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Recent work in ENIQ and related activities in Europe[1]

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Összefoglalás

Az ENIQ feladata és tevékenysége Európában

A cikk az 1992-ben alapított ENIQ (European Network for Inspection and Qualification), azaz az *ellenőrzés és minősítés európai hálózata* tevékenységét, és azokat az elsősorban atomerőművekben végzett időszakos roncsolásmentes vizsgálatokkal kapcsolatos munkákat ismerteti, amelyek inkább európai, mint nemzeti szinten folynak. Alapításakor az ENIQ a vizsgálatminősítésre koncentrált, de mára ezzel egyenértékű területévé vált a kockázati szempontokat figyelembe vevő időszakos vizsgálatok kérdésköre is.

Vizsgálatminősítés

Az ENIQ legjelentősebb eredménye az európai minősítési irányelvek publikálása [2], amit lényegében egész Európa alkalmaz.* Az irányelvben foglaltak gyakorlati alkalmazhatóságának ellenőrzése érdekében az ENIQ esettanulmányokat szervez. Az esettanulmányok keretében atomerőművek főberendezéseit szimuláló ellenőrző testeken hajtanak végre minősítést. Az első esettanulmány egy ausztenites csővezeték vizsgálatának minősítésével ([lásd pl. [1]), a jelenleg a befejezéséhez közeledő ***második esettanulmány*** egy forralóvizes atomerőmű plattírozott reaktortartálya csonkvarratának (*2. ábra*) gépesített ultrahangos vizsgálatával foglalkozik. Az utóbbi célja az, hogy megvizsgálja a műszaki bizonyításban rejlő potenciális lehetőségeket a teljes léptékű ellenőrző testeken végrehajtandó, és ezért rendkívül költséges gyakorlati vizsgák terjedelmének csökkentése vagy azok teljes elhagyása érdekében. A második esettanulmány, amelynek részleteit a cikk ismerteti, igazolja a műszaki bizonyítás lehetőségeit, de arra is rámutat, hogy ennek mértéke esetről esetre különböző lehet, és a vizsgálat bonyolultságától, a rendelkezésre álló információk mennyiségétől illetve új információhoz való jutás lehetőségétől függ. Világossá vált továbbá a vizsgálat modellezésének a jelentősége, amennyiben a modell kísérletileg verifikált és kizárólag az érvényességi tartományán belül alkalmazzák.

A vizsgálatminősítés európai módszertanának a támogatása érdekében ENIQ időről időre háttérdokumentumokat ad ki, amelyek a minősítés egy-egy területének javasolt gyakorlatát foglalják össze. Eddig nyolc *javasolt gyakorlat* dokumentumot adtak ki, amelyeket a cikk *1. táblázata* foglal össze.

A cikk ezt követően példákat sorol fel az európai módszertan alkalmazásáról különböző országokban, beleértve az Európai Unió új tagállamait is. Említett országok: Belgium, Csehország, Finnország, Svédország, Németország, Svájc** és az Egyesült Királyság.

Miután felismerték, hogy az európai minősítési irányelvekben foglaltak a nukleáris iparnál szélesebb körben is alkalmazhatók, a CEN (Commission for European Standardization), azaz az európai szabványosítási bizottság egy munkacsoportot hozott létre, amely kidolgozta és publikálta az ENIQ irány-elvekhez nagyon hasonló minősítési dokumentumot [5].

Kockázat-szempontú vizsgálatok

Egyre nagyobb érdeklődés mutatkozik a kockázati szempontokat figyelembe vevő időszakos vizsgálatok iránt, és miután az amerikai módszerek alkalmazása az európai hatósági környezetben nem egyszerű, az ENIQ egy erre vonatkozó keret jellegű dokumentumot dolgozott ki [7]. A dokumentum azokat az elveket foglalja össze, melyeket a kockázati szempontokat figyelembe vevő bármelyik koncepciónak tartalmaznia kell.

A különböző módszerek összehasonlítása céljából az ENIQ – együttműködve az OECD / NEA-vel – a RISMET (Risk-Informed ISI Methodologies) projektet indította el. A projektnek több mint húsz résztvevője van Európából, Észak-Amerikából, Japánból, valamint csatlakozott hozzá a Nemzetközi Atomenergia Ügynökség is. A projekt célja, hogy összehasonlítsa a különböző módszereket, amelyeket ugyanazokra a csővezeték rendszerekre alkalmaznak. A kiválasztott rendszerek a következők: egy svéd atomerőmű reaktor hűtőköre, üzemzavari hűtőrendszere, főgőz rendszere és kondenzátum rendszere.

A kockázati szempontokat figyelembe vevő vizsgálatok, és a vizsgálatminősítés közötti kapcsolat jelentőségét felismerték. Ezért a kockázati szempontokat figyelembe vevő koncepció a vizsgálat megbízhatóságának kvantitatív megadását igényli annak érdekében, hogy a kockázat csökkentését kifejezhesse. Ideális esetben ezt egy POD-görbe (Probability of Detection), azaz a hiba detektálásának valószínűségét kifejező görbe fejezné ki, de ezt a mai minősítések az ellenőrző testek, illetve az azokban el-

[1] Invited plenary lecture for the 5th Int. Conf. in Relation to Structural Integrity for Nuclear and Pressurized Components, 10–12 May, 2006, San Diego, CA. USA; Received: 15th May, 2006
[2] British Energy (ENIQ Chairman)
[3] JRC, Petten (ENIQ Network Manager)

* A magyar nukleáris hatóság is elfogadta az európai irányelveket és javasolta a Paksi Atomerőműnek annak követését.
** Habár Svájc nem tagja az Európai Uniónak, alapító tagja az ENIQ-nek

helyezett mesterséges folytonossági hiányok korlátozott száma miatt nem tudják előállítani. ENIQ azon dolgozik, hogy erre a kérdésre megoldást javasoljon.

A jövő feladatai: Az atomerőművek időszakos vizsgálataival kapcsolatos jövőbeni kutatási igényeket kívánja azonosítani az idén befejeződő GAIN projekt (Gap Analysis for Long Term Inspection Needs of Nuclear Plants). A projekt mind a felhasználói mind a hatósági igényeket figyelembe veszi. Az ENIQ pedig saját tevékenységi körében azt tervezi, hogy megújítja az európai vizsgálatminősítési irányelvet, valamint további *javasolt gyakorlat* típusú dokumentumokat ad ki; továbbá azt, hogy jövőbeni tevékenysége középpontjába a kockázatalapú vizsgálatok és a szerkezeti megbízhatósági modellel kapcsolatát, valamint a minősítés és a kockázat kapcsolatának számszerűsítését állítja.

Introduction

This paper describes recent work within ENIQ (the European Network for Inspection and Qualification), together with related activities within Europe, concentrating on those which are organised at European rather than national level. Recent ENIQ-related developments within individual countries are also discussed briefly. To some extent the paper updates a similar overview paper presented at the previous conference in this series [1], which also gave an overview of the history of ENIQ since its foundation in 1992.

ENIQ is perhaps the leading forum within Europe for the development and promotion of a harmonised European approach on issues relating to the in-service inspection of nuclear power plants. ENIQ also acts as a network for the exchange of information and views among its members.

Initially ENIQ focussed on inspection qualification, but more recently it has also been addressing risk-informed in-service inspection issues. ENIQ currently comprises a Steering Committee and two Task.Groups (*Figure 1*). The Steering Committee consists of voting members who are from utilities, and non-voting members who are invited onto the Committee by the voting members. The Chairmen of the two Task Groups are automatically members of the Steering Committee. All EU countries having nuclear power plant, together with Switzerland, are currently members of ENIQ, and recently the IAEA have begun to attend Steering Committee meetings as an observer.

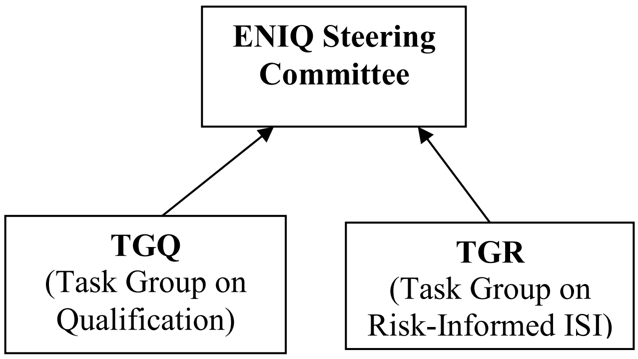

Figure 1: *Current structure of ENIQ*

1. ábra. *Az ENIQ jelenlegi szervezete: a Minősítő (TGQ) és a Kockázatalapú állapotellenőrző (TGR) csoport munkáját a Szervezőbizottság fogja össze*

Inspection qualification activities – recent developments

Second Pilot Study

A key achievement of ENIQ has been the issue of the European Qualification Methodology Document [2], which has been widely adopted across Europe. This document defines an approach to the qualification of inspection procedures, equipment and personnel based on a combination of technical justification (TJ) and test piece trials (open or blind). The TJ is a crucial element in the ENIQ approach, containing evidence justifying that the proposed inspection will meet its objectives in terms of defect detection and sizing capability. A Qualification Body reviews the TJ and the results of any test piece trials and issues the qualification certificates.

In order to test the European qualification methodology, two pilot studies have been conducted in which qualifications have been performed for inspections of mock-ups simulating specific plant components. The First Pilot Study, on an austenitic pipework weld, is complete and has been reported elsewhere (see e.g. [1]). A Second Pilot Study is now nearing completion, for an automated ultrasonic inspection of a clad ferritic BWR-type nozzle-to-shell weld. The aim of this study was to explore the potential of a TJ to reduce or remove the need for full-scale practical trials on mock-ups

In this Second Pilot Study, a full-scale test piece containing artificially inserted defects was made to simulate the real component (*Figure 2*). A specification was drawn up of the defects which the inspection was required to find, and an automated ultrasonic inspection was designed to detect them. A TJ was written which predicted whether the designated inspection would be successful in detecting the specified defects. The evidence in the

TJ came mainly from physical reasoning, theoretical modelling and results from previous work. The effect of the cladding was quantified partly using new experimental measurements on a clad "parametric studies" block, and partly from existing evidence in the literature. The predictions of the TJ were then compared with experimental measurements taken on the defects in the test piece – these measurements simulated the actual inspection of the component.

This exercise was largely successful in demonstrating that TJs have the potential to predict the outcome of specific inspections and thus to reduce or remove the need for large-scale test pieces in qualification. However, the extent to which this can be done in practice will vary from case to case, depending on the difficulty of the inspection, the availability of relevant existing data and the ability and resources to generate new data which can be used in the TJ. The exercise also showed the value of theoretical modelling, but emphasised the importance of only using models which have been experimentally validated and using them within their regimes of validity.

Further details of the Second Pilot Study can be found in a companion paper at this conference [3].

***Figure 2:** Test piece for ENIQ Second Pilot Study*

***2. ábra.** Ellenőrző test az EINQ második esettanulmányához*

Recommended Practices

RP number	Title	Issue no	Issue date	Report number
RP1	Influential/essential parameters	2	Jun 05	EUR 21751 EN
RP2	Recommended contents for a technical justification	1	Jul 98	EUR 18099 EN
RP3	Strategy document for a technical justification	1	Jul 98	EUR 18100 EN
RP4	Recommended contents for the qualification dossier	1	Feb 99	EUR 18685 EN
RP5	Guidelines for the design of test pieces and conduct of test piece trials	1	Feb 99	EUR 18686 EN
RP6	The use of modelling in inspection qualification	1	Dec 99	EUR 19017 EN
RP7	Recommended general requirements for a body operating qualification of non-destructive tests	1	Jun 02	EUR 20395 EN
RP8	Qualification levels and approaches	1	Jun 05	EUR 21761 EN
	ENIQ Glossary	2	Dec 99	EUR 18102 EN

***Table 1:** List of ENIQ Recommended Practices* **(available on the ENIQ website http://safelife.jrc.nl/eniq/)**

***1. táblázat.** Az ENIQ ajánlott gyakorlatának jegyzéke* (elérhető az ENIQ honlapján: http://safelife.jrc.nl/eniq/)

The European Qualification Methodology Document [2] is supported by eight issued Recommended Practices (*Table 1*), covering various aspects of qualification in more detail. All these documents provide guidance on conducting qualification, while retaining the flexibility to allow detailed variations in implementation between different countries.

Recent developments on Recommended Practices include a new issue of RP1 on influential and essential parameters, and the first issue of RP8 on qualification levels and approaches. A brief overview of these developments is given here; more detail can be found in another companion paper at this conference [4].

RP1 was revised to simplify and clarify the recommended approach to the treatment of influential and essential parameters, following feedback from users on applying Issue 1. This is a good example of how the Recommended Practices are regarded as "living documents", to be reviewed periodically in the light of feedback from users.

The influential parameters are those parameters (for example defect orientation or probe beam angle) which can potentially affect the outcome of an inspection, while the essential parameters are those which could actually affect the outcome of a specific inspection in such a way that the inspection would no longer meet its objectives. The main changes from Issue 1 of RP1 are:

- Combining the Procedure and Equipment Parameter Groups into a single Inspection System Group.
- Clarification that the non-inclusion of parameters which are clearly non-essential need not be justified in the TJ.
- Removal of the distinction between essential Inspection System parameters which are "fixed within a tolerance" and those "covering a range". Instead these parameters are categorised into so-called "Set 1" parameters (those which particularly affect the outcome of the inspection) and "Set 2" parameters (those which only affect the outcome if they differ substantially from their chosen values).
- Confirmation that the essential parameters should be listed in a table in the TJ, but with clarification of how each type of parameter (Input, Inspection System Set 1, Inspection System Set 2) should be addressed.

RP8 is a new Recommended Practice on qualification levels and approaches. It recognises that some countries or organisations might wish to introduce the concept of different qualification levels, depending on the assurance required that the inspection will attain its objectives in demonstrating structural integrity. One method of setting the qualify-cation level is using a risk-informed methodology, and the RP provides some guidance in doing this.

The qualification level in turn acts as one of the inputs in determining the qualification approach, that is, the range of qualification activities needed to achieve the desired qualification level. This qualification approach will depend on the difficulty or novelty of the proposed inspection as well as the qualification level itself. The chosen qualification approach will affect various aspects of qualification such as the realism of the test pieces used (full-scale, simplified, or flat plates), the requirements for the Qualification Body and the QA arrangements.

Examples of recent developments in qualification in European countries

The ENIQ approach to qualification has now been widely adopted across Europe, including the new EU members, and many successful qualifications have been completed. Several countries have set up their own qualification bodies. ENIQ members regularly report to ENIQ Steering Committee meetings on developments in their individual countries under a standing item on the agenda. Recent reports include:

- An update on qualification work in Belgium on RPV and primary circuit welds, including inconel safe-end welds.
- An update on the extensive qualification programme for VVER components underway in the Czech Republic.
- 10-15 qualifications underway in Finland, together with preparation of qualification of pre-service inspections at Olkiluoto 3, the new European Pressurised Reactor power station now under construction.
- Contacts initialised between Sweden and Finland to promote the mutual recognition of inspection qualification and intensify bilateral collaboration.
- A pilot study in progress to investigate the feasibility of introducing the ENIQ qualification methodology in Germany.
- A review of its activities by the Swedish Qualification Centre, which has now been in existence for 10 years.
- A 10-year timescale introduced in Switzerland in 2003 for the implementation of qualification.
- A qualification of the ultrasonic inspection of studbolts in boiler closure units at AGR power stations in the UK; also the qualified inspections of the Sizewell B RPV at the end of the first 10 years of operation.

There are several papers at this conference, from the Czech Republic, France, Germany, Sweden and the UK, describing recent developments in individual countries in more detail.

CEN Published Document on inspection qualification

Following preparation of the ENIQ Qualification Methodology Document [2], several people felt that a document describing a qualification methodology could also be of value outside the nuclear power industry. A proposal was therefore put to the CEN Technical Committee CEN/TC138 to work on developing such a document. This proposal was accepted on a vote, a Working Group (WG9) was set up under the convenorship of JRC Petten, and work began in 1999. The main reference documents were the ENIQ Methodology Document, a draft British Standard and a German DIN Standard. Seven technical meetings of WG9 were held over the next 3 years, resulting in an agreed document which was approved by CEN in September 2004. This Published Document [5] has much in common with the ENIQ Methodology Document.

Risk-informed inspection activities – Recent developments

There is a growing interest in moving towards risk-informed ISI approaches in several European countries [6]. In most cases, the US methodologies cannot be directly adopted as such, since they were originally developed in the US regulatory environment. Thus in many European countries activities are ongoing both to carry out their own methodology development and to adjust the US methodologies to comply with national requirements.

The European Framework Document for Risk Informed In-Service Inspection

At a European level, as a result of the work of ENIQ TGR, the European Framework Document for Risk Informed In-Service Inspection [7] was published in 2005. It is intended to serve as guidelines both for organisations developing their own RI-ISI approaches and for those using or adapting already established approaches to the European environment taking into account utility-specific characteristics and national regulatory requirements. The scope of the document is limited to setting out the principles that a body carrying out RI-ISI should follow. The decision on whether a risk-informed approach should or should not be applied when devising an inspection strategy is a matter for agreement between the parties involved.

The document identifies the key principles that any RI-ISI approach needs to meet, regardless of the level of quantification in the assessment of failure probabilities and consequences. However, purely qualitative methods that do not use the Probabilistic Safety Assessment (PSA) approach in order to define the consequences of failure, or any form of structural assessment to determine the probability of failure, are not considered in the document. The document is intended to be flexible so that different countries can use it to develop RI-ISI programmes which are consistent throughout Europe but which also meet their different national legal, regulatory and technical requirements.

The following key elements constituting the process of risk-informed ISI planning are identified in the Framework Document: (1) assurance of the long-term commitment of senior management to the risk-informed methodology; (2) formation of the RI-ISI assessment team; (3) definition of the scope of the equipment/structures to be considered in the application; (4) collection and analysis of the information required to carry out the risk assessment; (5) definition of the level of the evaluation; (6) assessment of the probability of failure for all the components included in the scope of the application; (7) assessment of the consequences of failure for all the components included in the scope of the application; (8) ranking the risk associated with all the components; (9) carrying out sensitivity studies to determine the impact of changes in key assumptions or data; (10) choice of the components to be inspected according to chosen criteria; (11) assessment of the implications for inspection qualification; (12) feedback of the obtained information after completing the inspection. The European Framework Document for RI-ISI can be downloaded from the ENIQ website: http://safelife.jrc.nl/eniq/.

International benchmark of RI-ISI methodologies – RISMET

The benchmarking of various RI-ISI methodologies was considered as one of the top priorities for ENIQ TGR. At present, there is no known direct comparison of different RI-ISI methodologies applied to an identical scope of components (system, class, etc.). Several international groups and committees have given recommendations and support for performing a benchmarking of various RI-ISI approaches (NRWG, OECD/NEA CSNI, ENIQ TGR, several national regulators etc.).

A benchmark project called RISMET – Risk-Informed ISI Methodologies – has been successfully launched in co-operation between JRC, TGR and the OECD Nuclear Energy Agency. The project has more than twenty participating organisations from Europe, USA, Canada and Japan, including also the IAEA. More than half of the participants are also members of TGR.

The overall objective of the project is to apply various RI-ISI methodologies to the same case, namely, selected pipe work systems at Ringhals NPP: the reactor coolant system, the safety injection system, the main steam system and the condensate system. The comparative study aims at identifying the impact of the differences in methodologies on the final results, i.e. the definition of the risk-informed inspection programme. In addition, one objective is to identify how the various approaches fulfil requirements and recommendations put forward in the ENIQ Framework Document for RI-ISI [7], in the

NRWG document [8] and in the NURBIM project. More information regarding the RISMET project can be found at http://safelife.jrc.nl/eniq/projects/RISMET.

Link between risk-informed ISI and inspection qualification

It is recognised that there is an important link between risk-informed ISI and inspection qualification. The RI-ISI approach requires a quantitative measure of inspection effectiveness in order to calculate the reduction in risk associated with the inspection. Ideally this would be provided through a probability of detection (POD) curve, and it would be helpful if inspection qualification could provide this POD information.

In reality, however, the outcome of an inspection qualification is usually expressed in qualitative terms, for example a statement that there is "high confidence" that the required inspection capability will be achieved. Quantitative statements based purely on factual evidence are difficult to make, because of the limited number of artificial defects introduced into any test pieces, and the problems of quantifying, in POD terms, any other evidence included in the TJ such as theoretical modelling predictions or results obtained from the literature.

Nevertheless, some possible methods for quantifying the POD have been proposed. One approach uses Bayesian modelling of the qualification process [9, 10] in which the "degree of belief" in the TJ is expressed in probabilistic terms, and then combined with the results of any practical trials. Work is about to start on applying this approach to a particular case study of a completed qualification of an ultrasonic inspection on Magnox power plant in the UK.

Another approach is to produce a user-defined POD curve as a target for qualification. This could be a simple curve such as a step-function. The results of work currently underway on relating POD to the margin of detection (signal to noise level or signal relative to reporting threshold) could be of value here. The user-defined POD curves could also be related to the risk reduction and the inspection interval. The objective of the qualification body would then be to assess whether or not the user-defined POD curve can be considered a lower bound for the NDT system under consideration.

Analysis of future R&D needs for nuclear plant

An ongoing European attempt to identify future research needs in the area of ISI is the GAIN project. GAIN – Gap Analysis for Long Term Inspection Needs of Nuclear Plant – is a project under the EURATOM Framework Program 6, funded by the European Commission. The three partners involved are Mitsui Babcock Technology, JRC Petten and the Nuclear Research Institute in the Czech Republic (NRI Rez).

The objective of the study is to identify the medium- to long-term inspection needs of the nuclear industry, assess where these can be met by recent/current research and technological development work (including EC Programmes), and perform a gap analysis which will attempt to direct future EC Research and Technological Development (RTD) activities and other initiatives.

The main activities are:

- Identification of desired future inspection methods/tools/strategies as well as training needs ("wish-list") through a questionnaire. This questionnaire has been addressed to "end users", meaning utilities and regulatory bodies. The replies received give good coverage of European Union countries as well as other east European countries with nuclear power, and should provide a very good insight of future research needs.
- Review of recent and current research and technological development (including training sources and unique facilities) relevant to nuclear inspection needs.
- Match-making of recent and current work to plant operators' and regulators' wish-lists.
- Analysis of gaps between recent and current work and plant operators' and regulators' wish-lists, so as to identify those gaps which could best be addressed either by future EC activities or other forms of collaboration (e.g. cost sharing).
- The project will end with a workshop where the results of the analysis are presented to, and discussed with, the end users (nuclear utilities and regulators). This workshop is to be held in Prague on 7-8 June 2006.

The project will publish a final report containing the main findings of the study. It is envisaged that the result will form part of a European research strategy for the future and will facilitate the formation of European consortia for future R&D projects.

Future work within ENIQ

As the Framework Document provides general principles without going into details of RI-ISI implementation, ENIQ recognised the need to produce more detailed Recommended Practices and discussion documents on several RI-ISI related issues. TGR identified the following list of issues that would need further consideration within the group, and now form part of its work programme:

- Interaction between RI-ISI and inspection qualification;
- Guidelines for expert panels;
- Guidelines for use of PSA in RI-ISI;
- Defence in depth issues;
- Expert elicitation for degradation mechanisms;
- Interaction between structural reliability models (SRM) and databases; verification and validation of SRM codes;
- RI-ISI application for internals and RPV.

TGR members are also involved with the RISMET benchmarking project described above, and in the work linking RI-ISI to inspection qualification.

On the TGQ side, it has been recognised that several of the qualification documents, including the European Qualification Methodology Document [2], are now getting quite old and are in need of some review and possible revision. Initially TGQ is planning to review the Methodology Document and the two Recommended Practices (2 and 3) relating to TJs. Some further work is also still needed to complete the Second Pilot Study, mainly the destructive examination of the test piece.

In the longer term, ENIQ remains ready to address any inspection-related issues which can benefit from a co-ordinated approach at the European level. The output of the GAIN project is likely to be helpful in identifying these issues. International collaboration, through organisations such as the IAEA and OECD/NEA, is also likely to increase

Conclusions

1. ENIQ has played a central role in the development of a European approach to inspection qualification, through the issue of the European Qualification Methodology Document and its supporting Recommended Practices.
2. ENIQ has complemented this work on qualification with recent significant work in the field of risk-informed in-service inspection, including the production of the ENIQ Framework Document on RI-ISI.
3. The ENIQ approach to qualification has been widely adopted across Europe, including the new EU members. Several qualification bodies have been set up and many qualifications have been successfully completed.
4. The RISMET project will provide a useful benchmarking exercise for the different RI-ISI methodologies.
5. Areas of work within ENIQ for the immediate future have been identified for both TGQ and TGR. The GAIN project is likely to provide useful input into longer-term plans.

Additional information concerning ENIQ and its task groups and activities, as well as publications, can be obtained from the ENIQ website:

http://safelife.jrc.nl/eniq/.

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