICrivm algorithm. Output of the algorithm are recorded. Summaries of various variables, such as the magnitude of any error in the wavelength scale, are prepared each month; Summary of summaries, detailing any problems or exceptional circumstances.

8.2. All spectra are passed through the SHICrivm algorithm, which measures and corrects wavelength errors.

8.3. The SHICrivm algorithm.

8.4. At the time of the audit, no detailed uncertainty analysis was available for the measurements of spectral UV irradiance or daily doses. Plans are afoot to estimate the uncertainty according to the procedure described in the

WMO/GAW guidelines for site quality control or to prepare a more detailed uncertainty budget along the lines of that described in Bernhard and Seckmeyer (1999);The WMO/GAW guidelines on site quality control of UV monitoring are not applied. Plans are afoot to estimate the uncertainty according to the procedure described in these guidelines.

8.5. The travelling spectroradiometer has taken part in several international intercomparisons. Overall, the spectral irradiance measured by the RIVM instrument during the NOGIC 2000 campaign (Sweden, June 2000) was within 2% to 3% of the reference spectrum. A similar result was obtained in the MAUVE/CUVRA campaign (Germany, March 1999). A blind comparison of measurements made during the SUSPEN 1997 campaign indicated large systematic errors. These errors were later shown to be attributable to an error in the calibration, and a retrospective correction brought the data to within 3% of the reference spectra. When new rooftop facility is commissioned, there will be possibilities of internal comparisons.

8.6. Any changes to the irradiance scale are applied retrospectively to the entire data set. Suspect data are not removed from the dataset, but all problems or exceptional circumstances are described in monthly and yearly summaries. Datasets are labelled alphabetically according to version. The data version number is included in the header information of each data file.

8.7. The Laboratory of Radiation Research at RIVM is subject to periodic internal audits, which ensure that the operational protocols are complete and adhered to, and appropriate records are kept.

RIVM comments

RIVM reply/action list related to EDUCE audit – January 2000

The major points we derive as action points are:

7.6 D (should be improved)

Establish an uncertainty budget for the spectral measurements and daily sums of UV.

Status: this evaluation is well underway and we now have a first draft version covering the majority of issues in the WMO guideline; the same holds for an analysis of the determination of daily doses of effective UV. For each day we can analyse the estimated uncertainty in the daily dose using the spectral measurements in combination with the pyranometer readings. Measuring spectra with 12 min time-steps we calculate a standard deviation of 2.2% for daily sums of CIE-weighted UV (somewhat less in clear sky conditions, somewhat larger under variable conditions). This uncertainty in view of it's randomness diminishes when monthly (this error contributes less than 0.4% for monthly sums) and yearly totals are calculated. An uncertainty analysis for yearly totals is already available.

5.4, 5.8 C (could be improved)

Order and use new calibration lamps from PTB and/or NIST, and establish a routine check (and correction) for lamp drifts, which adds to the presently operational information from the stability checks and the data-analysis from instrument intercomparisons (at the site and in campaigns), and systematic model-measurement comparisons.

Status: New calibration lamps have been ordered from PTB and a new procedure for routine checks and lamp drift analysis will be implemented in the first half year of 2002. A comparison of different calibration sources has shown lamp drift for the main calibration source to be within 2 % since 1998.

4.4 C (could be improved)

Azimuthal dependence of the flat diffuser will be further studied in 2002.

Minor points mentioned:

2.2 B

The influence of the horizon on the global irradiance will be analysed using the horizon as measured with the theodolite, in view of the open sky the influence is expected to be relatively small. The new set-up on top of the roof of one of the main buildings has no obstacles at all.

7.1 B

Further documentation of the data-analysis procedures is underway.

Improvements are planned: automatic spike detection will be included as part of the SHICrivm algorithm, which will also be made available to the EDUCE-community. Lamp drift checks: see point 2 above.

7.3 B

Dust effects on the dome are now evaluated in routine calibration checks, measuring prior and after cleaning of the dome.

7.4 B

Methods for automatic spike detection are included in the new version of SHICrivm which will be available early in 2002. Apart from SHIC-checks a routine for the detection and removal of erroneous spikes from spectra will be developed in 2002. Revised datasets will then be submitted to the EDUCE database.