SFT Report 1759/2000

Development of HARP Guidelines

Harmonised Quantification and Reporting Procedures for Nutrients

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Preface

Ministers at the Fourth North Sea Conference invited Norway to develop transparent and harmonised quantification and reporting procedures for nutrients. Norway has responded to this invitation by developing such procedures through the HARP project. Although the HARP project has been administrated and co-ordinated by Norway, i.e.

initiated by the Norwegian Ministry of Environment,
operated by the Norwegian Pollution Control Authority (SFT) and
managed by the Norwegian Institute for Water Research (NIVA),

it has had a broad participation of relevant international organisations and countries (administrators and scientists) in its development process.

A large number of civil servants and scientific researchers in Europe have contributed substantially to the development of the nine HARP Guidelines. In particular the project co-ordinators would like to thank:

Mr Lars M. Svendsen (Denmark)
Mr Horst Behrendt and Ms Heike Herata (Germany)
Mr Paul Boers and Ms Jeannette Plokker (the Netherlands),
Mr Jean Duchemin (DG Environment of the EC),
Mr Nils Vagstad and Mr Per Stålnacke, Norway
Mr Markus Braun, Switzerland
Mr Norman Thorp and Mr Martyn Silgram (the UK)

for their invaluable contributions. We would also like to thank Ms Linn Bryhn Jacobsen (SFT) for her 'heroic and successful struggle' to link and format all Guidelines into one 'harmonised and transparent' layout.

Furthermore, the project co-ordinators would like to emphasis that without the flexibility of Norwegian Authorities in adapting to changes in time-schedules and resource requirements throughout the HARP process, the development of the HARP Guidelines would not have been possible. Although the project has experienced difficult moments where differences in cultural and scientific backgrounds have emerged, this has only increased the 'fascination' of the project and enabled the substantial achievement of agreeing on nine Guidelines on difficult issues in a, for international organisations, short time span.

Oslo 1 December 2000

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The HARP Process

1. Background

In 1990, Ministers at the Third North Sea Conference asked for harmonised reporting systems and procedures for nutrients. This request was reiterated several times, most recently at the 4th North Sea Conference (4NSC), and the issue has been part of the Oslo and Paris Commissions' Action Plan (OSPAR) since 1992.

The background for the request for a harmonised reporting was, *inter alia*, that

- there were different practices among North Sea States concerning reporting on discharges and losses of nutrients to freshwater systems and marine waters. Belgium, France, Germany, the Netherlands and Switzerland based their reports on discharges/losses to surface waters. United Kingdom based its report on monitored riverine inputs and direct discharges to marine waters, whilst Denmark, Norway and Sweden provided figures both for inputs to surface waters (inland waters and marine waters) and inputs to the North Sea;

- the reports were generally based on "national interpretation" on how elements such as sampling frequency, calculation methods and the sources to be taken into account should be considered;

- there was considerable uncertainty related to the calculations of the nutrient inputs, in particular with regard to the 1985 input figures, but also with regard to today's nutrient inputs.

The calculation methods, the sources to be taken into account when reporting on inputs/discharges/losses of nutrients were, at various degrees, left to the discretion of each country within the relevant international organisations where reporting took place. The reporting systems and procedures amongst countries varied both with regard to calculation methods and sources, which were taken into account; in particular, there were significant differences in the methodologies used for quantifying the losses from the agricultural sector. Some of these differences stemmed from the fact that parties involved had (and have) different geography, geology as well as different ways of administrating the environmental issues of concern.

It is important to remember that HELCOM, OSPAR and the Rhine Commission all have a 50% reduction target on nutrient inputs. However, no internationally agreed quantification methodologies existed that could be applied in order to achieve the objective of Ministers at the 4NSC, namely: "to promote and co-ordinate the necessary reporting systems and procedures as a basis for transparent, reliable and comparable reports, including relevant sources, basic figures, calculation methods and emission factors".

Between 1990 and 1995 the Oslo and Paris Commissions prepared overview reports from all North Sea States on the (reduction of) inputs of nutrient from various sources. There was neither any agreed reporting format, nor any agreed procedures on how to calculate/estimate nutrient inputs. This was therefore left to the discretion of each country. The national reports showed that there were large differences in the reporting systems and procedures amongst countries concerned, as well as in the way the 50% reduction target was interpreted.

At the 4NSC, the Ministers invited Norway, as a host country for the 5th North Sea Conference (5NSC), in co-operation with the European Commission and the European Environmental Agency, to offer its services as lead country within OSPAR, to promote and co-ordinate the necessary reporting systems and Procedures, as a basis for transparent, reliable and comparable reports, including relevant sources, basic figures, calculation methods and emission factors.

2. Planning

The Norwegian Ministry of Environment initiated the work in 1996 and gave the operational responsibility of this task to the Norwegian Pollution Control Authority (SFT). SFT commissioned the Norwegian Institute for Water Research (NIVA) to start the planning of a project with the objective of developing harmonised quantification and reporting procedures for nutrients.

John Rune Selvik (project owner representative/SFT) and Stig A. Borgvang (project leader/NIVA) have co-ordinated the work (HARP Project co-ordinators).

At the very beginning of the project, the HARP Project co-ordinators established a Work Plan for the development of the Harmonised Quantification and Reporting Systems and Procedures. The Work Plan was circulated to North Sea Senior Officials (CONSSO) and OSPAR contact points for comments. A stepwise procedure was chosen which consisted of:

- the development of an Overview of current reporting systems and procedures for nutrients within "OSPAR countries";
- the development of detailed descriptions of major elements/processes, which would be part of Harmonised Quantification and Reporting Systems and Procedures, such as:
  - -principles for calculating retention of nutrients in freshwater systems and coastal areas;
  - -principles for estimating the background load of nutrients;
- the organisation of a workshop in order to give further impetus to the work;
- the development of Harmonised Quantification and Reporting Systems and Procedures for nutrients, including the following sectors:
  - -agriculture;
  - -industry;
  - -treatment of sewage;
  - -aquaculture;
  - -forests;
  - -uncultivated areas;
  - -atmospheric deposition on water bodies
- the organisation of a Pilot Study in order implement on a trial basis the draft Harmonised Quantification and Reporting Systems and Procedures;
- formal hearings/consultations on the basis of HARP with the EU and with OSPAR countries; and
- the adoption of HARP within OSPAR.

3. Prioritisation of the work

Review of existing reporting systems

As decided by CONSSO95, Norway prepared a draft Review of existing reporting systems and procedures within relevant international organisations for the Committee of North Sea Senior Officials at their meeting in 1996 (CONSSO June96). The review was an attempt to summarise some of the existing reporting systems and procedures on nutrients within relevant international organisations in Europe and in some North Sea States (See Annex 2). It can be seen as a first attempt to clarify the situation with regard to quantification and reporting systems and procedures on nutrients, as well as a starting point for categorising and prioritising the work in this field.

In 1996-1997, the HARP Project co-ordinators had meetings with representatives from the EC, EEA, HELCOM, OSPAR and the Rhine Commission in order to elucidate the scope of the end-user commitments and needs. These meetings showed that there was an overall interest in this harmonisation work in order to follow up the commitment made, *inter alia*, by Ministers at the 4NSC, but also in the various OSPAR Action Plans. All these organisations expressed their willingness to participate in the work to the extent possible e.g. by commenting on the drafts to come. In this process, the EC underlined the European dimension of such a development and encouraged the co-ordinators to send information to other European Countries than the OSPAR Contracting Parties.

The HARP Project co-ordinators volunteered to submit important drafts in the HARP development to relevant organisations for comments, as well as to all OSPAR countries.

Identification of Key Issues

In 1996, Norway undertook to take the lead within OSPAR on the development of harmonised quantification and reporting procedures. A series of key issues/elements to be included in the further development were discussed at the OSPAR Working Group on Nutrients (NUT) in 1997, starting with the very basic requirements shown in Figure 1 below. The advice given on these questions were taken as basis for further discussions on the topic at the HARP workshop in Norway in 1998.

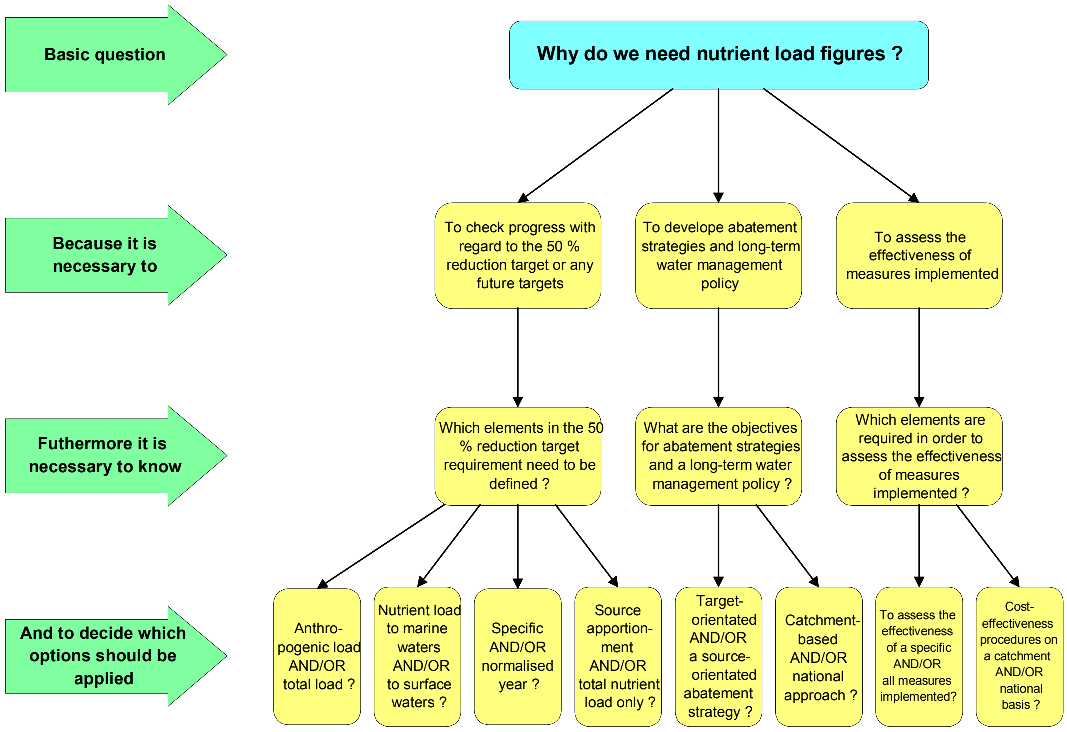

Figure 1. *Background for the outline of key issues discussed at OSPAR NUT 1997.*

Workshop

The HARP Workshop was organised by Norway, the DGXI of the EC and the EEA 26-29 January 1998 in order to give further impetus to the work on harmonisation of quantification and reporting procedures for nutrients. A consultation meeting was held in Oslo 6 October 1998 in order to finalise the programme. The Workshop was attended by more than 80 participants from 15 countries and 8 international organisations, i.e. all Contracting Parties/signatories to OSPAR, except Iceland and Luxembourg.

Starting points for discussions were the recommendations from OSPAR's working group on nutrients (NUT) as regard key issues /main elements to be included in HARP. The workshop gave further clarification of the delimitation of the project and the elements, which were to be included in HARP in order to achieve co-ordination between international organisations and to harmonise national quantification methods and reporting procedures. Figure 2 below shows some selected elements and the consequences for the reporting procedures.

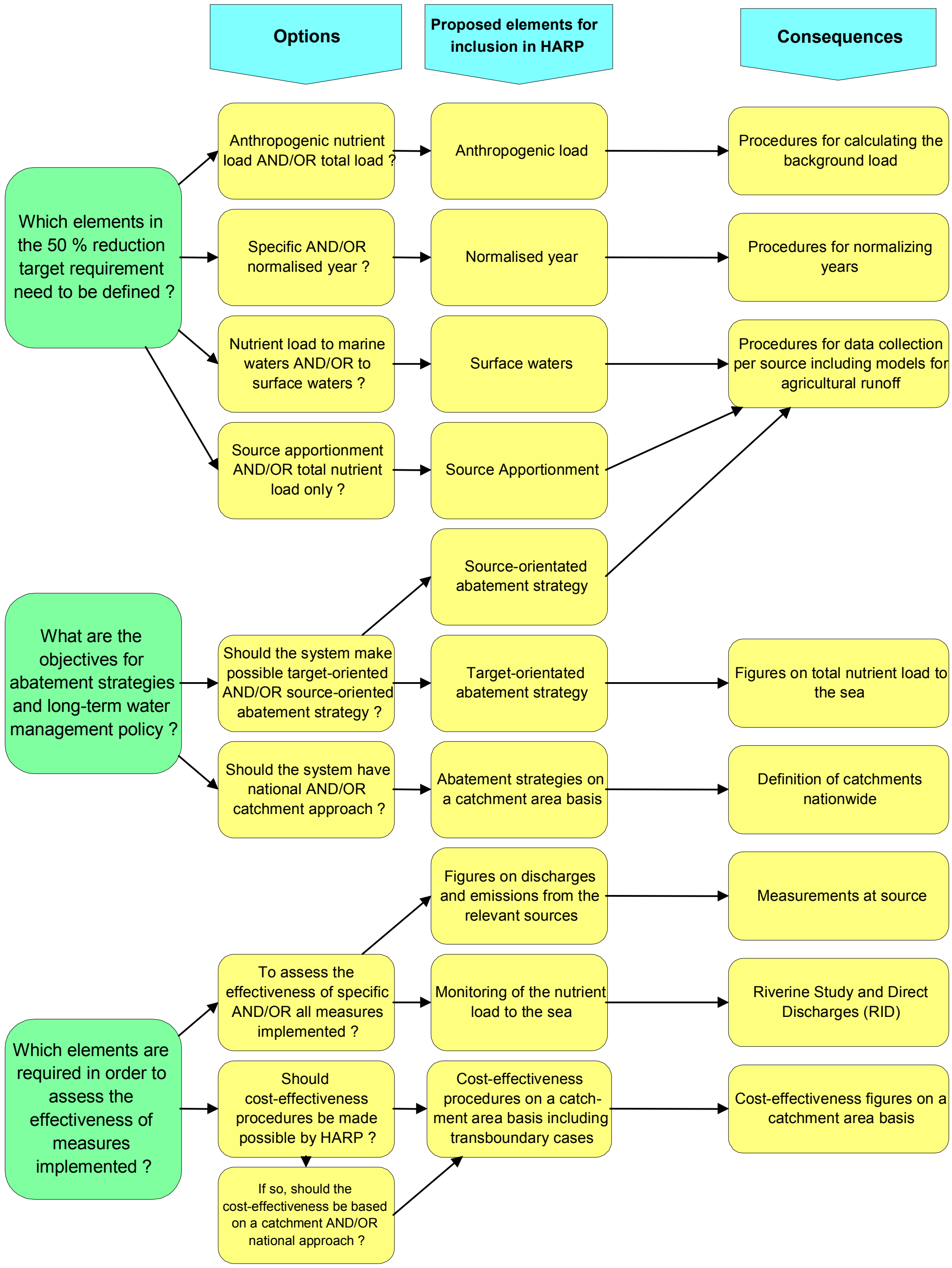

***Figure 2**. Selected elements and consequences for the HARP development.*

The HARP Workshop gave additional viewpoints on the use of harmonised information for reporting on the 50% reduction targets on nutrients, other reporting requirements/targets, today and in the future, assessment of effects of measures and development of abatement strategies/action plans on catchment levels. Retention in the coastal zone was discussed as an important but difficult element, but was not considered as a high priority task for developments in the short term. Furthermore, it was recommended that data on deposition on marine waters should not be a part of the developments, since such data could be made available from other organisations. It was acknowledged that deposition on fresh water bodies was needed to complete estimations of total discharges/losses of nutrients.

The Workshop resulted in recommendations and ideas for the further development of the various elements in HARP as regard catchment approach, quantification of agricultural nutrient losses to surface water, quantification of nutrient discharges from point sources, nutrient background load, normalisation of data, nutrient retention and riverine monitoring.

4. Development of technical guidelines

HARP Objectives

The aim of the HARP process was finally formulated, *inter alia*, based on the results of the Workshop conclusions. HARP should provide the information necessary to enable quantification of:

- the anthropogenic nutrient load;
- the total nutrient load;
- the nutrient load to marine waters;
- the nutrient load to inland surface waters, and
- the nutrient load per source.

The information provided through HARP should:

- be based on harmonised or comparable methods of quantification;
- be based on a harmonised catchment area approach;
- provide transparency as regards the information submitted by the relevant parties;
- make provisions for existing national and international reporting systems;
- comprise both point and diffuse sources of phosphorus and nitrogen; and
- use figures for both specific "normalised" years.

What has been achieved?

The degree of harmonisation was one of the key questions throughout the HARP development. The Guidelines present, in many cases, alternative quantification methods. It appeared unrealistic to think that a 'one-solution-system' could be developed and unanimously agreed by the parties concerned.

The HARP project can be viewed in light of the *process* or in light of the *product*. The project ran from 1996 until 1999 under the lead of Norway. The work took place in a number of HARP meetings, hosted by Belgium, the EC, Germany, Norway, Portugal and Switzerland. A substantial work load was taken on board by the HARP group members. The number of discussion documents and reports produced in this process is considerable (see Annex 1). The *product* is represented by the nine HARP Guidelines adopted on a trial basis by OSPAR in 2000, *viz.*:

1. Framework and Approach of the Harmonised Quantification and Reporting Procedures for Nitrogen and Phosphorus;
2. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Discharges/Losses from Aquaculture Plants;
3. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Discharges from Industrial Plants;
4. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Discharges from Sewage Treatment Works and Drainage Systems,
5. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Losses from Households not Connected to Public Sewerage;
6. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Losses from Diffuse Anthropogenic Sources, including Quantification of Background Losses of Nitrogen and Phosphorus;
7. Guideline for the Quantification and Reporting of the Monitored Riverine Load of Nitrogen and Phosphorus, including Procedures for Normalisation of the Nitrogen and Phosphorus Load;
8. Guideline on Principles for Source Apportionment for Quantifying Nitrogen and Phosphorus Discharges and Losses; and
9. Guideline for the Quantification and Reporting of the Retention of Nitrogen and Phosphorus in River Catchments.

The HARP Guidelines reconciles two approaches, namely the Source Orientated Approach and the Load Orientated Approach (see Figure 3 below).

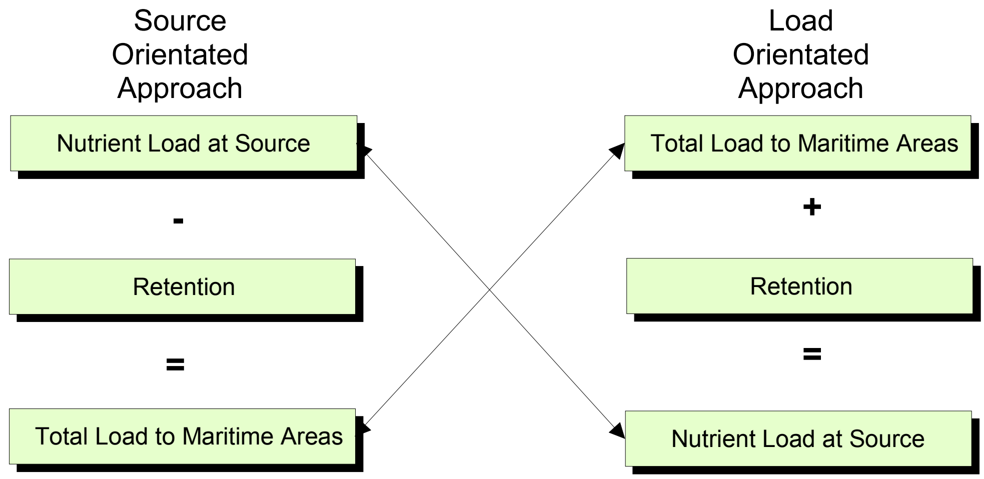

Figure 3*. The reconciliation of approaches.*

It is important to note that the 'catchment approach', as stipulated in the HARP Guidelines, is also the overall principle of the EU Water Framework Directive adopted this year.

During the HARP project development it became apparent that Harmonised Quantification and Reporting Systems for Nutrients were of great interest for other organisations than OSPAR e.g. the Rhine Commission, EEA, HELCOM, OECD and UNEP. However, taking into account that HARP needed to be operational within a short timeframe in order to ensure the presentation of a transparent and harmonised reporting system to the Ministerial meetings both in the North Sea Conference (2002) and OSPAR (20003) frameworks. Norway considered that it was important to establish HARP within OSPAR, as a first step.

5. Lessons learned

The HARP project represents a unique achievement in the history of OSPAR and the North Sea Conferences, both as regards the process and the product. With so many countries/organisations involved, so many complex issues to consider and after such a long project period, there are many aspects of the work that could be listed as 'lessons 'learned'. Below, we have singled out a few of them, viz.:

1. The organisation of such a complex project with a large number of participating countries require considerable resources both in terms of money and man-hours. From the point of view of the HARP project co-ordinators we can state that the time needed to run the project was heavily underestimated from the onset.
2. All participants in such a project need to believe in the achievement of the objectives and actively contribute throughout the process.
3. The organisation of the work in an independent project was a rather unusual approach in the context of OSPAR, but provided an efficient administration and easy decision-making, without any long-lasting organisational procedures.
4. The process in the HARP group showed clearly the need for flexibility in the negotiations of complex issues, in particular in cases with conflicting interests.

6. Future Work

The OSPAR Commission 2000 adopted the HARP NUT Guidelines on a three-year trial basis and the OSPAR working group on eutrophication (NEUT) agreed on terms of reference for work on revisions of the guidelines. Such revision should be based on experiences from the first time full-scale use of the guidelines in reporting on the 50% reduction targets and new developments as regards quantification of diffuse sources.

Further development of quantification methodology for diffuse sources require a comparative study of model performance. Such a study, called EUROHARP, is at present being planned as a proposal within EU's Fifth framework programme. However, with the preparations of the EUROHARP project and the interest shown by international organisations and national authorities in testing the HARP Guidelines, the scope of the Guidelines may well be extended way beyond the North Sea and OSPAR frameworks. EUROHARP is being planned as an international project with the objective of comparing selected methods for quantification of nutrient losses from diffuse sources by applying these methods in catchments throughout Europe. The results from the Comparative Study should form the scientific background for subsequent negotiations on the selection of recommended methods for quantifying diffuse sources to be considered for use by*, inter alia*, the European Union, OSPAR and HELCOM.

The aspect of harmonising the reporting on nutrients is firstly taken on board in the Guidelines themselves, secondly in an electronic reporting format developed by NIVA. Relevant parties are currently testing this format.

Annex 1: Documents prepared as part of the development of harmonised reporting procedures for nutrients (HARP)

Stig A. Borgvang, NIVA, 1996: The reporting systems and procedures in Germany, the Netherlands, Norway, Switzerland and the United Kingdom (CONSSO June 96/5/5).

HARP Co-ordination Group, May 1997: Workplan for the Development of Harmonised Reporting Systems and Procedures for Nutrients (distributed to all interested parties).

HARP Co-ordination Group, 1997: General Indication. Outline of relevant information to be provided by countries related to their calculation methods and procedures for discharges/emissions/losses of nutrients from various sources.

ASMO 97

HARP Co-ordination Group, 1997: Progress report on the development of Harmonised Reporting System and Procedures for Nutrients

PRAM 97

HARP Co-ordination Group, 1997: Progress report on the development of Harmonised Reporting System and Procedures for Nutrients (PRAM 97/7/2).

HARP Co-ordination Group, 1997: Proposal for organising an OSPAR Workshop on the Development of Harmonised Reporting Systems and Procedures for Nutrients. Presented to PRAM97 (PRAM 97/7/3).

CONSSO 97:

HARP Co-ordination Group, 1997: Conceptual Framework for Harmonised Reporting Systems and Procedures for Nutrients (CONSSO Oct 97/5/3).

HARP Co-ordination Group, 1997: Progress report. Development of Harmonised Reporting Systems and Procedures for Nutrients (CONSSO Oct 97/5/2).

NUT 97:

HARP Co-ordination Group, 1997: Progress report on the Development of Harmonised Reporting Systems and Procedures for Nutrients (NUT 97/6/1).

HARP Co-ordination Group, 1997: Workshop on the Development of Harmonised Reporting Procedures for Nutrients (HARP). Programme (NUT 97/6/2).

HARP Co-ordination Group, 1997: Conceptual framework for Harmonised Reporting Systems and Procedures for Nutrients, DRAFT (NUT 97/6/3).

HARP Co-ordination Group, 1997: Status reports of current reporting methods and procedures within OSPAR countries regard to Inputs of Nutrients to Maritime Areas from Land-based Sources (NUT 97/6/4).

HARP Co-ordination Group, 1997: Draft Annex 1 of the Harmonised Reporting Systems and Procedures: Background loads of nutrients. Sent out for comments, August 1997 (NUT 97/6/5).

HARP Co-ordination Group, 1997: Draft Annex 2 of the Harmonised Reporting Systems and Procedures: Retention of nutrients in freshwater systems. Sent out for comments, August 1997 (NUT 97/6/6).

HARP Co-ordination Group, 1997: Draft Annex 3 of the Harmonised Reporting Systems and Procedures: Retention of nutrients in marine systems. Sent out for comments, August 1997 (NUT 97/6/7).

HARP Co-ordination Group, 1997: Outcome of the deliberations at CONSSO97 as regards the development of HRSPN (NUT 97/6/8).

OTHER PROGRESS REPORTS 1997:

HELCOM Working Group meeting, June 97

Rhine Commission Working Group meeting, June 97

OSPAR - SIME 97

HARP Workshop, Oslo: 26-29 January 1998:

HARP Co-ordination Group: Outline of Workshop Programme on the Development of Harmonised Reporting Systems and Procedures for Nutrients. Prepared for a HELCOM Working Group meeting, June 97

HARP Co-ordination Group, 1997: HARP Workshop Programme. (see also NUT 97/6/2).

List of documents prepared for the workshop:

All Sessions

HARP 0-1-98:	Description of the issues to be covered at each Working Session. *HARPSecretariat*
HARP 0-2-98:	Conceptual framework for Harmonised Reporting Systems for Nutrients (HARP). *HARP Secretariat*
HARP 0-3-98:	Draft Structure of HARP. *HARP Secretariat*
HARP 0-4-98:	*Not issued*
HARP 0-5-98:	*Not issued*
HARP 0-6-98:	Input of Nutrients to Maritime Areas from Land-Based Sources in Germany. *Germany*

Session 1

HARP 1-1-98:	Draft List of Words and Expressions. *HARP Secretariat.*
HARP 2-2-98.	See below

Session 2

HARP 2-1-98:	Background Loads of Nutrients. *HARP Secretariat*
HARP 2-2-98:	Principles of OSPAR's Comprehensive Study on Riverine Inputs and Direct Discharges (RID). *OSPAR*
HARP 2-3-98:	Agricultural Nutrient Balance. *OECD*
HARP 2-4-98:	Agricultural Nutrient Surplus and Diffuse Nitrogen Losses to Surface Waters within England and Wales. *ADAS, United Kingdom*
HARP 2-5-98:	Principles of Source Apportionment Methodologies. *FOR SESSIONS 2 and 3. HELCOM*

HARP 2-6-98:	Guideline to Estimate Natural and Anthropogenic Contributions to Riverine Fluxes (Source Apportionment). *FOR SESSIONS 2 and 3. HELCOM*
HARP 2-7-98:	Council Directive (91/676/EEC) concerning the protection of waters against pollution caused by nitrate from agriculture. *EC*
HARP 2-8-98:	PARCOM Recommendation 92/7 on the reduction of nutrients from agriculture into areas where these inputs are likely, directly or indirectly, to cause pollution. *OSPAR*
HARP 2-9-98:	Work on Harmonisation of Nutrient Reporting Systems within OSPAR: Agriculture. *HARP Secretariat*
HARP 2-10-98:	The Implementation of Nitrate Policies in Europe: Processes of Change in Environmental Policy and Agriculture.
HARP 2-11-98:	Present and Future Emission of N and P from Agriculture to Surface Waters.
HARP 2-12-98:	Report of the Commission to the Council and European Parliament. Measures Taken pursuant to Council Directive 91/676/EEC concerning the Protection of Waters against Pollution caused by Nitrates from Agricultural Sources. Summary of Reports submitted to the Commission by Member States under Article 11. *EC.*
HARP 2-13-98:	Background of Nutrient Concentrations for the Lowland Region of Germany. G*ermany*
HARP 2-14-98:	Estimating Environmental Releases from Diffuse Sources – A Guide to Methods. *The Netherlands*
HARP 2-15-98:	Soil Surface Nitrogen Balances in EU Countries.*EUROSTAT*
<u>Session 3</u>	
HARP 3-1-98:	Council Directives 91/271/EEC Concerning the Urban Waste Water Treatment. *EC*
HARP 3-2-98:	Work on Harmonisation of Nutrient Reporting Systems within OSPAR: Aquaculture, *HARP Secretariat*
HARP 3-3-98:	Work on Harmonisation of Nutrient Reporting Systems within OSPAR: Industry, *HARP Secretariat*
HARP 3-4-98:	Work on Harmonisation of Nutrient Reporting Systems within OSPAR: Municipalities and Rural Settlements, *HARP Secretariat*
HARP 2-5-98:	See above
HARP 2-6-98:	See above
<u>Session 4</u>	
HARP 4-1-98:	Retention in Freshwater Systems. *HARP Secretariat*
HARP 4-2-98:	Retention in Coastal Areas. *HARP Secretariat*
HARP 4-3-98:	Work on Harmonisation of Nutrient Reporting Systems within OSPAR: Retention in Freshwater Systems. *HARP Secretariat*
<u>Session 5</u>	
HARP 2-2-98.	See above
HARP 5-1-98:	Guidelines for the Fourth Baltic Sea Pollution Load Compilation (PLC4). *Germany*

INPUT 98

HARP Co-ordination Group, 1998. Progress report on the Development of Harmonised Reporting Systems for Nutrients (HARP). INPUT (1)98/7/4.

HARP Co-ordination Group, 1998. Conceptual framework for Harmonised Reporting Systems for Nutrients (HARP). INPUT (1)98/7/5.

HARP Co-ordination Group, 1998. Follow-up from the HARP Workshop. INPUT (1)98/7/6.

PRAM 98

HARP Co-ordination Group, 1998. Draft OSPAR Guidelines for Harmonised Quantification and Reporting Procedures for Nutrients. PRAM 99/07/05.

HARP Co-ordination Group, 1998. Implementation of HARP-Guidelines and Some Future Activities. PRAM 99/07/09.

ASMO 98

HARP Co-ordination Group, 1998. Harmonised Reporting System and Procedures for Hazardous Substances: Draft elements of key issues. ASMO 98/5/10.

HARP Co-ordination Group, 1998. Workshop on the Development of harmonised Reporting Procedures for Nutrients (HARP): WORKSHOP REPORT. ASMO 98/05/11.

HARP Co-ordination Group, 1998. Progress report on the Development of Harmonised Reporting Procedures for Nutrients (HARP). ASMO 98/05/12.

HARP Co-ordination Group, 1998. Issues for consideration as regards the Development of Harmonised Reporting Procedures for Nutrients (HARP). ASMO 98/05/13.

NUT 98

HARP Co-ordination Group, 1998. Introduction to Harmonised Reporting Procedures for Nutrients (HARP). NEUT 98/06/02.

HARP Co-ordination Group, 1998. Draft OSPAR Recommendation on Harmonised Quantification and Reporting Procedures for Nutrients. NEUT 98/06/03.

HARP Co-ordination Group, 1998. Projet de recommandation OSPAR relative aux procédures d'harmonisation de la quantification et de la notification des nutriments. NEUT 98/06/03.

PRAM 99

HARP Co-ordination Group, 1999. Draft OSPAR Guidelines for Harmonised Quantification and Reporting Procedures for Nutrients. PRAM 99/07/05.

HARP Co-ordination Group, 1999. Implementation of HARP-Guidelines and Some Future Activities. PRAM 99/07/09.

NEUT 99

HARP Co-ordination Group, 1999. Harmonised Quantification and Reporting Procedures for Nutrients (HARP-NUT). NEUT 99/03/01, plus add 1-9.

HARP Co-ordination Group, 1999. HARP Trial Implementation – Report from the Pilot Study in Norway. NEUT 99/03/03.

HARP Co-ordination Group, 1999. Implementation of the HARP NUT Guidelines – Practical and Resource Implications for OSPAR. NEUT 99/03/04.

HARP Co-ordination Group, 1999. Guidance for the Trial Application of HARP. NEUT 99/03/Info.1.

CONSSO 99

HARP Co-ordination Group, 1999. Harmonised Quantification and Reporting Procedures for Nutrients (HARP) - Status Report CONSSO OCT 99/ 3/ 1.

Annex 2: Reporting on nutrients within International Governmental Organisations

Organisation/ type of commitment	50 % reduction target		Implementation reports of adopted measures	
	Reporting format	Frequency	Reporting format	Frequency
European Union (EU)			Reporting procedure in Council Directive 91/692 for some Directives, Council Directive 91/271/EEC on Urban Waste Water Treatment and reporting formats in Council Decisions 92/446/EEC and 95/337/EEC	Laid down in the various Directives e.g. every 3-4 years.
OSPAR	No format, but guidelines for the content of the national reports	Was annual up to 1995	Recommendations and Decisions with agreed reporting formats	Every 3-4 years
Rhine Commission	Yes	Once a year	NA	NA
HELCOM	Yes	Once a year	HELCOM Recommendations include reporting formats	Varies
North Sea Conference framework	No reporting takes place in the NSC framework, but OSPAR has submitted progress reports at regular intervals			

Guideline 1:
Framework and Approach of the Harmonised Quantification and Reporting Procedures for Nutrients (HARP)

Guideline 1: Framework and Approach of the Harmonised Quantification and Reporting Procedures for Nutrients (HARP)

Contents

1. Objectives

1.1 The purpose of the HARP guidelines is to serve as a tool for Contracting Parties to report, in a harmonised manner, their different commitments, present or future, with regard to nutrients under the OSPAR Convention, in particular the "Strategy to Combat Eutrophication".

1.2 To this end, the HARP guidelines should enable Contracting Parties to quantify and report where appropriate on both:

- Nitrogen and phosphorus discharges and losses from point and diffuse sources into inland surface waters; and
- Nitrogen and phosphorus inputs into the Maritime Area[1],
  in a harmonised and transparent way.

1.3 The implementation of the HARP Guidelines should facilitate the assessment of effectiveness of reduction measures[2] and the progress towards the 50% reduction targets (PARCOM Recommendations 88/2, 89/4 and 92/7) and any future targets if agreed by OSPAR.

1.4 The implementation of the HARP Guidelines may also facilitate the assessment of the eutrophication status of the problem and potential problem areas of the Maritime Area, as foreseen in OSPAR's Common Procedure and any review of the eutrophication status of the OSPAR Maritime Area.

2. General definitions

Nitrogen and phosphorus *means phosphorus (tot-P) and nitrogen (tot-N), except where specified differently.*

Phosphorus *includes both inorganic and organic fractions of phosphorus.*

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1 Excluding the quantification and reporting of atmospheric deposition of nitrogen and phosphorus on the waters of the Maritime Area.

2 This encompasses both existing and planned measures, including reduction measures at source and reduction measures for the Maritime Area and the links between them.

Nitrogen *includes both inorganic and organic fractions of nitrogen.*

Point sources of nitrogen and phosphorus *are defined as a clearly identified, individual discharge (or a number of discharges in close proximity) to a watercourse or a body of water, such as effluent discharged from a sewage collecting and treatment system via an outfall pipe or channel. Aquaculture should be considered as a point source.*

Diffuse sources of nitrogen and phosphorus *are defined as any source of nitrogen and phosphorus that is not accounted for as a point source. Small, dispersed point discharges (e.g. from scattered dwellings or from point sources in agriculture, e.g. farmyards) should be dealt with as diffuse sources. Based on this definition, losses from scattered dwellings are included as diffuse sources.*

Nitrogen and phosphorus inputs into the Maritime Area *are defined as nitrogen and phosphorus loads to the Maritime Area via rivers and direct discharges and losses of nitrogen and phosphorus, including groundwater, to the Maritime Area.*

Catchment *means the whole of an area having a common outlet for its drainage waters.*

Catchment-based reporting *means that the reporting is per catchment, according to the number of catchments decided by each country, so that the total of the nitrogen and phosphorus load from all catchments or group of catchments represents the whole of the drainage area relating to the part of the Maritime Area under consideration*.

Coastal areas *means the areas between main river catchments. When reporting, discharges and losses from these areas and discharges and losses from sources located in marine waters are added to a total.*

Unmonitored areas *include both sub-catchment(s) of river systems downstream monitoring points, with losses and discharges to the river downstream of monitoring points and direct losses and discharges to the Maritime Area (coastal area). Quantification of losses/discharges of nitrogen and phosphorus from unmonitored areas can be achieved by:*

- *The application of draft Guideline 6 in respect of diffuse losses of nitrogen and phosphorus or the extrapolation of diffuse losses monitored in a neighbouring area with similar physical conditions (soil, climate, topography) and land-use conditions; and*
- *Adding all monitored or estimated discharges from point sources in an unmonitored area, using a retention coefficient where appropriate (cf. Guideline 9).*

3. Structure of the guidelines

3.1 HARP encompasses nine Guidelines, accompanied by a specific reporting format, and four summary-reporting formats concerned only with the annual figures of the total discharges/losses/inputs of nitrogen and phosphorous per source category and catchment. The overview of the HARP structure below will assist you to navigate through HARP.

3.2 The nine Guidelines are:

1. Framework and Approach of the Harmonised Quantification and Reporting Procedures for Nitrogen and Phosphorus
2. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Discharges/Losses from Aquaculture Plants
3. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Discharges from Industrial Plants
4. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Discharges from Sewage Treatment Works and Drainage Systems
5. Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Losses from Households not Connected to Public Sewerage

6. Draft Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Losses from Diffuse Anthropogenic Sources, including Quantification of Background Losses of Nitrogen and Phosphorus
7. Guideline for the Quantification and Reporting of the Monitored Riverine Load of Nitrogen and Phosphorus, including Procedures for Normalisation of the Nitrogen and Phosphorus Load
8. Guideline on Principles for Source Apportionment for Quantifying Nitrogen and Phosphorus Discharges and Losses
9. Guideline for the Quantification and Reporting of the Retention of Nitrogen and Phosphorus in River Catchments

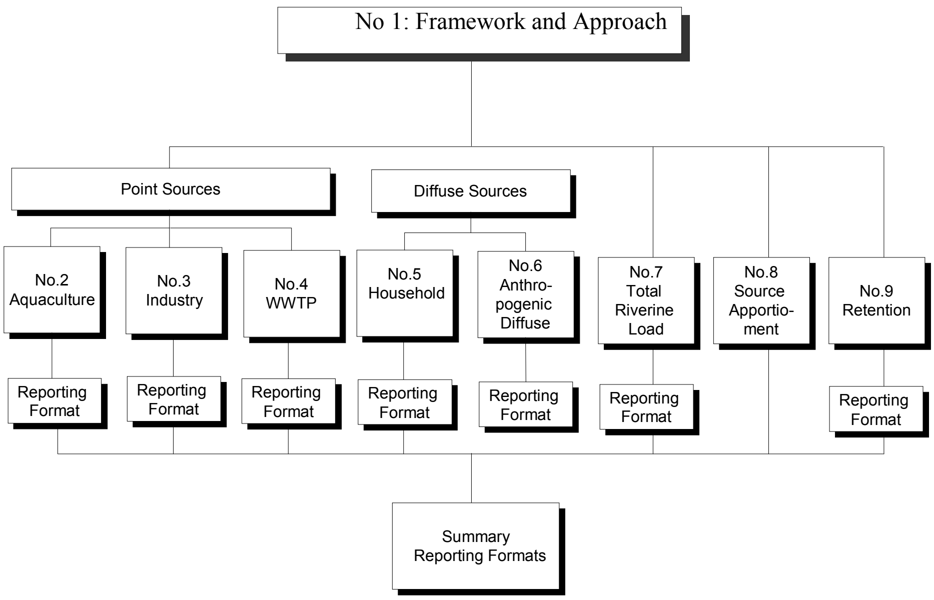


Figure 1. *Structure of HARP with nine Guidelines and their associated Reporting Formats*

4. Quantification approaches for discharges/losses of nitrogen and phosphorus to surface waters

4.1 HARP comprises two quantification approaches, namely:

a. The quantification of the nitrogen and phosphorus discharges/losses at source (Source Orientated Approach); and

b. The quantification of the nitrogen and phosphorus inputs at the river mouths, including the direct nitrogen and phosphorus discharges/diffuse losses into the sea (Load Orientated Approach).

Both approaches are necessary for verification purposes and both may be needed for providing the information required for the various commitments (see Section 1).

4.2 The development of HARP Guidelines to quantify and report on the individual components of nitrogen and phosphorus discharges/losses to inland surface waters is intended to allow the aggregation of the discharges/losses of nitrogen and phosphorus in each catchment (Source Orientated Approach). By taking account, where appropriate, of nitrogen and phosphorus retention processes in river systems and background losses of nitrogen and phosphorus, it is possible to compare the aggregated nitrogen and phosphorus figures on discharges/losses at source with the total riverine loads measured at downstream monitoring points (Load Orientated Approach), e.g. RID Monitoring Points, as a load reconciliation. Nitrogen and phosphorus retention in river systems represents the connecting link between the "Source Orientated Approach" and the "Load Orientated Approach" (c.f. Figure 2).

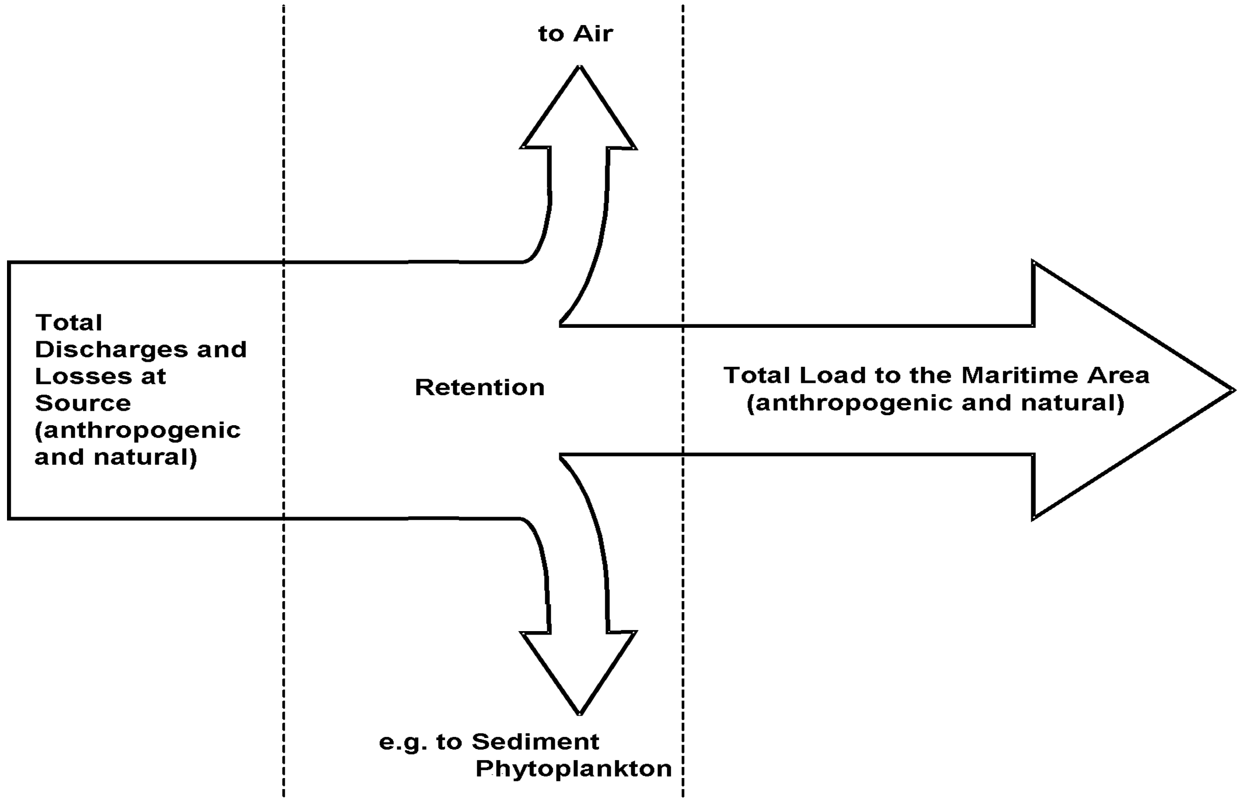


Figure 2*. Illustration of retention processes in a river system representing the connecting link between the "Source Orientated Approach" and the "Load Orientated Approach"*

The two approaches need to be taken into account in order to undertake load reconciliation (Table 1) and source apportionment (Guideline 8). Figure 3 shows the general overview of sources, entry routes, compartments and processes contributing to the total load of nitrogen and phosphorus to the Maritime Area.

Table 1. *Quantification procedure for the two approaches*

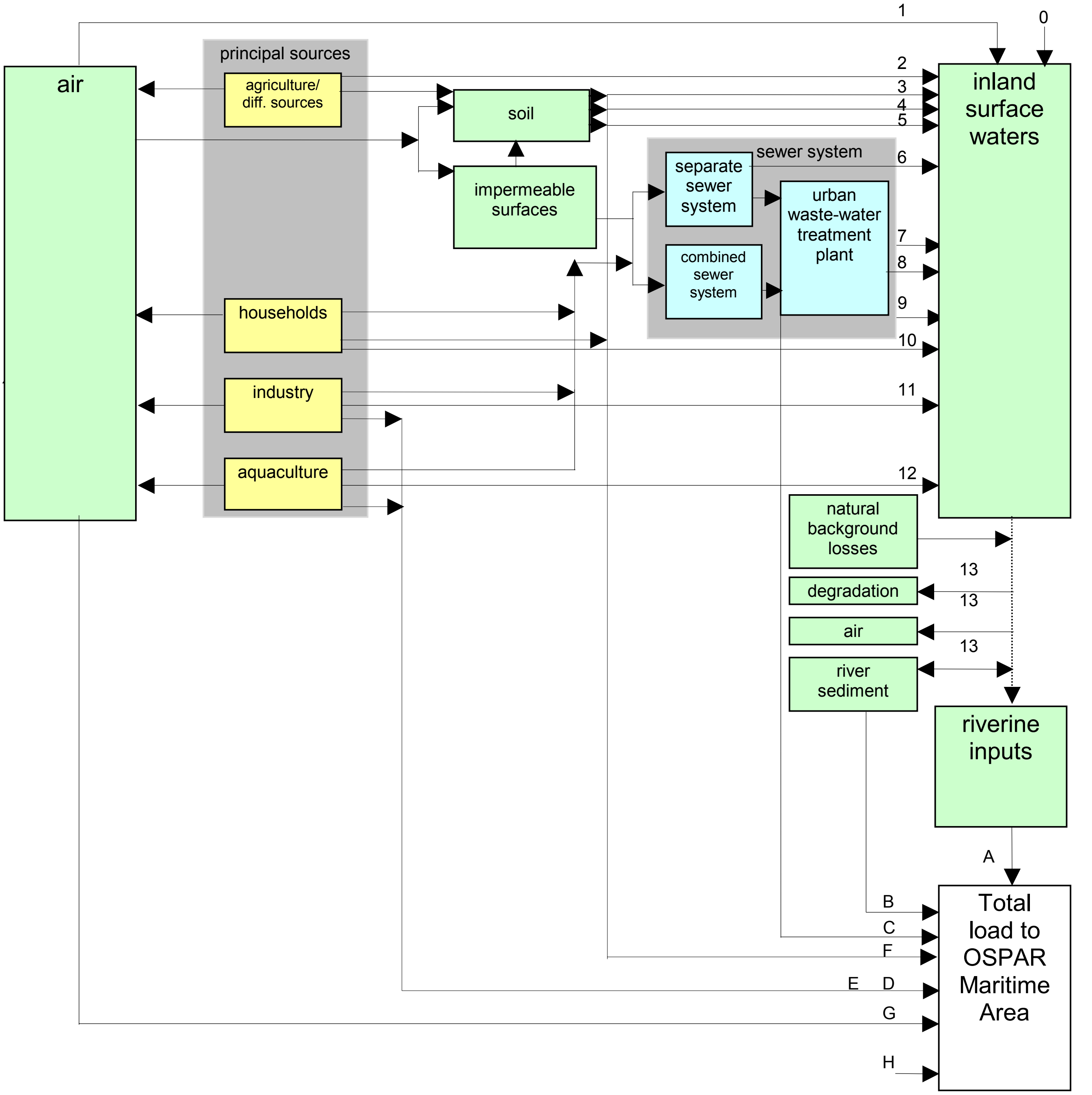
Operator	Quantification sequence for discharges and losses of nitrogen and phosphorus	Guideline
+	Upstream nitrogen and phosphorus inputs- e.g. water transferred into a river system	
+	Quantified nitrogen and phosphorus losses from aquaculture	2
+	Quantified nitrogen and phosphorus discharges from industry	3
+	Quantified nitrogen and phosphorus discharges from sewage treatment works and sewerage	4
+	Quantified nitrogen and phosphorus losses from households not connected to sewerage	5
+	Quantified diffuse anthropogenic nitrogen and phosphorus losses	6
+	Quantified natural nitrogen and phosphorus background losses	6
=	**Sum of all nitrogen and phosphorus losses/discharges (from Source Orientated Approach)**	
-	Quantified nitrogen and phosphorus retention in surface waters	9
-	Other quantified nitrogen and phosphorus removal processes, e.g. abstracted water, water transfer from a river system	
=	**Total estimated transport of nitrogen and phosphorus at the monitoring point (derived from the Source Orientated Approach)** ***To be compared with***	
	Total (from Load Orientated Approach)	7

For more detailed information about the HARP structure see explanation and Figure 4 below. It should be noted that HARP does not cover:

- neither the air compartment, i.e. the principal sources as far as the emissions to air are concerned, nor entry route F;
- Dumping in the sea (entry route B); or
- Nitrogen and phosphorus fluxes from water masses outside the Maritime Area.

Furthermore HARP:

- Guideline 2 covers entry routes 12 and E;
- Guideline 3 covers entry routes 11 and D;
- Guideline 4 covers entry routes 6, 7, 8, 9 and C;
- Guideline 5 covers entry route 10;
- Draft Guideline 6 covers entry routes 1, 2, 3, 4, and 5;
- Guideline 7 covers entry route A;
- Guideline 8 facilitates an apportionment of the contribution of the entry routes 0-12 to entry route A; and
- Guideline 9 (retention) concerns the quantification of nitrogen and phosphorus retained or released through process 13.



ENTRY ROUTES TO SURFACE WATER

0 upstream inputs
1 atmospheric deposition
2 diffuse losses
3 erosion direct to surface waters
4 drainage direct to surface waters
5 run-off
6 rainwater separate sewer
7 discharges UWWP
8 stormwater overflow
9 untreated discharges
10 households not connected
11 direct discharges from industry
12 direct aquaculture discharges
13 retention

ENTRY ROUTES TO OSPAR AREAS:

A riverine inputs
B dumping of harbour/river sludge
C discharges UWWP
D discharges industry
E discharges aquaculture
F agriculture/diff. sources
G atmospheric deposition
H flux from outside the Maritime Area

- compartments/ systems
- principal sources
- sewer system
- OSPAR Maritime Area

Figure 3. *General overview of sources, entry routes, compartments and processes, contributing to the total load of nitrogen and phosphorus to the Maritime Area.*

4.3 The Load Reconciliation procedure provides a means of:

- comparing and verifying the figures on nitrogen and phosphorus discharges/losses/inputs produced by the application of the two approaches; and
- evaluating the importance of the different source categories.

Where significant differences are identified, the source data should be re-examined and re-evaluated, and the nitrogen and phosphorus load should be verified for accuracy.

4.4 The total nitrogen and phosphorus inputs measured at monitoring points may be apportioned into different sources (c.f. Guideline 8 on Source Apportionment). The Source Apportionment guideline may also be used for consistency purposes, when comparing with data from previous years.

5. Common issues for the guidelines

5.1 The following issues are common for many of the Guidelines:

a. The method used for the quantification should be mentioned in the reporting, as well as any deviations from the recommended methods;

b. The reporting should be made both on a catchment basis and on the basis of the whole national area draining into the Maritime Area;

c. All catchments or groups of catchments (monitored, unmonitored and coastal areas), draining into the relevant Maritime Area, should be considered. Maps should be attached to the reports, showing the catchments reported on. The total nitrogen and phosphorus inputs from all catchments or group of catchments should represent the whole of the drainage area relating to the part of the Maritime Area under consideration. Furthermore

- it is up to the discretion of each country to decide the number of catchments to be notified. Possible criteria for the selection of catchments could be the size of the catchment and the length of the coastline covered by the catchment;
- criteria for the selection of catchment size should be related to the state of the receiving water body, in order to facilitate the development of appropriate action plans;
- generally, the reports should not encompass catchments smaller than 1000 km^2; that means that smaller catchments should be aggregated to cover at least 1000 km^2; and
- generally, catchments larger than 20 000 km^2 should be divided into sub-catchments;

d. The quantification of and/or reporting on discharges/losses/inputs of nitrogen and phosphorus should:

- provide actual and normalised estimates of nitrogen and phosphorus losses from diffuse sources and actual estimates of nitrogen and phosphorus discharges from point sources ;
- enable assessments of the effectiveness of measures implemented per sector.

5.2 Figure 4 below intends to illustrate the reporting categories and, in particular, the possible uncertainties that may subsist concerning quantification and reporting on monitored and unmonitored areas, within a main river system and in coastal areas.

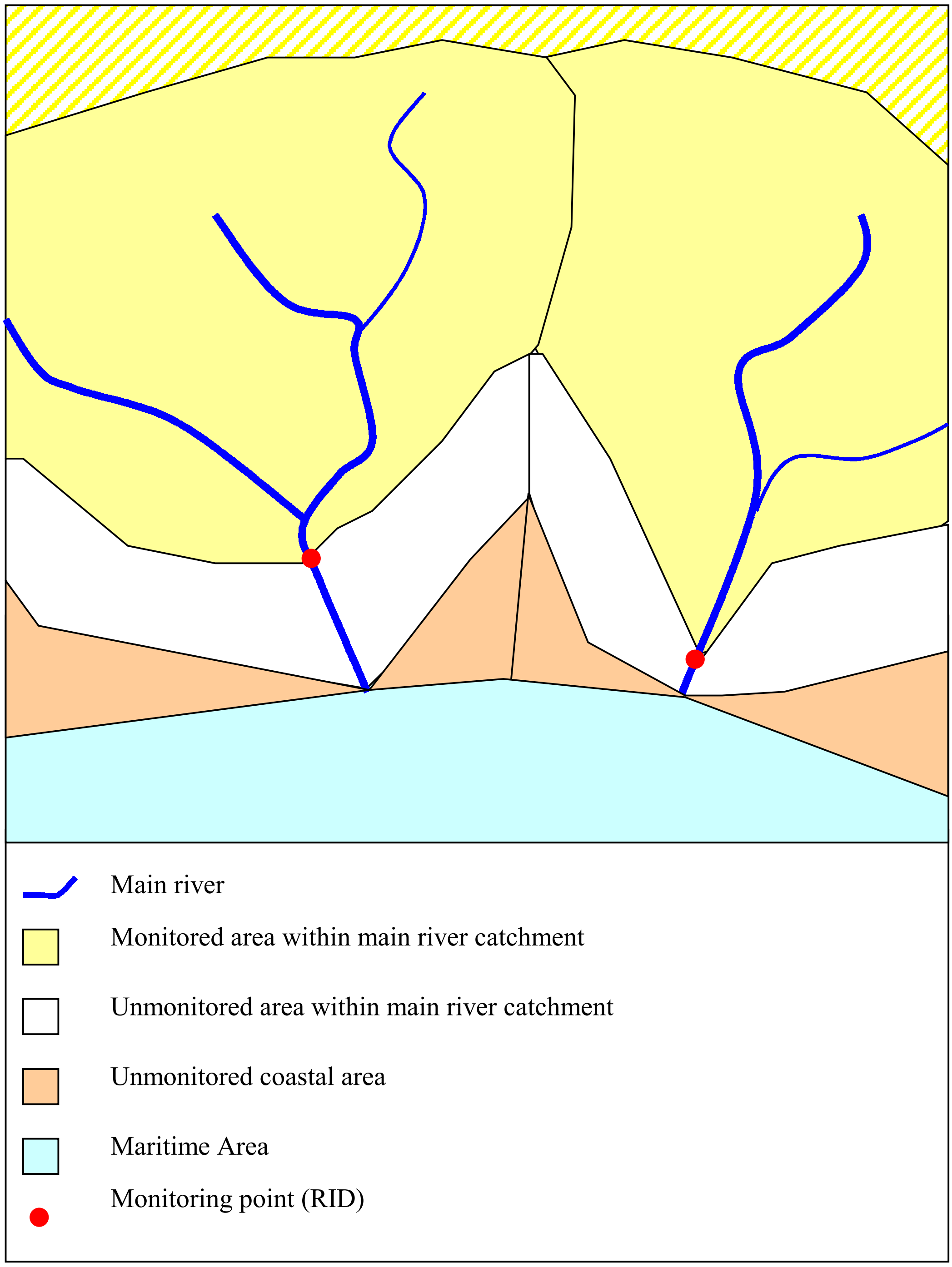


***Figure 4**. Illustration of river systems and related catchments*

5.3 For many of the HARP Guidelines there are common harmonisation features concerning sampling strategies and laboratory practices; some are listed below.

Sampling strategy

a. The sampling strategy should, for each plant (and industrial sector), be adequate to ensure a reliable quantification of the nitrogen and phosphorus discharges. When the production and/or wastewater discharges vary significantly over the year, the sampling strategy should be adjusted correspondingly;

b. Sampling of water for the purpose of nitrogen and phosphorus analyses of discharges from point sources should be flow-proportional, and be carried out using automatic samplers in order to ensure a reliable quantification of the nitrogen and phosphorus discharges. The water flow should preferably be registered continuously. Flow measurements should be performed according to international standards (e.g. ISO standards);

c. If the sampling is manual, the following additional information may need to be reported to relevant competent authorities:

- The number of samples included in the average annual nitrogen and phosphorus concentrations;
- The period the mean concentration is based on (daily, weekly, monthly or yearly).

Laboratory practices

d. The laboratories used should be accredited and/or approved by national authorities. Good international laboratory practice should be applied, aiming at minimising the degradation of the samples between sampling and analysis.

e. If the national assessment of the reporting procedures have resulted in an estimate of the accuracy of the figures reported, such estimates should be reported.

6. References

HELCOM, 1994: PCL-3, No 57, Baltic Sea Environmental Proceedings

ICES, 1987. Techniques in Marine Environment Sciences., No 6. Control Procedures: Good Laboratory Practice and Quality Assurance

ISO CD-13530, 1993. Water Quality-Precision and Accuracy-Guide to Analytical Control for Water Analysis (ISO TC 147/SC 7N 427)

CEN/CENELEC, 1989. EN 45001-General criteria for the operation of testing laboratories.

7. Application and reporting

7.1 The focus of the HARP Guidelines is, initially, on quantification/reporting on nitrogen and phosphorus in the context of OSPAR and the North Sea Conferences. Application of the Guidelines will therefore be primarily related to the evaluation of the sources and losses/discharges/inputs of nitrogen and phosphorus, to accord with the requirements of the OSPAR Strategy to combat eutrophication.

7.2 All parts of the OSPAR Maritime Area will be subject to review and classification with regard to eutrophication status through the application of the OSPAR Common Procedure. The outcome of this application, whereby those parts of the Maritime Area of greatest concern and their associated catchments will be identified, will indicate the priorities for the application of the Guidelines.

7.3 Given that figures on nitrogen and phosphorus discharges/losses are derived from Guidelines 2, 3, 4, 5 and draft Guideline 6 (Source Orientated Approach) and nitrogen and phosphorus input figures are derived from Guideline 7 (Load Orientated Approach), a relatively simple process of reconciling the two approaches is possible, by taking retention into account (c.f. Guideline 9). This process may be accommodated by the application of Guideline 9 on retention.

7.4 The Summary Reporting formats in section 8 need to be applied for each identified catchment (see paragraph 5.1). They concern the following:

- Format 9.1 sums up the catchment description and the monitored riverine nitrogen and phosphorus loads;
- Format 9.2 sums up figures for nitrogen and phosphorus discharges/losses to surface waters;
- Format 9.3 summarises the figures of nitrogen and phosphorus discharges to both the monitored and unmonitored parts of the rivers, as well as the nitrogen and phosphorus loads, taking account of any retention in both parts of the rivers; and
- Format 9.4 summarises figures on all nitrogen and phosphorus inputs into the Maritime Area per Contracting Party.

7.5 A common requirement is that quantification/reporting should be harmonised, as far as is reasonably possible. It is recognised that because of differences arising through geographical conditions and established national practices, true harmonisation may be difficult to achieve. The disadvantages relating to this can, to some extent, be compensated for by ensuring that transparency of quantification/reporting is sufficient to highlight any differences in approach or inconsistencies. To this end, any such variations or anomalies should be described and, where possible, quantified. In the Implementation format (see section 8.5), it should be indicated whether the HARP Guidelines are applied or not, including a description of any alternative methods applied and assessment of comparability with the relevant Guideline.

7.6 Information on uncertainty attached to specific nitrogen and phosphorus discharges/losses/inputs, should be provided (e.g. as standard deviation, standard error or confidence limits).

8. Future Work

8.1 The Guidelines should be reviewed periodically and revised as appropriate, e.g. in light of developments within OSPAR or other relevant fora, such as the EU. A future possible harmonisation of the quantification procedures may be achieved after the evaluation of the planned trial period, which will include a pilot study and a comprehensive evaluation study. Below is a provisional list of issues that may lead to revisions of one or several of the Guidelines.

- The harmonisation of the Quantification Procedures of Nitrogen and Phosphorus Losses from Diffuse Anthropogenic Sources, including Background losses (Draft Guideline 6) could not be achieved mainly because of different developments and experiences within Contracting Parties on this issue;
- The review of relevant OSPAR measures;
- Subject to the need being established, the development of a method for evaluating data on phosphorus deposition;
- Best Available Technology (BAT) descriptions for system categories referred to in Appendix I of the IPPC Directive are being developed in the EC framework. A recommendation to the Commission on reporting procedures from the industrial sectors (Committee of the Article 19 of the IPPC Directive) is expected to be ready in 2000. This may require a revision of the Guideline on the Quantification and Reporting of Nitrogen and Phosphorus Discharges from Industrial Plants (Guideline 3);
- The proposed Water Framework Directive;
- The EC reporting formats concerning the Nitrates Directive and the Urban Waste Water Directive; and
- Any future revision of the OSPAR's Programme on Riverine Inputs and Direct Discharges (RID programme).

8.2 Several guidelines comprise currently alternative methods, i.e. not one single recommended method. A true harmonisation of quantification procedures requires that each guideline, in principle, contain one recommended quantification procedure or that alternative methods give comparable results. In order to facilitate a development towards true harmonisation, comparative studies should be undertaken, applying different quantification methods on common data sets. In addition, experience of the application of the Guidelines in the framework of reporting within OSPAR/the North Sea Conference framework will enable further improvements of the Guidelines.

9. HARP Summary Reporting Formats

9.1 Catchment Description and Monitored Riverine Nitrogen and Phosphorus Loads

Catchment No. And Name	Total catchment area km^2	Total population Number	Long-term annual flow $10^6\ m^3/yr$	Riverine Load, without normalisation (tonnes/year) ± %		Riverine Load, flow-normalised (tonnes/year) ± %		Transboundary riverine inputs ± %	
				Tot-P	Tot-N	Tot-P	Tot-N	Tot-P	Tot-N
National figures[3]									

[3] Sum of the figures from all the catchments/coastal areas

9.2 Source Orientated Approach to quantify nitrogen and phosphorus discharges/losses to surface waters

Aquaculture

Catchment/ Coastal area	Aquaculture (tonnes/year) ± %					
No. and Name	Tot P			Tot N		
	Sp			Sp		
	C	I		C	I	
	Dir	Mon	Unmon	Dir	Mon	Unmon
National figures[4]						

Industry

Catchment/ Coastal area	Industry (tonnes/year) ± %					
No. and Name	Tot P			Tot N		
	Sp			Sp		
	C	I		C	I	
	Dir	Mon	Unmon	Dir	Mon	Unmon
National figures[4]						

Wastewater treatment plants

Catchment/ Coastal area	WWTP (tonnes/year) ± %					
No. and Name	Tot P			Tot N		
	Sp			Sp		
	C	I		C	I	
	Dir	Mon	Unmon	Dir	Mon	Unmon
National figures[4]						

Households

Catchment/ Coastal area	Households (tonnes/year) ± %					
No. and Name	Tot P			Tot N		
	Sp			Sp		
	C	I		C	I	
	Dir	Mon	Unmon	Dir	Mon	Unmon
National figures[4]						

Tot P: Total phosphorus **Tot N**: Total nitrogen **No**: Normalised data **Sp**: Year specific data **C**: Coastal waters **I**: Inland surface waters
Mon: Monitored inland surface waters **Unmon**: Non monitored inland surface waters **Dir**: Direct discharges/losses to marine waters
± %: Wherever possible, the accuracy of the figures should be indicated, e.g. 312 tonnes (+7%)

Diffuse sources

Catchment/ Coastal area	Diffuse Anthropogenic Losses (tonnes/year) ± %					
No. and Name	**Tot P**			**Tot N**		
	Sp			**Sp**		
	C	**I**		**C**	**I**	
	Dir	Mon	Unmon	Dir	Mon	Unmon
National figures[4]						

Tot P: Total phosphorus **Tot N**: Total nitrogen **No**: Normalised data

Sp: Year specific data **C**: Coastal waters **I**: Inland surface waters

Mon: Monitored inland surface waters **Unmon**: Non monitored inland surface waters

Dir: Direct discharges/losses to marine waters

± %: Wherever possible, the accuracy of the figures should be indicated, e.g. 312 tonnes (+7%)

Background losses and retention

Catchment/ Coastal area	Background losses (tonnes/year) ± %				Retention (tonnes/year) ± %	
No. and Name	**Tot P**		**Tot N**		**Tot P**	**Tot N**
	No		**No**		**Sp**	**Sp**
	C	**I**	**C**	**I**	**I**	**I**
National figures[4]						
Total nitrogen and phosphorus background load						
Total nitrogen and phosphorus anthropogenic load						

4 Sum of the figures from all the catchments/coastal areas

9.3 Total nitrogen and phosphorus inputs to the Maritime Area

Catchment name/no.	**Monitored part**							**Unmonitored part**[5]					
	% of area	Total discharge		Retention		Load		Total discharge		Retention		Load	
		P	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**
Total													

9.4 Total nitrogen and phosphorus inputs to the Maritime Area

Total national figures	**P**	**N**
Monitored riverine nitrogen and phosphorus inputs		
Unmonitored riverine nitrogen and phosphorus inputs		
Direct nitrogen and phosphorus discharges/losses into coastal waters[6]		
Total nitrogen and phosphorus inputs to the Maritime Area		

5 Retention in the unmonitored part of the river may be taken into account, if appropriate. The unmonitored part of the nutrient riverine inputs may be obtained either from the total nutrient discharges into these parts of the rivers, taking retention into account, or by comparison with comparable, monitored rivers.

6 The sum of all discharges/losses to coastal waters from Table 9.2.

10. HARP Implementation Format

No.	Guideline on	Is the Guideline applied ? (yes/no) Totally	Partly	Description of alternative methods and assessment of comparability with the relevant guidelines
2	Aquaculture plants			
3	Industrial plants			
4	Sewage Treatment Works and Drainage Systems			
5	Households not Connected to Public Sewerage			
6	Diffuse Anthropogenic Sources, including Quantification of Background Losses of Nitrogen and phosphorus			
7	Total Riverine Load of Nitrogen and phosphorus, including procedures for normalisation of the nitrogen and phosphorus load			
8	Principles for source Apportionment[7]			
9	Nitrogen and phosphorus retention in river catchments			

[7] To be applied and reported on a voluntary basis.

Guideline 2:
Quantification and Reporting of Nitrogen and Phosphorus Discharges/Losses from Aquaculture Plants

Guideline 2: Quantification and Reporting of Nitrogen and Phosphorus Discharges/losses from Aquaculture Plants

Contents

1. Objectives

1.1 To describe procedures for the quantification of discharges/losses of nitrogen and phosphorus from marine and freshwater from aquaculture plants that use artificial feed and where the discharge pipes are not connected to a public sewerage system.

1.2 To list the type of data which should be reported in addition to the data on discharges/losses of nitrogen and phosphorus from aquaculture plants.

2. Introduction

2.1 The main source for nitrogen and phosphorus discharges/losses from aquaculture plants is the feed administered into the farming system. It follows from the above objectives that mussel production and other aquaculture productions that do not use artificial feed are not covered by this guideline. Discharges of nitrogen and phosphorus are derived from uneaten feed, undigested nitrogen and phosphorus (faeces) and excretion via the gills and the urine.

2.2 Nitrogen and phosphorus discharges/losses from aquaculture plants can be determined by monitoring of discharges or by calculations based either on records of fish production and feed used or by using feed conversion rates (FCR) combined with chemical analyses of feed and fish.

2.3 The guideline does not distinguish between particulate and dissolved fractions of the nitrogen and phosphorus discharge/loss. This simple approach will therefore overestimate the nitrogen and phosphorus discharges/losses, as it does not take into account the burial of particulate nitrogen and phosphorus (especially phosphorus) in the sediments.

2.4 Quantification by the theoretical approaches (1 and 2) is not recommended for individual plants, but gives a good estimation when used on an aggregated level including several plants.

3. Data resolution

3.1 As a first priority, the quantification of discharges/losses of nitrogen and phosphorus from aquaculture activities should be based on aggregated information extracted from national registers of annual figures for relevant parameters from each individual plant. Such statistics are collected in some countries as part of the requirements in the discharge permits.

3.2 As second priority, national sales statistics on aquaculture products and/or feed used may be the basis for quantifying the discharges/losses of nitrogen and phosphorus. This is an approximation, which may be difficult to backtrack to the relevant geographical resolution (e.g. catchments/coastal regions), and should only be used until relevant statistics based on reports from each plant become available.

3.3 Data should be reported with a geographical resolution in accordance with the agreed selection of catchments and coastal areas used for harmonised reporting. Indirectly, this will enable a differentiation between direct discharges of nitrogen and phosphorus into marine waters and into freshwaters.

3.4 For the quantification of the nitrogen and phosphorus discharges/losses, the distinction is made between two main production types:

a. Plants without treatment (e.g. plants where the sludge is not collected or where the sludge is collected, but discharged to the aquatic environment without treatment); and

b. Plants with treatment (e.g. plants with permanent removal of sludge), where the N and P contents in the sludge removed are quantified.

4. Quantification methods

4.1 This Guideline describes three approaches to quantification of discharge/loss of N and P from aquaculture production systems to surface waters. The two first approaches are based on calculations from production parameters; the main difference between them being the degree of availability of information. In approach 1, the starting point is that information is available on both production and feed consumption at catchment level. In approach 2, only information on either production or feed used is available at national level. The quantification method itself is based on mass balance equations and is the same for the two approaches. Monitoring of N and P in the discharge (Approach 3) is practicable for ponds or other land based production systems where the discharges are distinct point discharges (such as end of pipe/channel.)

Approach 1

4.2 This approach forms a basis for the estimation of nitrogen and phosphorus discharges/losses from aquaculture plants (Cho *et al.* 1991).

a. For farms without treatment (sludge removal):

$$L = 0{,}01 \times (IC_i - PC_f) \qquad (1)$$

L : phosphorus (P) or nitrogen (N) discharge to water body (tonnes/year)

I : feed used (tonnes/year)

C_i : P or N content in feed (%)

P : production (tonnes/year)

C_f : P or N content in produced organisms (%)

b. For farms with treatment (sludge removal):

$$L = 0{,}01 \times (IC_i - PC_f)(1 - e) \qquad (2)$$

L : phosphorus (P) or nitrogen (N) discharge to water body (tonnes/year)

I : feed used (tonnes/year)

C_i : P or N content in feed (%)

P : production (tonnes/year)

C_f : P or N content in produced organisms (%)

e : treatment yield (P or N removal)

4.3 The production (P) in equations 1 and 2 is calculated as the sum of a, b and c below. The initial biomass at the beginning of the year must be added to the sum of:

a. organisms taken out of the water for slaughter (alternatively the sum of slaughter weight and slaughter offal) or sold alive (tonnes/year);

b. dead organisms collected during the year (tonnes/year); and

c. escaped organisms (tonnes/year).

4.4 The total P and N content in the feed may be obtained from the feed manufacturers. In order to facilitate national calculations, average figures based on the typical feed used in the catchment or region may be used. The indicative figures in table 1 may be used if the above mentioned figures are not available. If "moist/semi-moist feed" (higher content of water than "dry feed")[8] is used, the quantity of moist/semi-moist feed should be converted to the comparable quantity of dry feed, as an expression of the total quantity of feed used. The total P and N contents in the produced organisms can be obtained as a standard figure for each catchment or region. If such figures are not available, the figures in Table 1 may be used. The figures in Table 1are indicative for salmonide farming. Other indicative figures may be used for other species.

Table 1**. Content of nitrogen and phosphorus in dry feed and in produced organisms with respect to salmonid farming**

	Total phosphorus content (%)	**Total nitrogen content (%)**
Dry feed	1,2	7,5
Fish	0,45	3,0

4.5 The calculation of treatment yield requires that the content of P and N in the sludge is calculated/measured regularly (e.g. based on requirements in the discharge permits) as basis for quantification of the fraction that is removed by the sludge. If such figures are unavailable and, in the case of regular removal of sludge, an average removal of 10% N and 40% P due to decantation may be considered.

Approach 2

4.6 If national registers on feed use and production on individual farms are not available, national sales statistics could be used. If only statistics on production or feed used is available, an assumption of the feed conversion ratio (FCR) should be made. FCR is the ratio between weight of feed used (dry feed basis) and weight- gain of the organism (production), expressed as:

$$FCR = \frac{\textit{Feed used (tonnes/year)}}{\textit{Production (tonnes/year)}}$$

4.7 The FCR for various catchment/regions may be obtained from literature or be determined from other experimental work. If such literature values are being used, the report should include a literature reference. If no such values are available, a standard figure of FCR=1,1 is recommended for big fish and FCR=0,6 for fingerlings (the figures are obtained from salmonid production under optimal growth conditions). Other figures should be used for other fish or shellfish. When FCR is available for the catchment/region to be reported on, the missing figures of feed fed or production may be estimated from the above-mentioned equation. Method 1 can then be followed for the quantification of the discharge.

4.8 Administrative borders do not normally correspond to catchment borders. This may cause an error in the quantification of discharges from aquaculture in small catchments, but the relative importance will decrease when larger catchments are the basis for the reporting. Based on the available national statistics for aquaculture, information should be aggregated to the selected catchment level. This aggregation could be a simple summing up of the number of administrative units within the catchment. Alternatively, more sophisticated GIS procedures could be applied, taking into account the overlap between administrative borders and catchment borders.

[8] The water content in these feed category varies, but a general guidance can be: semi-moist feed (35-80% is dry matter), moist feed (< 35% is dry matter), while a dry feed has > 80% dry matter.

Approach 3

4.9 For landbased systems such as artificial ponds, basins, raceways, the discharges/losses of N and P may be quantified by monitoring the concentration of N, P and the water flux in the inlet(s) and outlet(s) of the production system, followed by a calculation of the increased load. The discharge of nitrogen and phosphorus (and organic matter) from a production system may vary considerably over both a short and long timescale and depend, *inter alia*, on operational factors such as time of feeding, time of cleaning operations and on the natural variations in the inlet(s). Effluent monitoring strategy must reflect this variation.

4.10 All aquaculture plants with an annual production of more than 200 tonnes should, ideally, take 12 samples a year in the inlet(s) and the outlet(s) for measurements of nitrogen and phosphorus concentrations.

4.11 Sampling of water for analyses of nitrogen and phosphorus should be flow-proportional over at least 24 hours and be carried out using automatic samplers in order to ensure a reliable quantification of the total nitrogen and phosphorus discharges. The Laboratory should be accredited or approved by national authorities. If the sampling is not automatic, the following additional information may need to be reported to relevant authorities:

a. The number of samples included in the average annual concentration;

b. The period the mean concentration is based on (daily, weekly, monthly, or yearly).

4.12 Good international laboratory practices, aiming at minimising the degradation of samples between collection and analysis should be applied.

The water flow should be registered continuously. Flow measurements should preferably be performed according to international standards (e.g. ISO standards).

4.13 The annual load of inlet(s) and outlet(s) may be calculated as follows:

$$L = \frac{\sum_{i=l}^{n} Q_i * C_i}{\sum_{i=l}^{n} Q_i} * Q_t$$

L	-	annual load
Q_i	-	wastewater volume of the period i
C_i	-	concentration of sample i
Q_t	-	total wastewater volume of the year
n	-	number of sampling periods

4.14 The total added load of nitrogen or phosphorus (or organic matter) from the production system is calculated by deducting the total nitrogen or phosphorus load in the inlet(s) from the total nitrogen or phosphorus load in the outlet(s).

Accuracy

4.15 If the national assessment of reporting procedures have resulted in an estimate of the accuracy of the reported figures, such estimates should be given. Methods for assessing accuracy of reported figures have not been included in this guideline. The method used for the quantification should be mentioned in the report, as well as any deviations from the recommended methods.

5. References

CHO, C.Y., HYNES, J.D., WOOD, K.R. AND H.K.YOSHIDA, 1991. Quantification of fish culture wastes by biological (nutritional) and chemical (limnological) methods; the development of high nutrient dense (HDN) diets. In: Nutritional Strategies and Aquaculture Waste (Ed. By COWEY, C.B. AND C.Y.CHO, pp 37-50. Proceedings of the first International Symposium on Nutritional Strategies in Management of Aquaculture Waste. University of Guelph, Guelph, Ontario, Canada.

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OSPAR, 1997. Draft Report on Nutrient Discharges from Fish and Shellfish farming in the OSPAR Convention Area (NUT 97/8/1).

ÅSGÅRD, T. AND M. HILLESTAD, 1998. Technological and nutritional aspects of safe food production. Eco-friendly aquafeeds and feeding. Contribution at the *Symposium Victam 98*. May 13-14, 1998. Utrecht, The Netherlands.

6. HARP Reporting Formats

Catchment/ coastal area (No. and name)	Quantification approach	No. of plants	Production (tonnes/year)	Feed consumption (tonnes/year)[9]	Nitrogen in feed (%)	Phosphorus in feed (%)	Nitrogen in organisms (%)	Phosphorus in organisms (%)
Sum-coastal-/inland waters								
National figure[10]								

Catchment/ coastal area (No. and name)	Feed conversion rate	Nitrogen treatment yield	Phosphorus treatment yield	Total nitrogen discharge (tonnes/year)			Total phosphorus discharge (tonnes/year)			Accuracy (+/- %)[10]	Description of alternative method(s) or deviations from the standard methods used, and assessment of their comparability with the recommended methods
				C	**I**		**C**	**I**			
	++*9/9802369 +/			Dir	Mon	Un mon	Dir	Mon	Un mon		
Sum-coastal-/inland waters											
National figure[11]											

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[9] All calculations involving weight of feed should be performed on a “dry feed” weight-basis.

[10] Best possible indication based on national experience. A reference to where further information on methods used should be given in the next column.

[11] The total nitrogen and phosphorus discharge from aquaculture in each country should be the sum of the discharge in the above catchments, unless only national figures are available.

Annex I: Example of quantification of nitrogen and phosphorus discharges/losses from aquaculture plants

General

1.1 This example describes, stepwise, the quantification of nitrogen and phosphorus discharges/losses from aquaculture plants not connected to municipal wastewater treatment plants in the catchment. In this 'theoretical catchment', the information is assumed to be reported regularly from the aquaculture plants, on an annual basis, according to requirements in the discharge permits.

Collection of information

1.2 Information on production, feed consumption and nitrogen and phosphorus in removed sludge is collected from each farmer in the catchment. Due to good supply of raw materials for feed production in this catchment, the farmers use both factory produced dry feed and locally produced wet feed.

Aqua-culture plant	A. Production (tonnes/year)	B. Dry feed used (tonnes/year)	C. Wet feed used (tonnes/year)	Sludge removed- dry weight (tonnes/year)	D. N in sludge removed (tonnes/year)	E. P in sludge removed (tonnes/year)
I	110	100	40	5	0,1	0,04
II	240	330	0	10	0,3	0,08
III	170	200	50	7	0,2	0,06
/IV	370	300	200	12	0,3	0,09
SUM	**890**	**930**	**290**	**34**	**0,9**	**0,27**

Total feed consumption

1.3 In order to have figures for total annual feed used (F), given on the same weight basis, figures for wet feed used are converted to the same dry weight basis as the dry feed. Dry matter content of dry and wet feed is found to be 90% and 35% respectively in this catchment.

$$F = Total\ feed\ consumption\,(tonnes/yr) = B + \frac{C * 35\%}{90\%} = 930 + \frac{290 * 35\%}{90\%} = 1043$$

Feed conversion

1.4 'Feed conversion' expresses the ratio between total quantity of feed used and the production calculated on an annual basis.

$$Feed\ conversion\ rate\,(FCR) = \frac{F}{A} = \frac{1043}{890} = 1{,}2$$

Total nitrogen and phosphorus discharges

1.5 In this catchment, the standard values of N and P content of feed and produced organisms given in the guideline (Table 1) are adjusted according to local knowledge. The adjustments are:

Total nitrogen content in fish produced	2,5 %
Total phosphorus content of dry feed	1,0 %
Total phosphorus content of fish produced	0,4 %

If the sludge is not separated from the discharge (which is the normal situation in a traditional net cage operation), the calculations are as follows:

G = *Nitrogen discharge (tonnes/year)*= $0{,}01 \cdot (IC_i - PC_f) = 0{,}01 \cdot ((1043 \cdot 7{,}5) - (890 \cdot 2{,}5)) = \mathbf{56}$
H = Phosphorus discharge (tonnes/year)= $0{,}01 \cdot (IC_i - PC_f) = 0{,}01 \cdot ((1043 \cdot 1{,}0) - (890 \cdot 0{,}4)) = 7$

Nitrogen and phosphorus discharge after sludge removal

1.6 If sludge is collected by a technical device, the yield of the treatment is estimated based on the N and P content of the sludge removed. The total N and P loss before treatment (see 1.5 above) is thereafter to be corrected correspondingly in order to quantify the discharge of N and P after treatment.

Estimation of yield:

$$e\,(yield\ nitrogen\ removal) = \frac{D}{G} = \frac{0{,}9}{56} = 0{,}016$$

$$e\,(yield\ phosphorus\ removal) = \frac{E}{H} = \frac{0{,}27}{7} = 0{,}039$$

Estimation of loss after treatment:
The N and P loss before treatment is then multiplied with the factor (1-e) resulting in the discharge of N and P after treatment:

Nitrogen discharge (tonnes/year) = *G (1-e) = 56 (1-0,016) = = **55,1***
Phosphorus discharge (tonnes/year) = *H (1-e) = 7(1-0,039) = **6,7***

Guideline 3:
Quantification and Reporting of Nitrogen and Phosphorus Discharges from Industrial Plants

Guideline 3: Quantification and reporting of nitrogen and phosphorus discharges from industrial plants

Contents

1. Objectives

1.1 To describe procedures for the quantification of nitrogen and phosphorus discharges from industrial plants not connected to public wastewater treatment plants. The guideline should enable the comparison of nitrogen and phosphorus figures from different industrial sectors and facilitate national assessments of measures implemented.

1.2 To list the type of data to be reported on in addition to annual figures on discharges of nitrogen and phosphorus from industrial plants.

2. Introduction

2.1 General

2.1.1 This Guideline concerns industrial plants with direct discharges of nitrogen and phosphorus from production water into surface waters. The procedures for the quantification of discharges from industrial plants connected to municipal sewerage systems are described in Guideline 4 (Sewer systems). However, the recommended procedures are also relevant for quantifying the industrial portion of the nitrogen and phosphorus loads in municipal wastewater.

2.1.2 The industrial sectors to be included in the reporting, and that may discharge significant quantities of nitrogen and/or phosphorus directly to surface waters are:

- Fertiliser industry;
- Food and drink related industry, incl. dairy industry, soft drinks, wine production and brewing industry; meat and fish processing, alcoholic beverages manufacture and bottling, manufacture of fruit and vegetable products, manufacture of gelatine, production of yeast;
- Organic chemical and biochemical industry, incl. pharmaceutics, detergents industry, manufacture of glue, production of industrial alcohol, manufacture or removal of ink;
- Waste processing industry, including manure processing industry;
- Pulp and paper industry;
- Cokeries and refineries; and
- Other sectors, such as non-ferrous metal industries that are considered to be of catchment related or national importance.

In cases where an industrial plant belongs to more than one distinguished industrial sector and that it is impossible to apportion the nitrogen and phosphorus discharge/emission of that plant to the various sectors, the total nitrogen and phosphorus discharge/emission of the plant should be addressed to the main industrial sector to which the plant belongs.

2.2. Quantification methods

2.2.1 Ideally, all industrial plants that discharge nitrogen and phosphorus should have a monitoring programme. Practically it is necessary to ensure that at least the most important industrial plants as regards nitrogen and phosphorus discharges have an adequate monitoring programme. Practical difficulties will arise when there are small plants with small discharges of nitrogen and phosphorus. It will therefore, in many cases, be necessary to agree on a 'discharge limit figure' for the purpose of distinguishing between significant and less significant annual discharges of nitrogen and phosphorus. The ultimate aim is that the catchment/national figures should provide comparable and transparent reports, and that the reported figures are as complete as practically possible.

2.2.2 There are many different types of industrial sectors and plants. For the sake of transparency and harmonisation, it is recommended that the 'annual discharge limit figure' be the same for all industrial sectors with discharges of nitrogen and phosphorus. The monitoring requirements for industrial plants should apply, as a minimum, to plants with discharges of the same order of magnitude as the equivalent discharges from urban wastewater treatment plants. The Urban Wastewater Directive requires monitoring of nutrient discharges for wastewater treatment plants with more than 10 000 p.e. connected, which corresponds to 44 tonnes N/year and 9 tonnes P/year before treatment. This indicates that all industrial plants with annual discharges into surface waters after treatment exceeding

10 tonnes N/year

and/or

2 tonnes P/year

should monitor their discharges of nitrogen and phosphorus according to the sampling frequency referred to in section 2.2.4. Furthermore all refineries and fertiliser plants should monitor their discharges of nitrogen and phosphorus.

2.2.3 The sampling strategy should, for each plant and sector, be sufficient to ensure a reliable quantification of the total nitrogen and phosphorus discharges. Where the production and/or wastewater discharges vary significantly over the year, the sampling frequency and methods of assessment should be adjusted correspondingly. Where the nutrient concentrations/discharges are relatively stable over the year, less frequent monitoring may be adopted. However, the reasons for such a reduction in frequency should be explained in the reporting.

2.2.4 All industrial plants discharging more than 10 tonnes of nitrogen and/or more than 2 tonnes of phosphorus per year should, ideally, take 12 samples a year for measurements of nitrogen and phosphorus content (c.f. section 2.2.3).

2.2.5 For industrial plants discharging less than the limits mentioned in section 2.2.2, relevant standard discharge coefficients should be used in cases where no monitoring data is available. The determination of such coefficients should be based on experience with discharges from larger plants that have monitoring programmes, taking account of differences in the degree of internal treatment at the plants.

2.2.6 Whenever possible, the annual nitrogen and phosphorus load from industrial plants should be calculated as the product of annual total quantity of wastewater and flow weighted concentrations; the three ISO standard methods below are examples of such quantification procedures. The wastewater flow should be measured continuously to calculate the total quantity over a specified time period (day, month and year). The three methods described below are examples of :

- Continuous flow measurement and sampling;
- Continuous flow measurement and non-continuous sampling; and
- Flow measurements only on sampling days and sampling rather seldom.

1. Continuous flow measurement and sampling (e.g. 24 hours flow-weighted composite samples seven times/week). The annual nutrient load is then the cumulative load of continuously monitored time periods and can be calculated as follows:

$$L = \sum_{i=l}^{n} Q_i * C_t$$

Where
L : annual load
Q_i : wastewater volume of period i
C_i : flow weighted concentration of period i
n : number of sampling periods.

2. Continuous flow measurement and non-continuous sampling every second day, once a week or twice a month (preferably as 24 hour composites). The annual nitrogen and phosphorus load can then be calculated as follows:

$$L = \frac{\sum_{i=l}^{n} Q_i * C_i}{\sum_{i=l}^{n} Q_i} * Q_t$$

Where
L : annual load
Q_i : wastewater volume of the period i
C_i : concentration of sample i
Q_t : total wastewater volume of the year
n : number of sampling periods.

3. Flow measurements only on sampling days and sampling rather seldom i.e. 1 - 12 times/year. In this case the annual nitrogen and phosphorus load can be calculated by multiplying the average load of sampling days by 365.

$$L = \frac{\sum_{i=l}^{n} Q_i * C_i}{n} * 365$$

Where
L : annual load
Q_i : wastewater volume on sampling day i
C_i : concentration of the period i
n : number of sampling days.

3. Reporting

3.1 The nutrient discharges from industrial plants should be reported on a sector by sector and catchment by catchment basis. This will enhance comparability of quantification methods, transparency of reporting, effectiveness of national planning and implementation of measures. For the sake of transparency and comparability, a description of any deviations from the recommended quantification methods should be notified on a catchment by catchment basis.

4. Future Line of Action

4.1 Best Available Technology (BAT) descriptions for system categories referred to in appendix I of the IPPC Directive are being developed in the EC framework. A recommendation to the Commission on reporting procedures from the industrial sectors (Committee of Article 19 of the IPPC Directive) is expected to be ready in 2000. This may require a revision of the Guideline.

5. References

EC, 1991. EEC Council Directive of 21 May 1991 concerning Urban Wastewater Treatment (91/271/EEC, Waste Water Directive)

EC, 1996. Council Directive of 24 September 1996 concerning Integrated Pollution Prevention and Control (Directive 96/61/E; IPPC Directive)

OSPAR, 1996. Principles of OSPAR’s Comprehensive Study on Riverine Inputs and Direct Discharges (RID)

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6. HARP Reporting Format

Catchment (No. and name)	Industrial sector	Tot N discharge in tonnes/year Accuracy (+/- %)[12]			Tot P discharge in tonnes/year Accuracy (+/- %)[12]		
		Coastal areas	Inland waters		Coastal areas	Inland waters	
		Dir	Mon	Unmon	Dir	Mon	Unmon
No 1	Pulp and paper industry						
No 1	Fertiliser industry						
No 1	Food and drink related industry						
No 1	Org. chemical and biochemical industry						
No 1	Waste processing industry						
No 1	Cokeries and refineries						
No 1	Other sectors						
Sum catchment 1	**All sectors**						
National figures	Pulp and paper industry						
National figures	Fertiliser industry						
National figures	Food and drink related industry						
National figures	Org. chemical and biochemical industry						
National figures	Waste processing industry						
National figures	Cokeries and refineries						
National figures	Other sectors						
Total coastal-/fresh-water	**All sectors**						
National figures[13]							

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[12] Best possible indication based on national experience. A reference to where further information on methods used should be given in the next column.

[13] Sum of the figures from all the catchments/coastal areas

Catchment (No. and name)	Industrial sector	**Number of industrial plants**	**Description of alternative method(s) or deviations from the standard methods used, and assessment of their comparability with the recommended methods**
No 1	Pulp and paper industry		
No 1	Fertiliser industry		
No 1	Food and drink related industry		
No 1	Org. chemical and biochemical industry		
No 1	Waste processing industry		
No 1	Cokeries and refineries		
No 1	Other sectors		
Sum catchment 1	**All sectors**		
National figures	Pulp and paper industry		
National figures	Fertiliser industry		
National figures	Food and drink related industry		
National figures	Org. chemical and biochemical industry		
National figures	Waste processing industry		
National figures	Cokeries and refineries		
National figures	Other sectors		

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Guideline 4:
Quantification and Reporting of Nitrogen and Phosphorus Discharges from Sewage Treatment Works and Sewerage

Guideline 4: Quantification and Reporting of Nitrogen and Phosphorus Discharges from Sewage Treatment Works and Sewerage

Contents

1. Objectives

1.1 To describe procedures for the quantification of nitrogen and phosphorus from:

- Discharges from sewage treatment works; and
- Drainage.

1.2 To list the type of data to be reported on in addition to annual figures on discharges of nitrogen and phosphorus from sewage treatment works and drainage.

2. Introduction

2.1 Nitrogen and phosphorus can be discharged or lost from agglomerations into the surface waters along various pathways. The figure below provides an overview on the various pathways within urban agglomerations.

2.2 The nitrogen and phosphorus losses from unpaved urban areas are already considered in draft Guideline 6 on diffuse losses of nitrogen and phosphorus. Figure 1 shows the various sources and pathways of nitrogen and phosphorus discharges and losses in urban areas.

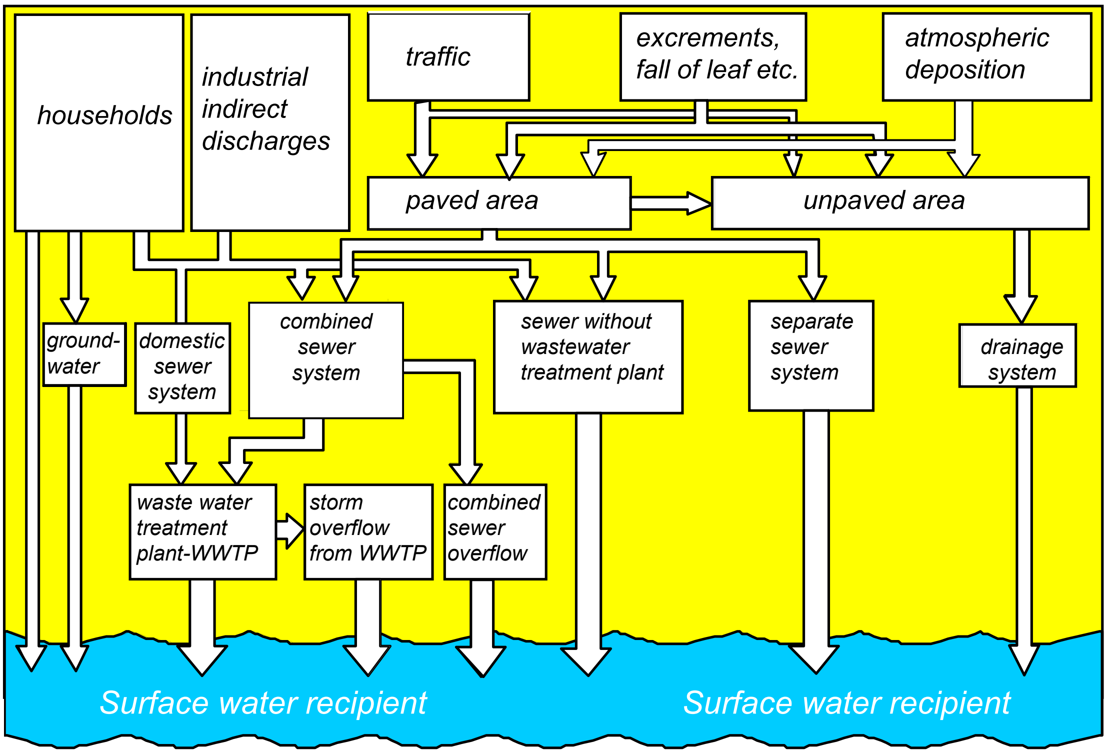

Figure 1*. Sources and pathways of nitrogen and phosphorus discharges and losses in urban areas (according to Behrendt, 1993; modified)*

2.3 Within this Guideline, the method for quantifying the nitrogen and phosphorus losses cover the following pathways (see Figure 1):

- Discharges of nitrogen and phosphorus by combined sewer systems;
- Discharges of nitrogen and phosphorus by separate sewer systems;
- Discharges of nitrogen and phosphorus by sewer systems that are not connected to a waste water treatment plants, and
- Households within the agglomeration which are not connected to a public sewer system, but that are expected to be connected in the near future.

2.4 Discharges/losses of nitrogen and phosphorus from households not connected to sewer systems, but which are expected to be connected in the near future, are considered in this Guideline as these households belong to urban agglomerations. Nitrogen and phosphorus losses from households not connected to sewer systems and that are not expected to be connected in the near future (5-10 years), are considered in Guideline 5.

2.5 Within the EC Urban Waste Water Directive (Council Directive 91/271/EEC concerning urban wastewater treatment) 'agglomerations' are used as a means to quantifying the potential nitrogen and phosphorus discharges/losses from urban waste water (annual nominal nitrogen and phosphorus loads). It gives a definition of 'agglomerations' as 'urban areas connected (or which will be connected in future), to a sewerage and treatment works'.

2.6 The corresponding ' annual nominal nitrogen and phosphorus loads' (expressed in inhabitants equivalents or population equivalents), includes households, business and industry, and tourist related activities, and has to be evaluated and reported on in the implementation of the Directive if it exceeds 2000 p.e., i.e. 8,8 t N/year and 1, 8 t P/year (based on 12 g N/day = 1 p.e. and 2,5 g P/day = 1 p.e.).

2.7 The Urban Waste Water Directive also calls for measurements at the outlet of waste water treatment plants, as well as for an evaluation of measurements at the inlet for calculating the percentage reduction of the nitrogen and phosphorus discharges (c.f. Annex 1D of the Directive). Furthermore, it indicates a minimum frequency of sampling according to the number of p.e. The relevant figures from the said Directive have been used in this Guideline.

2.8 During storm water events, the sewers may not be able to discharge all wastewater into the wastewater treatment plants. A portion may be discharged directly into water recipients. This portion needs to be quantified.

2.9 The quantification of leakage should be carried out in cases where it is obvious that the separate leakage contribution to the nitrogen and phosphorus load is judged to be significant. However, there is currently no proposed harmonised way of quantifying nitrogen and phosphorus leakage from sewer systems. Therefore, best available estimates should be included in the quantified nitrogen and phosphorus losses/discharges to surface waters.

3. Definitions

Urban wastewater *means domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water.*

Domestic wastewater *means wastewater from residential settlements and services, which originate predominately from the human metabolism and from household activities.*

Agglomeration *means an area where the population and/or economic activities are sufficiently concentrated for urban wastewater to be collected and conducted to an urban wastewater treatment plant or to a final discharge point.*

1 p.e. (population equivalent) *(concerns to industry and population together) means the organic biodegradable load having a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day. In terms of nitrogen and phosphorus, this corresponds to 12 g N/day = 1 p.e. and 2,5 g P/day = 1 p.e.*

Collection system *means a system of conduits that collects and conducts urban wastewater.*

Annual nitrogen and phosphorus nominal load *means the organic biodegradable load of the agglomeration, expressed in population equivalents (p.e.), including those from domestic wastewater and industrial waste waters that must be collected by collection systems; it does not include loads of industrial wastewater that are treated separately and directly discharged into surface waters.*

Total annual nitrogen and phosphorus served load *means the organic biodegradable load of the agglomeration, expressed in population equivalents (p.e.), that is generated in the areas served by an existing collection system of an agglomeration and that should be connected to an existing system.*

Total annual nitrogen and phosphorus connected load *means an organic biodegradable load of an agglomeration, expressed in population equivalents (p.e.), which is effectively collected by an existing collection system of an agglomeration and that reached the treatment plant. The difference between the total annual served load and the total annual collected load equals the annual load from areas with collecting systems, which doesn't reach the treatment plant.*

Sewerage *means the infrastructure of a drainage system, comprising sewers, manholes, pumping stations and pumping mains, for the collection and conveyance of foul and surface waters, separately or combined, from source to a required point of delivery/discharge.*

4. Quantification methods

4.1 General

4.1.1 The recommended quantification methods are either based on:

- Monitoring (for larger plants) (c.f. section 4.2); or
- Theoretical quantification, in the case of plants of less than 2000 p.e. connected and that are not monitored (see section 4.3.1-4.3.3) and the quantification of losses such as leakage and overflows (see section 4.3.4-4.3.8).

4.2 Quantification methods concerned with discharges of nitrogen and phosphorus from monitored wastewater treatment plants

4.2.1 Flow-proportional or time-based 24-hour samples[14] should be collected at the same well-defined point in the outlet of the treatment plants.

4.2.2 Good international laboratory practices, aiming at minimising the degradation of samples between collection and analysis, should be applied.

4.2.3 The minimum annual number of samples to be taken for nitrogen and phosphorus analyses depends on the number of p.e. connected to the treatment plants. The samples should be collected at regular intervals during the year[15]. The Urban Wastewater Directive requires analyses of nitrogen and phosphorus only wastewater treatment plants with more than 10 000 p.e. connected. However, water samples are also required for wastewater treatment plants with from 2000 to 10000 p.e. connected, but there are no requirements for analyses of the nitrogen and phosphorus concentrations (c.f. Table 1).

Table 1*: Number of p.e. connected required number of samples*

Number of p.e. connected	***Number of samples***
Less than 2 000 p.e.	4 samples or theoretical quantification when no sampling
2 000-9 999 p.e.	4 samples[16]
10 000-49 999 p.e.	12 samples
50 000 p.e. or more	24 samples

4.2.4 Extreme values for the water quality in question should not be taken into consideration when they are the result of unusual situations, such as those due to heavy rain.

4.2.5 Whenever possible, the annual nitrogen and phosphorus load from sewer systems should be calculated as the product of annual total quantity of wastewater and flow weighted concentrations, c.f. the three ISO standard methods below are examples of such quantification procedures. The wastewater flow should be measured continuously to calculate the total quantity over a specified time period (day, month and year).

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14 According to the Urban Waste Water Directive (Council Directive 91/271 EEC, Annex 1) alternative methods to those mentioned above may be used provided that it can be demonstrated that equivalent results are obtained.

15 Except for the Member States (currently only the Netherlands and Luxembourg), which apply Article 5.4 of the Directive (overall reductions of 75% of the nutrients, taking into account all the UWWT plants). The monitoring of nutrients is required only in agglomerations of more than 10 000 p.e. under the UWWT Directive (Articles 5.2 and 5.3).

16 If one sample of the four fails to comply with the requirements of Urban Waste Water Directive, 12 samples should be taken in the year that follows.

1. Continuous flow measurement and sampling (e.g. 24 hours flow-weighted composite samples seven times/week). The annual nitrogen and phosphorus load is then the cumulative load of continuously monitored time periods and can be calculated as follows:

$$L = \sum_{i=1}^{n} Q_i * C_t$$

Where:

L	=	annual load
Q_i	=	wastewater volume of period i
C_i	=	flow weighted concentration of period i
n	=	number of sampling periods.

2. Continuous flow measurement and non-continuous sampling every second day, once a week or twice a month (preferably as 24 hour composites).
The annual nitrogen and phosphorus load can then be calculated as follows:

$$L = \frac{\sum_{i=1}^{n} Q_i * C_i}{\sum_{i=1}^{n} Q_i} * Q_t$$

Where:

L	=	annual load
Q_i	=	wastewater volume of the period i
C_i	=	concentration of sample i
Q_t	=	total wastewater volume of the year
n	=	number of sampling periods.

3. Flow measurement only on sampling days and sampling rather seldom i.e. 1 - 12 times/year. In this case the annual nitrogen and phosphorus load can be calculated by multiplying the average load of sampling days by 365.

$$L = \frac{\sum_{i=1}^{n} Q_i * C_i}{n} * 365$$

Where:

L	=	annual load
Q_i	=	wastewater volume on sampling day i
C_i	=	concentration of the period i
n	=	number of sampling days.

4.3 Calculation methods concerning discharges of nitrogen and phosphorus from unmonitored wastewater treatment plants

Total annual nominal nitrogen and phosphorus loads

4.3.1 The nitrogen and phosphorus nominal load from the population (Np) is important for the quantification of nitrogen and phosphorus discharges from unmonitored sewage works. It is quantified by adding the permanent and temporary population equivalents according to:

$$Np= (365\ P_o+\sum P_i d_I)12*10^{-6}$$
(for nitrogen)

$$Np= (365P_o+\sum P_i d_I)\ 2,5*10^{-6}$$
(for phosphorus)

Where:

P_o = permanent population;
P_i = category of temporary population; and
d_i = average stay in days per year.

Total annual served load

4.3.2 The yearly quantity in tonnes of nitrogen and phosphorus delivered into municipal sewer systems (T) is defined as:

T (in tonnes) = (1-F) Np+C+D

Where:

T = Total produced N and P delivered into municipal sewer systems;

Np= Product of specific production in tonnes/person and year, and the number of inhabitants connected to sewer systems, including occupation of accommodations such as offices, shops, hotels, tourist accommodations, secondary houses;

C= Nitrogen and phosphorus discharges from industry (including workshops which have discharges of nitrogen and phosphorus) in tonnes/year (to be quantified using the same procedures as industrial plants not connected to public sewerage systems, see Guideline 3, Industry);

D= Drainage from paved areas connected to sewerage; and

F= Estimate of that part of the total annual load for which collection via a system and connection to such a system is not expected within the near future (5-10 years).

Total connected annual load and loss coefficients

4.3.3 The yearly transport of municipal wastewater to treatment plant by sewerage (M) is defined as:

M (tonnes/year) = T-LO

Where:

M = Total connected annual load (tonnes/year);
T = Total produced N and P delivered into municipal sewer systems; and
LO = Loss, including overflow and leakage (tonnes/year).

4.3.4 The total nitrogen and phosphorus discharges from the wastewater treatment plants and the losses due to leakage and overflow are quantified as follows:

$$\text{Nitrogen and phosphorus load (tonnes/year)} = \sum_{0}^{n} M_i\,(1-E_I) + LO$$

Where:

M	=	Total connected annual load (tonnes/year);
I	=	Type of treatment plant according to removal efficiency;
E_I	=	Efficiency of removal of N and P for a specific type of treatment plant, e.g. if the removal efficiency is 15%, E_i is 0,15; and if $_I$=0, that means there is no treatment;
LO	=	Loss

Quantification of nitrogen and phosphorus losses into the environment from sewerage (overflows and leakage) and overflows at sewage treatment works

4.3.5 There are two basic approaches to quantifying the nitrogen and phosphorus losses into the environment from sewerage (such as overflows and leakage) and overflows at sewage treatment works. These are described below. Whichever approach is used, the onus is on the Contracting Party to demonstrate that all sewage effluent and drainage related nitrogen and phosphorus loads to surface waters are appropriately accounted for. In the case of re-use of effluent from wastewater treatment plants for irrigation purposes, it should be indicated that the actual load of nitrogen and phosphorus of this effluent discharged into surface waters is reduced as a consequence of this re-use.[17]

4.3.6 **Approach 1**: This approach involves the deduction of the total connected annual nitrogen and phosphorus loads (as defined in section 4.3.3) from the total annual nitrogen and phosphorus served load (as defined in section 4.3.2). The total annual connected nitrogen and phosphorus loads may be obtained by:

- An evaluation of measurements at the inlet, for calculating the percentage reduction of the nitrogen and phosphorus discharges;
- Quantifying the total nitrogen and phosphorus loads generated by an agglomeration; and
- Quantifying an accounted load discharged to the environment by deducting:
  - ❖ The nitrogen and phosphorus loads reduction achieved by the treatment process; and
  - ❖ The nitrogen and phosphorus loads in the effluent from sewage treatment works.

4.3.7 **Approach 2**: This approach relies on quantifying the actual nitrogen and phosphorus loads associated with storm overflows and other sewage and drainage flows entering the environment upstream of or separately to the sewage treatment works effluent discharge.

4.3.8 One alternative way of quantifying the nitrogen and phosphorus load due to overflow into surface waters is based on the estimation of the run-off from paved areas through relevant pathways. This method requires detailed information about the entire system (see Annex 1).

17 In this case, the re-use of this effluent in agriculture should be accounted for in the application of draft Guideline 6: Quantification of Nitrogen and Phosphorus Losses from Diffuse Anthropogenic Sources, and Natural Background Losses.

5. Reporting

5.1 The nitrogen and phosphorus discharges from sewer systems should be reported on a catchment by catchment basis. In order to obtain transparency in the reporting and to achieve comparability between countries as regards quantification and reporting, the following additional information should be provided:

a. Description of calculation methods used, if the Guidelines have not been followed (partly or fully);

b. Figures for specific production of N and P in tonnes per person and year;

c. Figures for the total served load (N, P);

d. If measured monitoring data is available on effluent concentrations, it is not necessary to provide figures/estimates of the total production of municipal wastewater;

e. Average treatment efficiency (N, P);

f. Figures on leakage and overflow; and

g. Number of wastewater treatment plants, sub-divided into the categories used in the Urban Wastewater Directive (see Section 7, HARP Reporting Format).

6. References

EC 1991, Council Directive of 21 May 1991 concerning Urban Wastewater Treatment (91/271/EEC, WasteWater Directive).

EUROPEAN WASTE WATER GROUP, 1995. Storm water pollution control systems in EU Member States. Final Report.

7. HARP Reporting Format

Catchment / Coastal area (No. and name)	Total served load (tonnes/year)		Quantity of municipal wastewater at the outlet of the treatment plants (tonnes/year)		Total nitrogen discharge (tonnes/ year)			Total phosphorus discharge (tonnes/year)			Description of alternative method(s) or deviations from the standard methods used, and assessment of their comparability with the recommended methods
	N	P			CA[18]	IW[19]		CA	IW		
					Dir	Mon	Unmon	Dir	Mon	Unmon	
Total CA[20]/IW[21]											
National figure[22]											

To Summary Reporting Format in Guideline 1	To Implementation Format in Guideline 1

[18] Coastal waters.
[19] Inland waters.
[20] Directly into marine waters.
[21] Into inland surface water recipients.
[22] Sum of the figures from all the catchments/coastal areas.

Catchment/ Coastal area (No. and name)	**Estimates of the load from overflow/ leakage**		**Connection rate in the catchment[23] (p.e.)**	**Average treatment efficiency**		**Number of wastewater treatment plants, categorised according to number of p.e. connected**			
	N	P		N	P	<2000	2000-9999	10 000-49999	>50 000
Total CA[24]/IW[25]									
National figure[26]									

23 Portion of the population in the catchment connected to sewerage
24 Directly into marine waters
25 Into inland surface water recipients
26 Sum of the figures from all the catchments/coastal areas

Annex I: Description of the Method used within the International Commission for the Protection of the River Rhine for the determination of storm water overflows

1. Estimation of the proportion paved urban areas

Digital maps on the land cover (e.g. CORINE-land cover map) or NUTS statistics include the urban areas in different categories, but not the paved urban areas. The proportion of the paved urban areas should, in general, be calculated. One possibility calculation method is provided by the following formula of Heaney et al. (1976)

$$A_{PURB} = u_1 \left(u_2 \cdot POP_{DENSITY}\right)^{u_3 - u_4 \cdot \log\left(u_2 \cdot POP_{DENSITY}\right)} \cdot A_{URBTOT} \qquad (1)$$

Where
A_{PURB} is the paved urban area;
A_{URBTOT} is the total urban area in km²; and
$POP_{DENSITY}$ is the population density in inhabitants per hectare total urban area.

The original coefficients of Heaney *et al.* (1976) are converted into the metric system as follows:

u_1=9,6, u_2=0,4047, u_3=0,573 and u_4=0,0391.

2. Estimation of the specific runoff (percentage of precipitation discharged into the sewer systems from paved urban areas)

The specific runoff into the sewer systems can be estimated by an another equation by Heaney *et al.* (1986):

$$q_{PURB} = \left(0{,}15 + 0{,}75 \cdot \frac{A_{PURB}}{A_{URBTOT}}\right) \cdot N_Y \quad \left[\frac{l}{m^2 \cdot a}\right] \qquad (2)$$

Where
q_{PURB} is the specific runoff of paved urban areas into the sewer system; and
N_Y is the mean annual precipitation.

3. Estimation of the proportion of the different sewer systems in the urban area

NUTS-statistics on wastewater treatment and sewer systems include the proportion of the population that is connected to sewer systems (POP_{SEW}) and wastewater treatment plants (POP_{WWTP}). Furthermore, information about the length of the combined (L_{CS}) and wastewater sewers of the separate sewer systems (L_{WSS}) is available. From these data the urban area connected to the three considered pathways (combined sewer system – A_{CSS}; separate sewer system – A_{SS} and sewer system without connection to waste water treatment plants – A_{SWW} may be calculated as follows:

$$A_{CSS} = \frac{L_{CS}}{L_{CS} + L_{WSS}} \cdot \frac{POP_{WWTP}}{POP_{SEW}} \cdot A_{PURB} \qquad (3)$$

$$A_{SS} = \frac{L_{WSS}}{L_{CS} + L_{WSS}} \cdot \frac{POP_{WWTP}}{POP_{SEW}} \cdot A_{PURB} \qquad (4)$$

$$A_{SWW} = \frac{POP_{SEW} - POP_{WWTP}}{POP_{SEW}} \cdot A_{PURB} \qquad (5)$$

The total storm water runoff into the different sewer systems may be estimated by multiplying the specific runoff of the total paved urban areas with the proportion of areas connected to the different sewer systems.

4. Nitrogen and phosphorus discharges by separate sewer systems

The main sources of nitrogen and phosphorus discharges from paved urban areas are atmospheric deposition, excrements of domestic animals, litter fall and traffic. The measured nitrogen and phosphorus concentrations in separate sewer systems vary in a large range and are dependent on precipitation. Brombach & Michelbach (1998) therefore proposed, to calculate the nitrogen and phosphorus discharges by separate sewers by means of specific discharges. Table 1 gives an overview of the ranges of these specific discharges of phosphorus (ESS_P) and nitrogen (ESS_N). The total nitrogen and phosphorus discharges from the separate sewer system may be estimated by the following equation:

$$DSS_{N,P} = ESS_{N,P} \cdot A_{SS} \qquad (6)$$

Table 1. *Ranges of specific nitrogen and phosphorus discharges by separate sewer systems given by various authors*

Reference	**Specific P-discharges (ESS_P) (kg P/ha/year)**	**Specific N-discharges (ESS_N) (kg N/ha/year)**
Novotny & Chesters (1981)	1,25 – 3,00	5,0 – 7,0
Klein & Wassmann (1986)	1,20 – 2,80	
Paulsen (1984)	2,10 – 3,30	
Meißner (1991)	2,50	
Koppe & Stozek (1986)	2,00 – 12,00	17,0 – 35,0
Loehr (1974)		7,0 – 9,0
Ahl (1980)		1,4 – 21,2
Behrendt et al. (1999)	2,50	N_{DEP} + 4[27]

This equation does not take account of the retention or elimination of nitrogen and phosphorus within specific storm water treatments of the separate sewer system.

5. Nitrogen and phosphorus discharges by combined sewer overflows

In combined sewer system the storm water is mixed with the discharges/losses from households and indirect industrial discharges. During storm water events the sewers can not discharge all of the wastewater into the wastewater treatment plant. A portion is directly discharged into water bodies. The wastewater discharges by combined sewers may be calculated according to the following equation:

$$Q_{CSO} = q_{PURB} \cdot A_{CSS} + RT \cdot (POP_{WWTP} \cdot q_{POP} \frac{A_{CSO}}{A_{PURB}} + \frac{a_{IID} \cdot q_{IID} \cdot A_{CS}}{100} \qquad (7)$$

Where

Q_{CSO} is the total wastewater volume discharge by the combined sewer;

A_{CSO} is the paved urban area connected to combined sewer system;

POP_{WWTP} is the population connected to waste water treatment plants,

RT is the number of days with storm water overflows;

q_{POP} is the specific daily wastewater discharge from households;

27 N_{DEP} is the N-Deposition in the area according to EMEP-data; the additional 4 kg N/ha/year represents the inputs by litter fall and excrements from domestic animals.

a_{IID} is the percentage of the industrial area within the total urban area;
q_{IID} is the daily specific runoff from the industrial area.

Table 2 shows typical values of coefficients in Equation (7), used for German river basins (Mohaupt et al., 1998; Behrendt et al., 1999).

***Table 2**. Typical values of coefficients in equation (7) for German river systems*

Coefficient	**RT (d)**	**q_{POP} (m³/inh/d)**	**a_{IID} (%)**	**q_{IID} (m³/ha/d)**
Value	65	0,130	0,8	432

A portion of the total wastewater discharges in the combined sewers at the days of storm events flows into the wastewater treatment plant, another portion is discharged into the rivers via overflows. The rate of wastewater discharged into rivers via overflows may be estimated by an empirical formula, according to Meissner (1991):

$$E_r = \frac{2595}{V_S + 33,5} - 6 + \frac{N_Y - 800}{40} \quad (8)$$

Where
E_r is the percentage of wastewater discharged into rivers via overflows (%),
V_S is the volume of the specific storage of waste water in the combined sewer system (m^3/ha paved urban area); and
N_Y is the mean annual precipitation in mm.

Data on V_S is available in wastewater statistics. The value of V_S varies in German rivers between 2 and 21 m³/ha. Depending on precipitation and volume of storage, the percentage of wastewater discharged into rivers via overflows (E_r) varies between 40 and 70%.

The nitrogen and phosphorus concentrations in the combined sewer systems during storm events ($C_{CSON,P}$) may be calculated by applying the following formula:

$$C_{CSO_{N,P}} = \frac{((EA_{POP_{N,P}} \cdot POP_{WWTP} \cdot \frac{A_{CSS}}{A_{PURP}} + C_{IID_{N,P}} \cdot a_{IID} \cdot q_{IID} \cdot A_{CSS}) \cdot RT + ESS_{N,P} \cdot A_{CSS}) \cdot \frac{E_r}{100}}{Q_{CSO}} \quad (9)$$

Where
$EA_{POPN,P}$ is the specific nitrogen and phosphorus losses from inhabitants; and
$C_{IIDN,P}$ is the nitrogen and phosphorus concentration in industrial waste water.

An overview on the parameter values in equation (9) used for German rivers is presented in Table 3. The indicated value for the specific phosphorus losses per inhabitant applies to areas where phosphorus free detergents are used.

Based on these values, the typical nitrogen and phosphorus concentrations in the overflows during storm water events are, for German rivers, as presented in Table 4.

Table 3. *Values of coefficients in EQ (9) used for German rivers*

	EA_{POP} (g/E/d)	**C_{IID} (g/m³)**	**DSS (kg/ha/year)**
Nitrogen	11	0,1	2,5
Phosphorus	1,8	1	$4+N_{DEP}$

Table 4. *Typical nitrogen and phosphorus concentrations in the combined sewer overflows of German rivers for different volumes of storm water storage*

	Nitrogen (gN/m³)	**Phosphorus (gP/m³)**
V_S = 0 m³/ha	11,2	2,2
V_S = 11,5m³/ha	8,3	1,7
V_S = 23 m³/ha	6,6	1,3

On the basis of equations (7) and (9), the total nitrogen and phosphorus discharges from combined sewer overflows ($DCSO_{N,P}$) may be calculated according to the following:

$$DCSO_{N,P} = C_{CSO_{N,P}} \cdot E_r \cdot Q_{CSO} \quad (10)$$

6. Nitrogen and phosphorus discharged by sewer systems without connection to wastewater treatment plants

This pathway includes nitrogen and phosphorus discharges from the proportion of paved urban area, population and indirect industrial sources, that are connected to a sewer system, but not to a waste water treatment plant. According to the former estimations, the nitrogen and phosphorus discharges from this pathway may be calculated according to the following:

$$DSWW_{N,P} = ESS_{N,P} \cdot A_{SWW} + 365 \cdot ((POP_{SEW} - POP_{WWTP}) \cdot EA_{POPDIS_{N;P}} + C_{IDD_{N,P}} \cdot \frac{a_{IID} \cdot q_{iid} \cdot A_{SWW}}{100}) \quad (11)$$

Where

$D_{SWWN,P}$ is the nitrogen and phosphorus discharges from sewer systems without connection to waste water treatment and $EA_{POPDISN,P}$ is the specific dissolved nitrogen and phosphorus losses from inhabitants.

It is assumed that only the dissolved part of the nitrogen and phosphorus discharges per inhabitant (Phosphorus: 1,05g PE/d, Nitrogen: 9g NE/d) is discharged into the sewer systems and that the particulate part is transported to the next larger wastewater treatment plant.

7. References

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Guideline 5:
Quantification and Reporting of Nitrogen and Phosphorus Losses from Households not Connected to Public Sewerage

Guideline 5: Quantification and reporting of nitrogen and phosphorus losses from households not connected to public sewerage

Contents

1. Objectives

1.1 To describe procedures for the quantification of phosphorus and nitrogen losses from households not connected to sewerage into aquatic systems.

1.2 To list the type of data to be reported on in addition to annual figures on losses of nitrogen and phosphorus from households not connected to sewerage.

2. Introduction

2.1 'Households not connected to public sewerage systems' include both scattered dwellings and households within urban areas that are not connected and will not be connected in the near future 5-10 years. The diffuse anthropogenic nitrogen and phosphorus losses from households encompass the phosphorus and nitrogen losses from sanitary wastewater. The procedures for quantifying the nitrogen and phosphorus discharges from industrial plants not connected to sewerage systems are described in Guideline 2; those from households and industry connected to sewerage in Guideline 3.

2.2 Technical solutions for treatment of wastewater from households not connected to sewerage are highly variable and the distance from the households to the inlet into surface waters will influence the quantity of the nitrogen and phosphorus losses into surface waters.

2.3 In many densely populated catchments, the quantity of wastewater from scattered dwellings is insignificant when compared with the discharge from wastewater treatment plants. However, these areas may have a significant portion of the households that are not connected to public sewerage. In addition, there are catchments with fewer infrastructures, where the proportion of the nitrogen and phosphorus losses from scattered dwellings may be relatively high. The procedures for quantifying the nitrogen and phosphorus losses from households not connected to sewerage are based on theoretical approximations, using national statistics.

3. Quantification methods

3.1 The nitrogen and phosphorus loss quantification should be based on average specific loss figures of nitrogen and phosphorus into water bodies, taking account the level of water consuming equipment, treatment methods, ways of discharge and distance from the water bodies.

3.2 The quantification should be made on the basis of national statistics. The national statistics should be as up to date as possible. Most countries will have national registers providing information on:

- The number of households not connected to sewerage systems; and of
- The number of people living in the households, taking account the 'part of the year inhabitants' (e.g. offices, shops, hotels, tourist accommodations and secondary houses).

3.3 General statistics should provide information about:

- The waste-water treatment methods and water consuming devices in the households; and
- Location of the households in relation to watercourses (if available) and soil conditions (the part of the load actually reaches the surface waters).

3.4 Taking account of the level of water consuming equipment, treatment methods, ways of discharge and distance from water body, indicative specific loads of phosphorus and nitrogen (kg/person*year), according to the level of treatment and water consuming equipment are:

- For households with water flushed toilets, with no specific external treatment (except sedimentation tanks): 0,43 kg/p*year P and 3,1 kg/p*year N;
- For households with water flushed toilets, with specific external treatment: 0,25 kg/p*year P; 2,5 kg/p*year N; and
- For households located far from the primary recipient and summer cottages (used on average 60 days a year): 0,02 kg P/p*year; 0,05 kg N/p*year.

3.5 Many factors, such as technical solutions and distance from water body, may influence the specific nitrogen and phosphorus losses. The figures above are indicative and more site-specific, better data may be available at national level. The validity of the figures on nitrogen and phosphorus load, per person from households not connected to sewerage systems, may be verified by monitoring a small river stretch receiving nitrogen and phosphorus from households (valid for areas with scattered dwellings), provided that all the other main nitrogen and phosphorus sources are known.

4. Reporting

4.1 The geographical resolution in national statistics on the number of persons living in households is usually related to administrative units (e.g. municipalities), whilst the reporting in this guideline is at catchment related. Administrative borders do not necessarily correspond to catchment borders. This may cause an error in the quantification of nitrogen and phosphorus losses from households in small catchments, but the relative importance will decrease with increasing catchment size.

4.2 In order to obtain transparency in the reporting and to achieve appropriate comparability between countries, the following additional information should be provided:

- Description of calculation methods used, if the guidelines has not been followed; and
- Specific production of P and N in gram per person and day (cf. Annex).

5. References

EWPCA, 1997. Final Report to the European Commission DG XI B1 on The Comparability of Quantitative Data on WasteWater Collection and Treatment. European Water Pollution Control Association (WPCA) report to the European Commission. 196 pp.

6. HARP Reporting Format

Catchment/coastal area (No. and name)	**Number of people not connected to public sewerage**	Total nitrogen losses in tonnes/year **Accuracy (+/- %)**[28]			**Total phosphorus losses in tonnes /year Accuracy (+/- %)**[28]			**Average specific loss coefficient (after treatment) g/p / year**		**Description of alternative method(s) or deviations from the standard methods used, and assessment of their comparability with the recommended methods**
		Coastal areas	**Inland waters**		**Coastal areas**	**Inland waters**		**Tot-N**	**Tot-P**	
		Dir	**Mon**	**Unmon**	**Dir**	**Mon**	**Unmon**			
Sum coastal areas- / inland waters										
Total national figures[29]										

To the Summary Reporting Format in Guideline1

To the Implementation Format in Guideline 1

[28] Best possible indication based on national experience. A reference to where further information on methods used should be given in the next column.
[29] Total of the figures from all catchments/coastal areas.

Annex I: Definitions of population equivalents in various European countries (EWPCA 1997)[30]

EU Member States:	**A**	**B-FLAN**	**B - WAL**	**B-BRUX**	**DK**	**FIN**	**F**	**D**	**GR**	**IR**	**I**	**L**	**P**	**E**	**Swe**	**Swi** [31]	**NL**	**UK**
p.e. g BOD_5/d	60	60	54/60 [32]		60	60	50-70	60	50-60	60	54-60	60	54/60	60	60[33]	60	54	60
p.e. g COD/d	120		135					120				120			120			120
p.e. g N/d	12				12	12-15	12-15	11	10-14		12	11			12	8,5		
p.e. g P/d	2				2,5	2,5-3	3-4	2,5	2-2,5		2-3	2,5			2,5	1,7		
Other European countries:	**HR**	**EST**	**N**	**RUS**	**SK**													
p.e. g BOD_5/d	54	54	45[29]	6[34]	60													
p.e. g COD/d			90	[34]	120													
p.e. g N/d			12	[34]	11													
p.e. g P/d			1,6	[34]	2,5													

30 In Guidelines 3 and 5, average values for N and P have been used.

31 All figures for raw sewage.

32 54g BOD_5/d is used for calculating tax; 60 g BOD_5/d is used in relation to the EC Directive.

33 BOD_7.

34 The term is not used.

Guideline 6:
Quantification and Reporting of Nitrogen and Phosphorus Losses from Diffuse Anthropogenic Sources, and Natural Background Losses

Guideline 6: Quantification and Reporting of Nitrogen and Phosphorus Losses from Diffuse Anthropogenic Sources, and Natural Background Losses

Contents

1. Objectives

1.1 To describe procedures for the quantification and harmonised reporting of total phosphorus (P) and total nitrogen (N) losses from anthropogenic diffuse sources into primary surface water recipients.

1.2 To describe procedures for the quantification and harmonised reporting of natural background losses of total phosphorus (P) and total nitrogen (N) into primary surface water recipients.

2. Introduction

2.1 The harmonisation of the quantification procedures of nitrogen and phosphorus losses from diffuse anthropogenic sources, including natural background losses, has not been achieved. This is mainly because of different developments and experiences within Contracting Parties on this issue. This draft Guideline therefore focuses on harmonising the reporting procedures. In addition, the draft Guideline identifies factors that need to be taken into account when quantifying nitrogen and phosphorus losses from diffuse anthropogenic sources.

2.2 Draft Guideline 6 also includes examples of current quantification procedures applied by some Contracting Parties (c.f. Annexes I-V), which should ensure that at least the goal of transparency will be reached. Annex VI presents the Guideline for Calculating Mineral Balances and Annex VII shows some examples of figures on background losses of nitrogen and phosphorus.

2.3 The draft Guideline concerns diffuse phosphorus and nitrogen losses[35] to primary surface water recipients from:

- Agricultural land;

[35] Excluding nitrogen and phosphorus losses from scattered dwellings and stormwater flow from paved areas.

- Other land categories;
- Direct atmospheric deposition on inland water surfaces; and
- Natural background losses.

Furthermore, the draft Guideline deals with calculations of mineral balances.

3. Definitions of words and expressions

Land Cover: *Main land categories, such as forest, grassland and arable land.*

Land Use: *Land use related to agricultural practices, with classification of land into grassland and different arable crops.*

Natural background losses of nitrogen and phosphorus: *Nitrogen and phosphorus losses that would occur from unpaved areas if they were unaffected by human activities (except anthropogenic atmospheric deposition) and if they were in the state of natural pristine land.*

Direct atmospheric deposition: *Direct deposition of anthropogenic origin of nitrogen from the atmosphere onto inland surface waters.*

Year specific losses: *The actual losses of nitrogen and phosphorus for a specific year, influenced by the weather conditions for that year, and the current land use and agricultural practices.*

Normalised losses of nitrogen and phosphorus: *Annual nitrogen and phosphorus losses standardised, using either long-term weather data (e.g. 30 years) or weather data for a reference year.*

Surface runoff/soil erosion: *Direct losses of dissolved, organic and particulate associated (erosion) nitrogen and phosphorus from the land surface to primary surface water recipients.*

Root zone losses: *The total sum of nitrogen and phosphorus lost by pathways other than surface runoff/erosion; the net sum of nitrogen and phosphorus lost from the root zone through tile drains, interflow, or to the vadose zone/groundwater.*

Primary surface waters recipient: *The open water system to which diffuse inputs of nitrogen and phosphorus from the surrounding catchment and/or the atmosphere arrive through different hydrological pathways.*

Mineral balance: *The difference, at any scale, between input and output of nitrogen and phosphorus in agriculture, either by applying a 'farm gate level approach' or a 'field level (soil surface) approach'.*

4. Aspects of quantification procedures

4.1 Land-use categories and pathways

4.1.1 The potential nitrogen and phosphorus inputs to primary surface water recipients are transferred via a number of pathways. A large number of removal, storage or transformation processes may influence the final quantities of nitrogen and phosphorus entering primary surface water recipients.

4.1.2 The nitrogen and phosphorus loss pathways to surface waters include (see also Figure 1):

- Losses by surface runoff (transport of dissolved nitrogen and phosphorus);
- Losses by soil erosion (transport of particular, adsorbed nitrogen and phosphorus);
- Bank and riverbed erosion;
- Losses by artificial drainage flow (through drainage pipes/tile drainage);
- Losses by leaching (net mineralisation, percolating waters *i.e.* interflow, tile drain flow, spring water and groundwater); and
- Direct atmospheric deposition on inland surface waters

4.1.3 The different loss processes and pathways are very complex and variable, the significance of their effects also varies between nitrogen and phosphorus. It is therefore inherently difficult to quantify diffuse losses accurately. In the absence of comprehensive measurements, it is necessary to apply calculation methodologies (i.e. computer-based modelling techniques). Using such tools, losses from diffuse sources of nitrogen and phosphorus can be estimated either as the sum of all delivery pathways or as losses by every individual pathway.

4.1.4 The losses of nitrogen and phosphorus via the various pathways can vary substantially, depending on land use and management. In addressing the pathways, the following land cover categories can be taken into account, viz. agricultural land and categories such as forests, unproductive land and unpaved urban areas not connected to sewerage.

4.1.5 Natural background losses of nitrogen and phosphorus constitute a part of the total estimated nitrogen and phosphorus inputs to primary surface water recipients and include:

- Losses from unmanaged land; and
- That part of the losses of nitrogen and phosphorus from managed land that would occur irrespectively of anthropogenic activities.

4.1.6 Direct atmospheric deposition of nitrogen on inland surface waters may represent an important input and should be quantified where it is considered as a major source of the total inputs of nitrogen to inland surface waters. The atmospheric deposition of nitrogen on land is accounted for within the quantification of nitrogen and phosphorus reaching the primary surface water recipients via the soil-related pathways (c.f. Figure 1). Atmospheric deposition of phosphorus should be considered if the source is of significant importance, such as in areas where lakes constitute a major part of the catchment.

4.1.7 Three levels can be considered for the purpose of quantifying the nitrogen and phosphorus inputs via pathways related to nitrogen and phosphorus reaching the primary surface water recipients via soils, viz.:

- Level 1: Net nitrogen and phosphorus inputs into the soil, e.g. mineral balances, loss coefficients;
- Level 2: Retention, sedimentation on land and nitrogen and phosphorus leaching from the root-zone; and
- Level 3: The total nitrogen and phosphorus inputs to the primary inland surface water recipients via the various pathways.

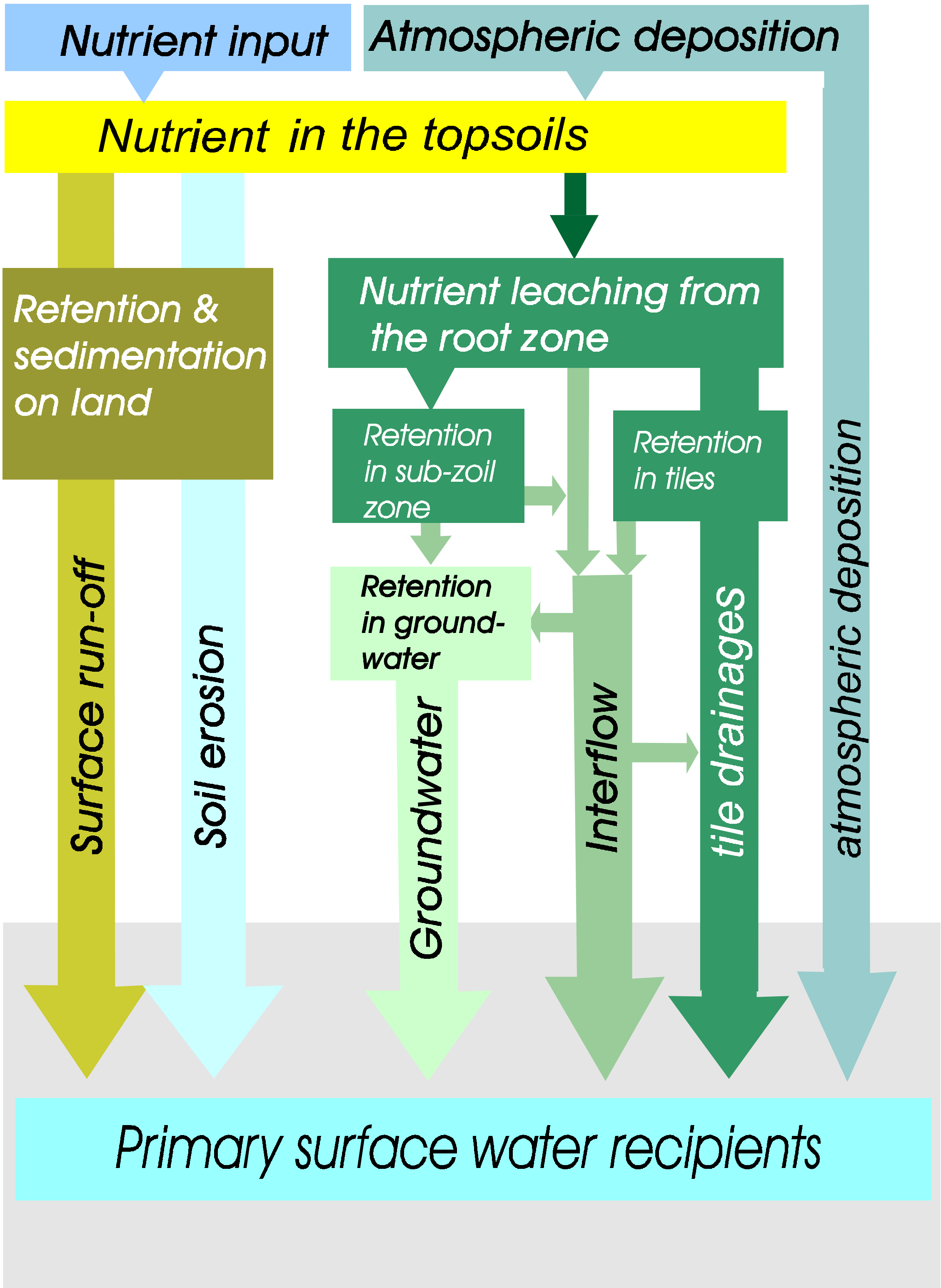

***Figure 1**. Pathways of nitrogen and phosphorus losses from diffuse sources to primary surface water recipients*

4.1.8 Mineral balance calculations are appropriate for characterising the intensity of the agricultural system, and can serve to indicate the likely magnitude of potential long-term nitrogen and phosphorus losses, including ammonia volatilisation. Mineral balances are most informative within regions of high nitrogen and phosphorus surplus, although diffuse nitrogen and phosphorus losses are still possible even under zero or negative surplus conditions, *e.g.* due to soil nitrogen mineralisation.

4.1.9 Root zone losses of nitrogen may indicate the potential input of nitrate to primary surface water recipients. Changes in agricultural management practices will influence the nitrogen and phosphorus root zone losses, but they may not be fully reflected in the figures of total nitrogen and phosphorus inputs to primary surface water recipients, due to time lags caused by hydrological conditions and processes in the soil. It is therefore helpful to quantify nitrogen and phosphorus losses from the root zone as this intermediate level represents a valuable basis for both assessing the effects of nitrogen reduction measures and for comparing different catchments.

4.1.10 The potential inputs of phosphorus to primary inland surface water recipients are usually much more difficult to quantify than the nitrogen inputs. In addition they are often more spatially and temporally variable. Phosphorus losses are better correlated with soil P-saturation, erosion risks and run-off pathways.

4.2 Existing methodologies

4.2.1 It is recognised that local environmental conditions and land management practices are important factors regulating diffuse nitrogen and phosphorus losses to surface waters. The choice of methodology is principally constrained by data availability and the understanding of environmental processes at the scale of reporting. Thus, no single quantification methodology can currently be recommended for all Contracting Parties.

4.2.2 In order to assist Contracting Parties in quantifying nitrogen and phosphorus losses from diffuse anthropogenic sources, annexes I-V provide examples of methodologies developed and validated in specific countries, which are suitable for use with national data sets.

Annex I	Example of methodology used in Switzerland and Germany
Annex II	Example of methodology used in the UK
Annex III	Example of methodology used in Denmark
Annex IV	Example of methodology used in the Netherlands
Annex V	Example of methodology used in Ireland.

4.3 Interim approach to quantification of diffuse losses

4.3.1 In the absence of harmonised quantification procedures, Contracting Parties should apply the most appropriate methodology for their circumstances, subject to the provisions of the Quality Control clause below and that the reporting fulfils the transparency requirements.

4.3.2 Whatever methodology is adopted by a Contracting Party, it is essential that certain minimum requirements be respected. In particular, the methodology should be based on measurements or upon objectively determined loss coefficients which must be both sensitive to variations in losses associated with different land uses (e.g. different agricultural crops and livestock densities) and responsive to the impact of nitrogen and phosphorus reduction policy measures. One of the most important measures is that of changes in nitrogen and phosphorus management by farmers; e.g. the timing of manure/slurry applications to land, which feature strongly in Nitrate Vulnerable Zone regulations. It is not obvious that a fixed N or P loss coefficient will be responsible to such changes, which are more subtle but just as (or more) effective in pollution mitigation than the reduction in nitrogen and phosphorus applications to land.

4.3.3 It is recognised that it is difficult to quantify typical background losses of nitrogen and phosphorus. Contracting Parties may estimate these losses either on the basis of measurements in small, undisturbed catchments or by modelling.

4.3.4 Deposition of airborne nitrogen compounds on open water bodies may be quantified by using atmospheric dispersion models. Such models are run within the EMEP programme. Relevant deposition coefficients may be derived on the basis of the EMEP data.

4.3.5 Atmospheric deposition of phosphorus should be considered if the source is of significant importance, such as in areas where lakes constitute a major part of the catchment. National phosphorus deposition coefficients may be applied, as the quantification of the deposition of phosphorus is not part of the EMEP programme.

4.3.6 Where other direct inputs of nitrogen and phosphorus (*e.g.* from direct excretion from livestock, direct spreading of manure, accidental spills, spray drift of fertiliser, litter fall and direct losses of nitrogen from groundwater into the Maritime Area) represent significant losses, these should be estimated.

4.3.7 The quantification of mineral balances should be carried out according to the method in Annex VI.

4.4 Data sources

4.4.1 As losses of N and P can vary substantially, spatially accurate land cover and/or land use data is therefore a prerequisite for assessing diffuse losses of nitrogen and phosphorus to surface waters. Land cover data, from for example satellite imagery, identifies areas of forest, grass and arable land, although satellite imagery has limitations because it is not possible to discriminate whether grassland belongs to agricultural land or amenities. Land use data from, for example national census, provides a more detailed classification of the nature of agricultural practices (e.g. stocking density, areas of different arable crops). This level of detail can be important as for example diffuse N and P losses may vary with arable crop type.

4.4.2 Contracting Parties should use the most appropriate land use data for their adopted methodologies (e.g. national agricultural census, NUTS, CORINE). The «NUTS» classification methodology (Eurostat 1995) provides detailed, annually updated data on crop areas and livestock number. However, it is spatially imprecise and omits non-agricultural and common land. In contrast, the «CORINE» land cover map (EC 1993), derived from satellite imagery, is spatially precise and has complete land cover. However, it is not frequently updated and lacks agricultural detail, especially concerning land use and livestock densities. CORINE has a uniform spatial resolution across European states, while the spatial resolution at NUTS' level may vary between countries.

4.4.3 Atmospheric dispersion models are run within the EMEP programme. Relevant deposition coefficients may be derived on the basis of EMEP data.

4.5 Normalisation of nitrogen and phosphorus losses

4.5.1 Differences in weather conditions cause considerable variations in nitrogen and phosphorus losses between years. In order to compare nitrogen and phosphorus losses between individual years or with other reported data (e.g. riverine loads), data on nitrogen and phosphorus losses may need to be normalised.

4.5.2 Statistical data on land use, land cover and agricultural census from the most recent available year should be used in the quantification. There are typically large annual variations in diffuse nitrogen and phosphorus losses due to prevailing weather conditions. Therefore, it is helpful for information to be provided both on nitrogen and phosphorus losses during an individual (specific) year, and nitrogen and phosphorus losses normalised either by using longer-term weather data (e.g. 30 years) or weather data for a reference year. The normalised nitrogen and phosphorus losses will be most suitable for determining the effect of measures to reduce diffuse losses. Year-specific data will be more valuable in the nitrogen and phosphorus load reconciliation method described in Guideline 1.

4.5.3 The precise procedures for standardising data will depend on whether an empirical or modelling approach has been used, and on the availability of data within individual catchments. Contracting Parties should report on:

- Diffuse losses, using long term weather data, or weather data from a reference year; and

- Losses for an individual year on a voluntary basis, bearing in mind that there is a mandatory reporting requirement on inputs of nitrogen and phosphorus via rivers and direct discharges (RID Programme), and that the figures enable the quantification of total inputs/losses/discharges of nitrogen and phosphorus to the Maritime Area, to be used in marine eutrophication assessments.

The methods applied in the quantification should also be notified.

4.6 Quality Control

4.6.1 Any modelling approach should be supported by appropriate measured calibration and/or validation data. It is expected that all measured data should conform to standardised «Good Field and Laboratory Practices». Contracting Parties should submit scientific evidence supporting the methodology used to quantify diffuses nitrogen and phosphorus losses.

5. Reporting

5.1 The diffuse anthropogenic losses of nitrogen and phosphorus should be reported as total nitrogen and phosphorus inputs to primary surface water recipients as a sum of all pathways.

The normalised nitrogen and phosphorus losses should be used when the reporting is concerned with determining the effect of measures to reduce diffuse losses, whereas year-specific data should be used when the reporting is concerned the nitrogen and phosphorus load reconciliation method described in Guideline 1.

5.2 In addition, Contracting Parties are encouraged to report estimates of:

- The potential inputs of nitrogen to surface waters, as determined by the losses from the root zone;
- Mineral balances (see Annex VI); and
- The magnitude of individual hydrological pathways (e.g. tile drainage, interflow, groundwater).

5.3 It is difficult to quantify natural background losses of nitrogen and phosphorus as these are unavoidable losses of nitrogen and phosphorus, not subject to mitigation measures, only the total inputs to primary surface water recipients need to be reported.

5.4 Deposition of airborne nitrogen compounds on open water bodies should be reported on the basis of data from atmospheric dispersion models (e.g. the EMEP programme).

5.5 Other direct inputs of nitrogen and phosphorus (*e.g.* from direct excretion from livestock, direct spreading of manure, accidental spills, spray drift of fertiliser, fall of the leaf, and direct losses of nitrogen from groundwater into the Maritime Area) should be reported when they represent significant losses.

5.6 The land cover categories to be used for reporting on nitrogen and phosphorus losses are:

- Agricultural land;
- Other lands (such as forest and unproductive land); and
- Water surfaces.

6. Future Developments

6.1 The 91/676/EEC Directive, which aims to protect waters against pollution caused by nitrates from agricultural losses, calls on E.U. Member States and those countries to monitor and report every four years, about fresh and marine waters' quality, diffuse sources assessment, and action programmes evaluation. Attempts will be made to harmonise monitoring and reporting guidelines of both "the Nitrates Directive» and relevant HARP Guidelines, in particular for:

- Inputs measurements and modelling;
- Classification of sampling points (nitrate concentration, eutrophication criteria); and
- Nitrogen and phosphorus balance assessment (at farm or watershed level).

6.2 Contracting Parties are encouraged to continue co-operation with the aim of harmonising methodological aspects of the quantification procedures. To that end, it is intended to carry out a comprehensive Evaluation Study, involving as many Contracting Parties as possible, in order to provide the best possible background for the overall assessment of the system, to take place in the year 2002 or 2003.

6.3 In planning mitigating measures to reduce nitrogen and phosphorus losses to primary surface water recipients it is, *inter alia*, necessary to understand the various hydrological pathways, and their time of response to preventive measures. The greater the volume of waters travelling via the fast pathways, the greater the potential for short-term improvements in water quality.

6.4 Contracting Parties are encouraged to continue to develop their understanding and quantification of the hydrological processes and pathways, to assist assessment of the impacts and rate of change of water quality following improvements in land management practices. It is important to recognise that the biochemical soil processes and the relative importance of individual hydrological pathways will differ for nitrogen and phosphorus.

7. Reporting Formats

7.1 Nitrogen and phosphorus inputs to primary surface water on the basis of normalised data

	Total phosphorus loss (tonnes/year) per catchment					Total nitrogen losses (tonnes/year) per catchment					Description of method(s) used
	Catchment 1 Coastal areas	Catchment 1 Inland waters		Catchment n		Catchment 1 Coastal areas	Catchment 1 Inland waters		Catchment n		
	Dir	Mon	Unmon			Dir	Mon	Unmon			
Agricultural land, sum of all pathways [36]											
Other land, sum of all pathways [37]											
Direct atmospheric deposition on inland water surfaces											
Total per catchment											
Of which the background losses of nitrogen and phosphorus[38] **constitute**											
Total national figures											

To the Summary Reporting Format in Guideline 1	To the Implementation Format in Guideline 1

36 Contracting Parties are invited to divide into and report on the losses from agricultural land according to different hydrological pathways and into different land use categories, if data is available. This reporting is optional.

37 All nitrogen and phosphorus inputs that are not included in agricultural land, such as forest, unproductive land, parks, golf courses and other amenity land.

38 See section 3 on definitions, and paragraphs 4.1.5 and 4.3.3 concerning background losses of nitrogen and phosphorus.

7.2 Nitrogen and phosphorus inputs to primary surface water on the basis of year specific data

	Total phosphorus loss (tonnes/year) per catchment					Total nitrogen losses (tonnes/year) per catchment					Description of method(s) used
	Catchment 1 Coastal areas	Catchment 1 Inland waters		Catchment n		Catchment 1 Coastal areas	Catchment 1 Inland waters		Catchment n		
	Dir	Mon	Unmon	Mon	Unmon	Dir	Mon	Unmon	Mon	Unmon	
Agricultural land, sum of all pathways [39]											
Other land, sum of all pathways [40]											
Direct atmospheric deposition on inland water surfaces											
Total per catchment											
Of which the background losses of nitrogen and phosphorus [41] **constitute**											
Total national figures											

To the Summary Reporting Format in Guideline 1	To the Implementation Format in Guideline 1

39 Contracting Parties are invited to divide into and report on the losses from agricultural land according to different hydrological pathways and into different land use categories, if data is available. This reporting is optional.

40 All nitrogen and phosphorus inputs that are not included in agricultural land, such as forest, unproductive land, parks, golf courses and other amenity land.

41 See section 3 on definitions, and paragraphs 4.1.5and 4.3.3 concerning background losses of nitrogen and phosphorus.

7.3 Potential inputs of nitrogen[42] to primary inland surface water recipients (root zone losses)

	Total nitrogen losses (tonnes/year) per catchment					Description of alternative method(s) or deviations from the standard methods used, and assessment of their comparability with the recommended methods
	Catchment 1 Coastal areas	Catchment 1 Inland waters		Catchment n		
	Direct	Mon	Un mon	normal year	spec. year	
Agricultural land[43], root zone losses						
Other land[44], root zone losses						
Direct atmospheric deposition on water surface						
Total per catchment						
Total national figures						

To the Summary Reporting Format in Guideline 1	To the Implementation Format in Guideline 1

42 See sections 4.1.1, 4.1.9, 4.1.10 and 5.1 on potential nitrogen inputs

43 Contracting Parties are invited to divide the nitrogen and phosphorus inputs from agricultural land into different land use categories if data are available.

44 All inputs that are not included in agricultural land, as forest, unproductive land, parks, golf courses and other amenity land.

8. References

EUROSTAT, 1995. NUTS regions «Nomenclature of territorial units for statistics», March 1995, Eurostat E-4 Regional statistics and accounting, L-2920 Luxembourg.

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Annex I: Quantification Method for Diffuse Losses of Nitrogen and Phosphorus to Surface Waters: Swiss and German approach

Contents

1. Introduction

This procedure (hereafter called the loss coefficient procedure) links land use data to loss-coefficients specific for different processes/pathways of the nitrogen and phosphorus losses to surface waters. Attachment 1 describes the application of the loss coefficient procedure on a step by step basis in order to quantify nitrogen and phosphorus losses from diffuse anthropogenic sources.

A detailed description of the methodology is given in BRAUN ET AL. (1991), WERNER *et al.* 1991, PRASUHN and BRAUN (1994) and BRAUN 1998. The Quantification of the Nitrogen and phosphorus Background Load considers the non-anthropogenic part of the diffuse nitrogen and phosphorus losses. Discharges/losses from scattered dwellings will not be described separately.

An advantage of the loss coefficient procedure is that it provides a breakdown of phosphorus and nitrogen losses from diffuse sources into the relevant water bodies taking into account, when appropriate, the various processes such as surface run-off, soil erosion, artificial drainage and leaching. The adoption of a loss coefficient procedure will assist the assessment and quantification of the effects of nitrogen and phosphorus reduction measures.

Depending on the land use, losses of phosphorus and nitrogen can vary substantially. The loss coefficient procedure assumes that the water quality reflects the land use in the hydrological region of the considered aquatic system. Therefore, every catchment has to be characterised by its land-use area, e.g. its portion of:

- Grass land;
- Arable land;
- Forest;
- Unproductive land;
- Urban areas (without connections to sewage treatment plants); and
- Water surfaces.

For the sake of transparency and harmonisation, the land-use data could be obtained from the CORINE Land-Cover (Co-ordination of information on the environment) (CORINE Land Cover, Technical Guide 1994). The scale of CORINE data is 1/100 000 for data on a 100 m grid, or 1/250 000 for data on a 250 m grid. If the CORINE Land-cover is not used, e.g. if at national level the data is more detailed/accurate, the land-use categories used should be harmonised with the land-cover categorisation in CORINE Land Cover.

The main land-use categories are listed above. Greater accuracy will be obtained if the agricultural land uses are sub-divided into the predominant arable crops and grassland usage (i.e. taking into account stocking density). Where only the broad categories are used, it will be necessary to use average loss coefficients for agricultural land. This coarser approach is suitable only for large-scale catchment assessment, e.g. 100 000 ha and greater.

There are different processes or pathways by which phosphorus and nitrogen are lost and transported to aquatic systems. The most important are listed below (see also Figure 1):

- Losses by surface run-off (transport of dissolved nitrogen and phosphorus);
- Losses by soil erosion (transport of particular, adsorbed nitrogen and phosphorus);
- Losses by artificial drainage flow (through drainage pipes);
- Losses by leaching (transport by percolation waters, i.e. interflow, spring water and ground water);
- Direct atmospheric deposition on open water bodies; and
- Direct inputs (e.g. litter fall, direct excretion from livestock, direct spreading of manure, accidental spills, spray drift of fertiliser).

It should be borne in mind that the importance of the various pathways for the nitrogen and phosphorus transport is different for phosphorus and nitrogen.

The deposition of airborne nitrogen compounds on open water bodies may be estimated by using atmospheric dispersion models. Such models are run within the EMEP programme. Relevant deposition coefficients should be derived on the basis of the EMEP data. Atmospheric deposition of phosphorus should be considered if the source is of significant importance as in watershed where lakes constitute a major part of the catchment area. National coefficients of atmospheric deposition of phosphorus may be applied, as deposition of phosphorus is not part of the EMEP programme.

Data concerning land-use categories, soil types, nitrogen and phosphorus balances (see PARCOM Guidelines for Calculating Mineral Balances), knowledge about management practices and about the importance of different processes within the considered catchment represent the main input data for implementing the loss coefficient procedure for the quantification of nitrogen and phosphorus losses from diffuse sources.

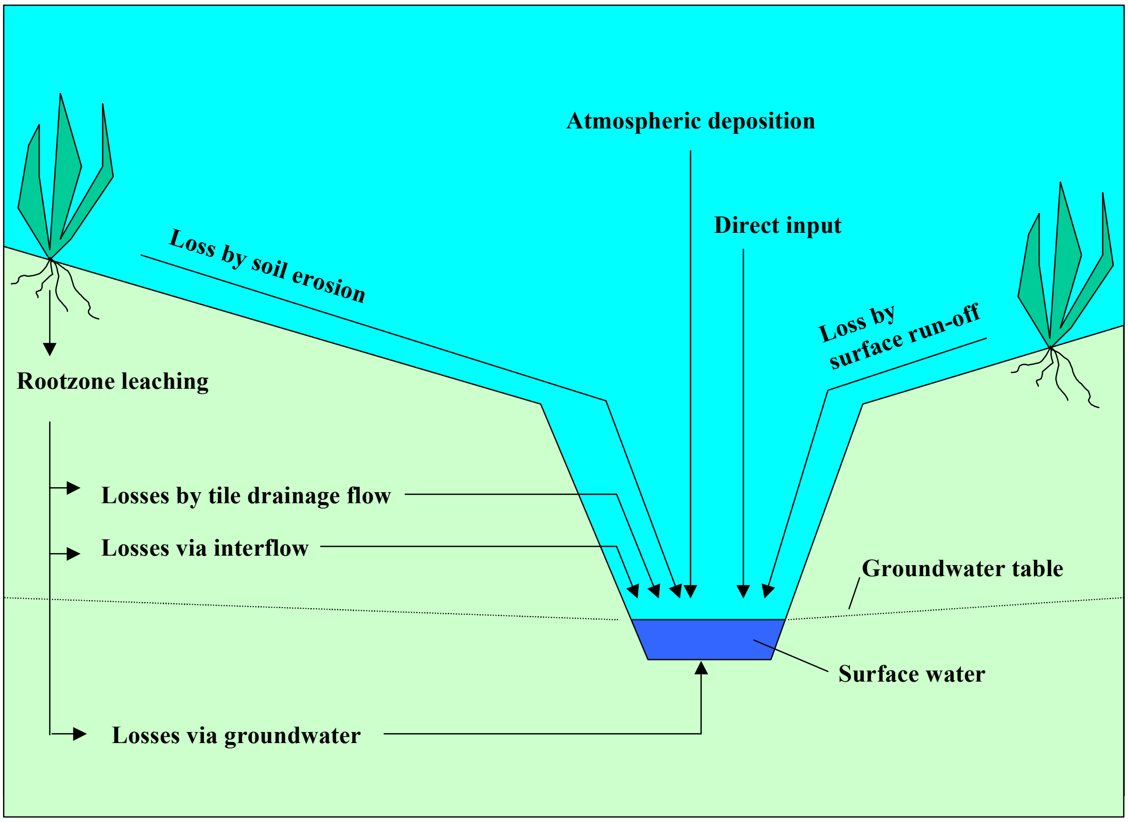

***Figure 1**. The most important ‘hydrological’ processes/pathways as regards nitrogen and phosphorus losses from diffuse sources to aquatic systems*

2. Quantification methods

Catchment approach

This quantification of the nitrogen and phosphorus losses from diffuse anthropogenic sources at catchment level and sub-catchment/field level is described. The quantification procedure does not depend on the size of the area considered. The differences are in the resolution of the baseline data (see Table 1 below) and in the way the loss coefficients are chosen (see Attachment 1). The smaller the area, the better data resolution is required. Attachment 2 gives an example of how to implement the loss coefficient procedure (example from three Swiss regions). The part of an area under consideration classified into one land-use category is called a 'homogenous land-use area'.

Table 1. *Catchment size and the need for locally adjusted loss-coefficient*

Area under consideration	**Choice of loss coefficients**
Catchments of the order of magnitude of 100 000 ha	Average loss coefficients, c.f. tables 2 and 3
Catchments of the order of magnitude of 10 000 ha	Use of either average or locally adjusted loss-coefficients
Homogenous land-use areas/ catchments of the order of magnitude of 100 ha	Adjusted loss-coefficients, c.f. Attachment 1

Procedure

In order to implement the loss coefficient procedure for the quantification of nitrogen and phosphorus losses from diffuse anthropogenic sources for a catchment, the following steps for the calculation should be performed (see also Figure 2):

Step 1: Compilation of baseline data

The characteristic baseline data are compiled for each homogenous land-use area, field or group of similar fields. These could include all relevant information about:

a. assignment to the land use categories and their size;

b. information about precipitation (mm/year), evapotranspiration (mm/year), run-off (m^3/s), soil types, slopes (in %); and

c. information about anthropogenic conditions, out of which the most important are:
   - The percentage of drainage land;
   - Intensity of utilisation;
   - Nitrogen and phosphorus surplus;
   - Time of ploughing;
   - Bare land in winter and use of green cover;
   - Quantity of manure and fertiliser applied;
   - Time of spreading; and
   - The numbers of livestock of each type kept within each catchment.

The smaller the considered catchment is, the more detailed information is required.

Step 2: Selection of loss coefficients

The loss coefficients are obtained by firstly distributing the total annual run-off into hydrological pathways, according to land-use (see table 2). The specific run-offs are then multiplied by the relevant nitrogen and phosphorus concentrations (see table 3). In order to quantify the nitrogen and phosphorus losses from diffuse sources into surface waters, the loss coefficients for each relevant pathway shown in Figure 1 should be determined in relation to the land-use categories for each homogenous area. For leaching losses, an intermediate step in this procedure is the determination of the loss coefficients for the root zone leaching. After taking into account any retention (including denitrification) in the subsoil or groundwater aquifer, the loss coefficients for the relevant pathways, such as interflow, drainage flow and groundwater can be determined. The loss coefficients can be derived from measurements, models or from the literature. Generally, national or catchment related methods can be used in order to determine the loss coefficients for each pathway related to land-use categories. Attachment 1 provides a description of a procedure to determine these loss coefficients.

Table 2. *Distribution of total annual run-off into hydrological processes according to land use*

	Surface run-off	Drainage water	Percolation water
Grassland	6%	55 – 75%	19 – 100%
Arable land	4-8%	55 – 75%	17 – 100%
Forest	2% [45]	-	98 – 100%
Unproductive land	4%	-	96 – 100%
Urban areas	30%[46]	-	70 – 100%

Table 3. *Range of nitrogen and phosphorus concentrations corresponding to the different water fluxes, and loss-coefficients in the case of direct atmospheric deposition, erosion and direct input, depending on land use and pathways (Where there are no values, the process does not exist or is not important for the corresponding land use category). The figures in the table are indicative and represent specific conditions of land-use, soil type and climate. In many cases they will need to be adjusted according to local conditions.*

	Losses by surface run-off mg/l	Losses by drainage flow mg/l	Leaching losses by percolation mg/l [47]	Direct atmospheric deposition kg/ha	Losses by erosion kg/ha	Losses by direct diffuse inputs kg/ha
Phosphorus						
Grassland[48]	0,40 – 3,00	0,06 – 0,15	0,005 – 0,04	-	-	-
Arable land[49]	0,25 – 1,50	0,06 – 0,15	0,010 – 0,05	-	0,25 – 3,30[50]	-
Forest	0,04 – 0,07[51]	-	0,005 – 0,02	-	-	-
Unproductive land[52]	0,04 – 0,10	-	0,005 – 0,02	-	-	-
Urban areas	0,04 – 0,10 [54]	-	0,005 – 0,03 [55]	-	-	-
Water surface	-	-	-	0,46 – 0,76	-	-
Total area	-	-	-	-	0,07 – 2,11[53]	0,017 – 0,086
Nitrogen						
Grassland	0,4 – 3,0	1,5 - 7,0	0,55 - 4,5	-	-	-
Arable land	0,4 – 3,0	8,0 – 25,0	5,0 - 16,0	-	0,7 – 6,0 [50]	-
Forest	0,3 – 0,85 [51]	-	0,5 - 3,5	-	-	-
Unproductive land	0,3 – 1,0	-	0,15 - 2,5	-	-	-
Urban areas	0,3 – 1,0 [54]	-	0,5 - 7,0[55]	-	-	-
Water surface	-	-	-	7,4 – 21,6	-	-
Total area	-	-	-	-	0,2 – 5,3 [53]	0,1 – 0,5

Step 3: Quantification of losses from homogenous areas

Nitrogen and phosphorus losses from each homogenous land-use area are given by the sum of the losses due to all hydrological pathways. Hence, annual area-specific nitrogen and phosphorus losses for each homogenous land-use are obtained.

45 Only for alpine regions and pre-alpine regions.

46 Only for paved areas without connections to sewage treatment plants.

47 Excluding losses by drainage flow.

48 Grassland: For accuracy, it is preferably to identify separate loss coefficients to represent the different levels of grassland management.

49 Arable land: For accuracy, it is preferably to identify separate loss coefficients in respect of the main arable crops in order to reflect their different nitrogen and phosphorus loss attributes.

50 Soil erosion on arable land.

51 Only for alpine regions and pre-alpine regions.

52 'Unproductive Land' includes:

a) Unproductive Vegetation (areas with e.g. bushes, as long as they are not included in the category 'Forest', wetland and dry land);

b) Areas without Vegetation (e.g. glaciers and rocky declivity).

53 Natural' erosion on the total area.

54 Only for roads without connections to sewage treatment plants.

55 Green areas within urban areas.

Step 4: Aggregation of the nitrogen and phosphorus losses from homogenous land-use areas to catchment level

Each catchment can be characterised as the sum of its homogenous land-use areas. The characteristic baseline data for all homogenous areas in a catchment are obtained from area-related statistics (CORINE Land Cover) or censuses of agricultural holdings. Steps 1 to 3 should then be performed with the data for all homogenous areas in the catchment. The sum of all nitrogen and phosphorus losses from all homogenous areas provides the nitrogen and phosphorus losses for the entire catchment.

3. Quality control

Comparisons

If the considered region is identical to the hydrological catchment, the results of the loss coefficient procedure are then compared with the nitrogen and phosphorus load quantified on the basis of monitoring results from the lowest point of the catchment under consideration; taking account of the natural background losses of nitrogen and phosphorus, retention in surface waters and nitrogen and phosphorus discharges from point sources. Other comparisons can be:

- A comparison of the results with the results from catchments with similar conditions may be performed to allow correlation with the results obtained.
- A comparison with other models may be performed to allow correlation with the results obtained.
- When evaluating losses of soil erosion, bank and bed erosion in streams and rivers should be considered if appropriate.

Adjustment

There are significant uncertainties inherent in any system of assessing the contribution of diffuse nitrogen and phosphorus losses to surface waters. Where the above comparison methods show a substantial difference in the results, consideration should be given to investigating the likely cause. This might require, for example, a review of the loss coefficients or the retention factors built into the loss coefficients approach. Equally, it might require an investigation into the accuracy of the water monitoring data and the associated load figures, or the retention factors related to the surface water system.

4. Examples

Tables 1-5 in Attachment 2 show, as simplified examples, the proposed baseline data, the chosen loss-coefficients and the nitrogen and phosphorus losses to surface waters in three different regions in Switzerland, resulting from the application of the described loss coefficient procedure. Each catchment has its own land use characteristic, has different main pathways to be considered and needs a specific choice of loss-coefficients.

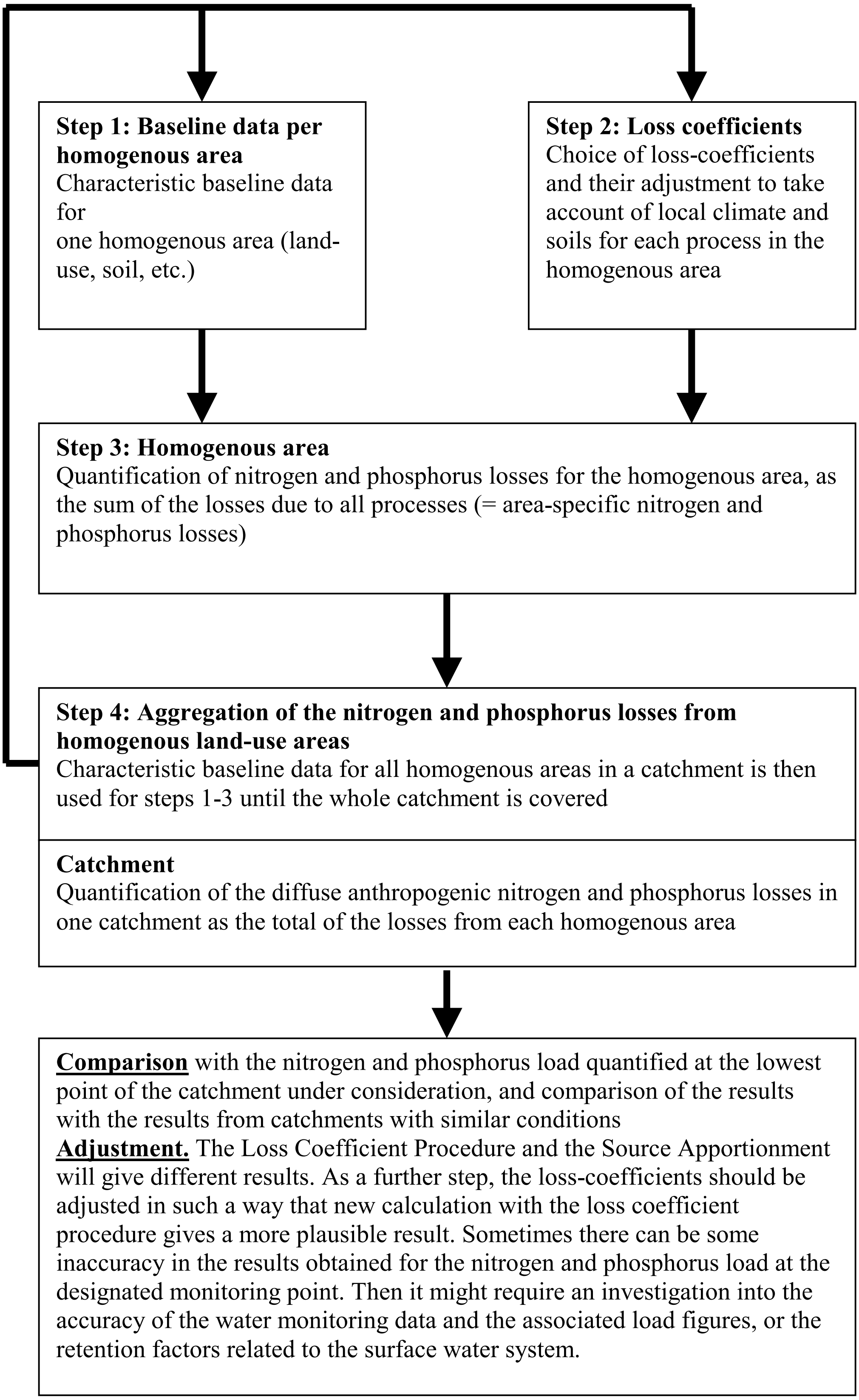

Figure 2. *Elements of the loss coefficient procedure for quantifying the nitrogen and phosphorus losses from diffuse anthropogenic nitrogen and phosphorus sources into aquatic systems in a catchment.*

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Attachment 1: Selection of Loss Coefficients for Nitrogen and Phosphorus

Introduction

The ranges of loss coefficients given in Annex I are indicative. In many cases, there will be national/catchment-related methods, which will provide more accurate, site-specific loss coefficients and also more site-specific procedures for selecting loss coefficients.

According to the loss coefficient procedure, the values in Tables 2 and 3 in Annex I should be adjusted in accordance with natural and anthropogenic conditions of the land use categories under consideration. This choice can be made either from experience or by calculation; a risk level (1-4) being assigned to each individual parameter (see below), and the overall risk of the homogenous area being calculated by addition of the risk values of the individual parameters. The values will be chosen in the upper range of the tabulated values in Tables 6 and 7 if the overall risk is high and in the lower range if the overall risk is low.

Leaching

In the case of leaching, the most important individual parameters are:

- Quantity of precipitation;
- Soil;
- Plant cover;
- Land use intensity; and
- Nitrogen surplus.

In the case of a catchment with:

- High annual precipitation;
- Sandy soils with a high permeability; and
- High nitrogen surplus figures,

all individual parameters have a high-risk level, i.e. the overall risk is high. The values in Tables 6 and 7 should therefore be chosen in the upper range.

In the case of a catchment:

- With low annual precipitation;
- With poor soil permeability; and
- Where the land is cultivated in an extensive way without nitrogen surplus,

all individual parameters have a low risk level, i.e. the overall risk is low. The values in Tables 6 and 7 should therefore be chosen in the lower range.

Surface run-off

In the case of surface run-off, a risk level for the following individual parameters may be assigned:

- Amount of rainfall;
- Total annual run-off;
- Soil;
- Topography;
- Distance to surface waters;
- Land use intensity; and
- Existence of buffer zones.

In the case of a homogenous area with:

- Wet soils;
- Steep slopes; and
- High intensity of land use,

all individual parameters have a high-risk level. The overall risk will therefore be high. This means that values should be chosen in the upper range of those tabulated in Tables 6 and 7.

If there is a soil with:

- High permeability in the plain; and
- Extensively used grassland,

the risk level of all the individual parameters is low and so is the overall risk. This means that values in the lower range in Tables 2 and 3 in Annex I should be chosen (c.f. also BRAUN *et al.* 1991 or PRASUHN and BRAUN 1994).

Soil erosion

The important individual parameters affecting soil erosion are:

- Quantity and intensity of rainfall;
- Soil;
- Topography;
- Density of the plant cover; and
- Intensity of soil utilisation.

If there is a homogenous area with:

- Steep and long slopes;
- High soil-erodibility; and
- A crop rotation system which does not cover the soil during long periods and which needs an intensive cultivation of the soil,

all individual parameters have a high-risk level, i.e. the overall risk is high. The values in Tables 2 and 3 (Annex I) should therefore be chosen in the upper range.

In the case of arable land in the plain with:

- Low soil-erodibility;
- An intensive plant cover; and
- Conservation tillage,

all individual parameters have a low risk level, i.e. the overall risk is low. The values in Tables 2 and 3 (Annex I) should therefore be chosen in the lower range.

Attachment 2: Example of methodology from Switzerland, applied on three Swiss regions

1. Introduction

This attachment serves as an example on the stepwise use of the loss coefficient procedure in three Swiss regions. Below follows a simplified description of the quantification procedure in 4 steps. The approach does not use any numerical process-models or other tools to define loss coefficients.

2. Quantification procedure

Step 1: Baseline data

As a first step, the characteristic baseline data are compiled for each homogenous land-use area, field or group of similar fields in the area under consideration (e.g. catchment, sub-catchment or region). Table 1 provides information about land-use distribution in three different regions.

Table 1. *Examples of land use data for three different regions.*

	Alpine region	Pre-alpine region	Central Plateau
Total surface[56]	245 000 ha	112 100 ha	183 200 ha
Grassland	31%	46%	31%
Arable land	< 1%	7%	25%
Forest	24%	38%	31%
Unproductive land	38%	3%	< 1%
Urban areas	2%	5%	12%
Water surfaces	4%	1%	1%
Total area	100%	100%	100%

The data is obtained from area-related statistics. Information on land-use categories is not the only baseline data that should be compiled, but serves as an example on compilation of data. In step 2, compiled data on precipitation and evapo-transpiration and total annual run-off is referred to, but only the estimated results on water flow according to land-use and pathway are listed.

[56] This identifies the main land-use categories. In many cases, more detailed analysis will possible by sub-dividing:
(i) arable land into the main crop; and
(ii) grassland into the main uses (related to stocking density).

Step 2: Choice of loss coefficients

In Switzerland, loss coefficients of various land-use categories are defined on the basis of water flow and nitrogen and phosphorus concentrations in different pathways, according to values given in Tables 2 and 3, Attachment 1, following a selection of values based on criteria given in Attachment 1.

Firstly, the waterflow via different pathways has to be established. It is necessary to quantify the annual run-off, based on compiled baseline data on precipitation and evapo-transpiration. The total annual run-off is then distributed into hydrological processes according to land-use, which results in an overview for the whole catchment/region (see Table 2 below). The flow distribution is empirical and indicative, and it follows that specific knowledge about the catchment under consideration is preferable. Table 2 shows examples of water flow depending on land use categories and pathways in three different regions in Switzerland.

Table 2*. Examples of water flows depending of land use categories and processes in three different regions in Switzerland.*

	Water flows mm/year		
	Alpine region	Pre-alpine region	Central Plateau
Grassland			
Surface run-off	55	37	23
Leaching / drainage flow	1184	808	574
Arable land			
Surface run-off	26	22	14
Leaching / drainage flow	885	653	569
Soil erosion	--	--	--
Forest			
Surface run-off	16	10	--
Leaching	1076	724	434
Unproductive land			
Surface run-off / leaching	1782	1183	766
Urban areas			
Surface run-off [57]/ leaching [58]	1045	708	495
Water surfaces			
Atmospheric deposition	1573	875	505
Total area			
'Natural' erosion	--	--	--
Diffuse direct input	--	--	--

When the flow pattern is established, the corresponding nitrogen and phosphorus concentration in the water has to be considered. The concentrations of nitrogen and phosphorus in water vary considerably. An indicative range of values for various land-use categories and pathways is found in Table 3, Annex I. Switzerland uses a selection scheme according to Attachment 1 in order to select values. For the three Swiss regions under consideration the values selected are listed in Table 3 below.

57 Roads without connections to sewage treatment plants.

58 Green areas within urban areas.

***Table 3**. Nitrogen and phosphorus concentrations depending on land use and processes in three different regions in Switzerland.*

	Phosphorus concentrations, mg P/l			**Nitrogen concentrations,** mg N/l		
	Alpine region	Pre-alpine region	Central Plateau	Alpine region	Pre-alpine region	Central Plateau
Grassland						
Surface run-off	0,47	1,1	1,9	0,5	1,2	1,9
Leaching / drainage flow	0,005	0,01	0,015	0,7	1,4	3,2
Arable land						
Surface run-off	0,25	0,5	0,5	0,4	1,2	1,9
Leaching / drainage flow	0,015	0,02	0,028	6,9	8,8	10,8
Soil erosion	--	--	--	--	--	--
Forest						
Surface run-off	0,050	0,07	--	0,4	0,7	--
Leaching	0,005	0,008	0,01	0,6	1,0	2,0
Unproductive land						
Surface run-off / leaching	0,005	0,008	0,01	0,3	0,8	1,6
Urban areas						
Surface run-off [59]/ leaching [60]	0,01	0,02	0,02	2,0	2,6	4,0
Water surfaces						
Atmospheric deposition	0,03	0,06	0,12	0,5	1,9	3,7
Total area						
'Natural' erosion	--	--	--	--	--	--
Diffuse direct input	--	--	--	--	--	--

Finally, the loss-coefficients are found as the product of the water flow and the corresponding nitrogen and phosphorus concentrations. The estimated loss-coefficients depending on land use, hydrological pathways in the three different Swiss regions are shown in Table 4 below.

[59] Concerns paved areas without connection to sewage treatment plants.
[60] Green areas within urban areas.

Table 4*. Loss-coefficients depending on land use, processes in three different regions in Switzerland.*

	Total phosphorus losses, kg P/ha/y			Total nitrogen losses, kg N/ha/y		
	Alpine region	Pre-alpine region	Central Plateau	Alpine region	Pre-alpine region	Central Plateau
Grassland						
Surface run-off	0,26	0,41	0,44	0,3	0,4	0,4
Leaching / drainage flow	0,07	0,09	0,09	8,7	11,4	18,3
Arable land						
Surface run-off	0,07	0,11	0,07	0,1	0,3	0,3
Leaching / drainage flow	0,14	0,14	0,16	61,2	57,2	61,7
Soil erosion	0,25	0,37	0,38	0,7	0,8	0,8
Forest						
Surface run-off	0,01	0,01	--	0,1	0,1	--
Leaching	0,05	0,05	0,04	6,7	7,1	8,7
Unproductive land						
Surface run-off / leaching	0,09	0,10	0,09	4,7	9,9	12,2
Urban areas						
Surface run-off [59]/ leaching [60]	0,14	0,15	0,13	20,3	18,5	19,6
Water surfaces						
Atmospheric deposition	0,58	0,54	0,60	8,1	16,3	18,6
Total area						
'Natural' erosion	1,46	0,22	0,10	2,2	0,6	0,4
Diffuse direct input	0,02	0,06	0,07	0,1	0,4	0,4

Steps 3 and 4: Estimation of nitrogen and phosphorus losses from all regions

The combination of compiled land-use information (step 1) and the chosen loss coefficients (step2) results in estimated losses of nitrogen and phosphorus according to land-use and hydrological pathways. This information can be presented as quantitative figures or as percentages of the total loss as shown in Table 5 below. The total of the figures in the various columns gives the total nitrogen and phosphorus inputs from each region.

***Table 5**. Examples of nitrogen and phosphorus losses by different processes for different land use categories and for three different regions (given as percentage of the total diffuse nitrogen and phosphorus losses)*

	Total phosphorus losses			Total nitrogen losses		
	Alpine region	Pre-alpine region	Central Plateau	Alpine region	Pre-alpine region	Central Plateau
Surface run-off						
Grassland	5%	32%	26%	1%	1%	1%
Arable land	<1%	1%	3%	<1%	<1%	<1%
Other areas	<1%	1%	1%	<1%	<1%	<1%
Leaching/drainage flow						
Grassland	1%	7%	6%	29%	37%	21%
Arable land	<1%	2%	8%	1%	29%	57%
Forest	1%	3%	3%	17%	19%	10%
Other areas	2%	1%	1%	22%	6%	6%
Direct deposition						
Water surfaces	1%	1%	1%	4%	1%	1%
Soil erosion						
Arable land	<1%	5%	18%	<1%	<1%	1%
Other surfaces	88%	37%	19%	24%	4%	1%
Direct diffuse input	1%	10%	14%	1%	3%	1%
Total diffuse losses	406 t/year	67 t/year	94 t/year	2 292 t/year	1 619 t/year	4 909 t/year
Natural background[61]	85%	49%	32%	57%	29%	18%
Diffuse anthropogenic losses of nitrogen and phosphorus[62]	15%	51%	68%	43%	71%	82%

61 Percentage of the total diffuse losses of nitrogen and phosphorus.
62 Mainly agriculture.

Annex II: Assessment of Diffuse Losses of Nitrate from Agricultural Land to Surface Water: UK approach

Contents

1. Summary of UK methodology

Within the UK, a national system has been developed for estimating *nitrate* loss to ground and surface waters. It takes detailed account of crops, soil type and climate. The structure is similar to that of an export coefficient model, but with added adjustments for excess rainfall volume and soil type.

The export coefficients themselves, for crops and livestock, are based on detailed modelling supported by experimental data, so that they can be adjusted to take account of changes in practice. A single set of coefficients is used for the whole country, giving consistency between catchments. It would be possible to vary the coefficients regionally, but within the UK we have found that the adjustment for climate/soil interaction is sufficient.

For *phosphate*, no such comprehensive system exists as yet in the UK, mainly because the interactions between crop, inputs, soil, climate/weather, topography and flow paths are much less well understood or defined compared to nitrate. The approach used so far, in a number of separate studies, has depended on determining 'appropriate' export coefficients for the catchment based on knowledge of 'similar' catchments. No quantitative *a priori* adjustment for differences between catchments has been developed. Development of a more comprehensive, generalised approach is the subject of research.

The UK considers that for both N and P, *balance calculations* can help to identify regions of serious pollution risk, and nitrogen and phosphorus input/output data should be a component of the models used to arrive at appropriate export coefficients. However the relationship between balance and export of nitrogen and phosphorus is complex and varies between crops, management systems, locations and climatic areas both because of differences in losses by other pathways, and because of the 'lag' within the system, which can be decades or centuries. The correlation between balance and export has been found to be weak for the relatively modest balances typical of UK farming. Therefore we do not use the balance itself as a direct driver for the calculation of exports.

Validation and testing of the modelling system and of the data-sets is considered a continuing necessity, because of the great uncertainties in catchment scale modelling. This includes checking the validity of the detailed models at the scale of single plots or fields; and testing catchment predictions against river measurements.

2. Relationship between N and P loss modelling

The striking difference between N and P loss is that nitrate is soluble, and remains dissolved as the water moves from soil to river. Thus, apart from allowing for denitrification and temporal lags, it can generally be assumed that what leaves the field reaches the river, and the pathway is of secondary importance.

In contrast, phosphorus is often held on soil or organic particles, and even soluble phosphorus compounds are in constant exchange with adsorbed and insoluble forms. The quantity of P removed is often more sensitive to erosion-risk factors than to nitrogen and phosphorus transformations. Surface runoff even if small and sporadic can be the major contributor to P in surface waters. The quantity, which eventually reaches the river, is also sensitive to the pathway of water movement. Thus a model of P loss should give greater prominence to erosion risk factors and pathways of water movement than a model of N loss. This will affect both model structure and data requirements.

3. Data available - Catchment modelling

The catchment model structure is constrained by the data reliably available at national/regional scale.

For the UK, we have built up a comprehensive GIS system based on 1 km grid cells. For each cell, actual or interpolated values are held for:

- Land use types (agricultural, urban etc)
- Crops grown (annually updated)
- Livestock numbers (annually updated)
- Climate
- Soil physical properties
- Altitude

In addition, at UK or regional scale, we hold management data for each crop type, including fertiliser input, crop yields, typical dates of cultivation, sowing and harvest; manure management practices, etc. These are used as input to more detailed models to determine the appropriate nitrate loading coefficients associated with each crop or livestock type for catchment modelling. In some cases these data could be further refined e.g. by soil type, or from local information.

4. Catchment model structure

The model calculates potential nitrate export from soil (notionally the root zone) independently for each grid cell. These values are then adjusted to take account of soil type and climate to give an actual export of water and nitrate. The grid exports are accumulated to catchment scale. Allowance for delay (or loss) during movement to the surface water and for in-river processes, is made on the aggregated data. Where the catchment contains zones which differ substantially in terms of these processes, or in terms of excess rainfall, the calculation is split into sub-catchments.

The coefficients used are derived from more detailed models supplemented by experimental data. Simplified algorithms, e.g. for quantifying mean excess rainfall (hydrologically effective rainfall); and adjusting for the leaching process, are also derived from multiple runs of more detailed models under the range of relevant conditions. They are followed by extraction of simplified relationships expressed in terms of the data actually available at catchment scale (see Appendix 1).

4.1. Model stage 1. Calculating potential export from soil

Calculating actual export from the soil zone consists of two stages:

- Calculation of potential export using export coefficients; and
- Adjustment of this export for rainfall/soil interactions (i.e. the leaching process).

This method has the advantage that the same coefficients are equally applicable for wheat crops anywhere in the UK, and the greater concentrations typical of drier areas will automatically be predicted correctly. It would be possible, if required, to use different sets of coefficients for different regions or conditions, but we have not found evidence that this would be helpful in the UK. The ability to adjust for the leaching process also means that the coefficients can be related to data from experiments under differing weather and soil conditions.

The export coefficients are greater for crops such as potatoes and vegetables than for cereal crops. For grass, no single value can be assigned since grass in the UK may receive anything from 0 to more than 400 kg/ha N, as fertiliser. Therefore for grass, export is calculated in terms of the stocking density of grazing-type livestock (sheep and cattle). The underlying assumption is that farmers will (roughly) match fertiliser inputs to feed requirements, and most of the N eaten by livestock is recycled as manure.

Export coefficients are also assigned to non-grazing livestock (pigs, poultry), based on (standard government) manure N output coefficients, and best estimates of the effect of this loading on leaching losses under typical management practices.

Non-agricultural land is assigned a small export coefficient.

4.2. Model stage 2: Adjustments for soil and climate

Denitrification is assumed negligible on arable soils, but set at 50% for grassland systems on heavy clay soils, which are often poorly drained.

The main impact of soil type is through its impact on excess rainfall, and especially on the leaching process itself. Excess rainfall (drainage volume) is estimated for each grid cell by an algorithm which takes account of rainfall, potential evapo-transpiration, soil type and cropping in that cell.

The amount of nitrogen actually leached is then adjusted as a function of the ratio between excess rainfall and soil water-holding capacity. Thus the smaller the excess rainfall, the smaller the quantity of nitrate actually leached but the greater the mean concentration. The greater the soil water capacity, the more excess rainfall required to leach all the nitrate, and the smaller the peak concentration for a given load.

The same function is also used to derive the time course of nitrate loss and concentrations over winter in terms of the time course of excess rainfall movement through the soil (see below).

The result is, for each grid cell, and for each land use type, an estimate of actual and potential annual N loss and water loss. These values can be aggregated to give a catchment's annual total nitrate loss and mean concentration.

4.3. Model stage 3: Time-course of N concentrations at catchment scale

A water balance model is used with daily weather data and soil/crop information to give a daily water loss from each main soil and land use type in the catchment. The number of categories is kept modest since many land uses have essentially similar impacts on water balance. The leaching function together with the potential N loss value is then applied to give area-weighted daily values for water and nitrate loss from the root zone.

Detailed pathways of movement to the river are not calculated. Instead lag functions are applied to the daily values, based on the hydrological characteristics of soils in the catchment. Thus in rapid-response catchments, nitrate and flow respond rapidly to rainfall events and nitrate concentrations show wide fluctuations over the year. In more slowly responding catchments, both flow and concentrations tend to be smoothed out. A national database of soil and catchment hydrological response characteristics is used for this purpose. The results are then accumulated (and area-weighted) to give a time series of river flow and nitrate concentration attributable to diffuse inputs.

Point-source inputs to the rivers can then be added. These generally have a relatively uniform distribution through the year, unlike inputs from diffuse sources. Finally, temperature-dependent adjustments must be made to allow for denitrification and other processes within the river system. The details of this final stage are under further refinement and testing, in current research projects.

Appendix 1. Illustration of the method

The method is illustrated for a catchment in Eastern England. Summarised data for this catchment include:

Location	**East Anglia**
Average annual rainfall (mm)	592
Mean excess winter rainfall (mm)	144
Mean Altitude (m)	128
Area (km^2)	573
% Arable land	76
- of which:	
% Wheat	35
% W Barley	11
% Setaside	11
% Sugar beet	2
% Oilseed rape	5
% Agricultural grass	6
Dairy herd	1600
Beef >6 months	1400
Pigs fattening	8100
Poultry	168000
Soil type	Glacial drift over clay; Low-flow HOST group classes 6-7, some class 3
Catchment Base Flow index	0,51

The more clayey soils are to the west of the catchment, with some impact on cropping. Housed livestock such as poultry are concentrated in small areas of high stocking density.

The model predicted annual nitrate-N loss from agricultural soils of 20 kg per ha, with a flow-weighted mean concentration of 14 mg/l nitrate-N (62 mg/l nitrate). Inclusion of non-agricultural land reduced the mean modelled concentration by about 20%. These estimates are sensitive to the assumptions made about non-agricultural land, for which some uncertainty exists.

It was shown that addition of sewage inputs at 20 mg/l nitrate-N had relatively little impact during the winter, when flow was dominated by diffuse sources. Winter nitrate concentrations, and the risk of exceedence of the 50 mg/l Nitrate, were well predicted. Correct simulation of summer concentrations, when flow was small, temperatures high, and sewage a significant component, required inclusion of a temperature-sensitive 'retention' factor to account for losses by denitrification, plant uptake etc. However the impact of these corrections on both risk of exceedence and total export was relatively small because they operate most strongly in summer when flow is small.

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Annex III: Agricultural Practices and Diffuse Nitrogen Pollution in Denmark: Empirical Leaching and Catchment Models

Contents

1. Abstract

An empirical leaching model was applied to data on agricultural practices at the field level within 6 small Danish agricultural catchments in order to document any changes in nitrogen (N) leaching from the root zone during the period 1989-96. The model calculations performed at normal climate revealed an average reduction in N-leaching that amounted to 30% in the loamy catchments and 9% in the sandy catchments. The reductions in N leaching could be ascribed to several improvements in agricultural practices during the study period: (i) regulations on livestock density; (ii) regulations on the utilisation of animal manure; (iii) regulations concerning application practices for manure. The average annual total N-loss from agricultural areas to surface water constituted only 54% of the annual average N leached from the root zone in the three loamy catchments and 17% in the three sandy catchments. Thus, subsurface N-removal processes are capable of removing large amounts of N leached from agricultural land. An empirical model for the annual diffuse N-loss to streams from small catchments is presented. The model predicts annual N-loss as a function of the average annual use of mineral fertiliser and manure in the catchment and the total annual runoff from the unsaturated zone.

2. Introduction

Throughout Europe the magnitude of diffuse nitrogen (N) loading of surface waters varies considerably, depending on land use and agricultural practices as well as the prevailing climatic conditions and physical properties within the catchment (Neill, 1989; Wright *et al*., 1991; Kronvang *et al*., 1995). In Denmark agricultural production is very intensive and the use of N in mineral fertiliser and manure is among the highest in Europe (Stanners and Bourdeau, 1995). Moreover, agricultural land constitutes about 64% of the total Danish land area of which more than 90% is arable (Iversen *et al*., 1997). The agricultural sectors pressure on aquatic ecosystems are therefore of great importance in Denmark. Eutrophication of Danish coastal waters is greatly influenced by excessive diffuse N-loading of which on average 80% are derived from agricultural areas (Kronvang *et al*., 1993; Kronvang *et al*., 1996). In comparison, the contribution from agricultural land to the diffuse riverine N-loading from Germany is 53%, 54% for the river Po, Italy and 1% for the Swedish catchment area to the Gulf of Bothnia (Iversen *et al*., 1997).

In general much more N is applied to agricultural land than harvested with the crops and a large part of the N-surplus leaches out of the root zone to groundwater or directly to surface waters via drains (Kronvang et al., 1995). The amount of N leached from the root zone does not necessarily correspond to the amount of N which is delivered to surface waters because nitrate is removed during its transport in subsurface waters due to denitrification processes (Postma *et al*., 1991).

This paper examines the changes observed in agricultural practices in 6 small agricultural catchments during the period 1989 to 1996 and the implications of the observed changes for N-budgets, N-leaching from the root zone and N-loss to surface waters. Moreover, the N removal capacity in catchments with different hydrology and soil types is investigated and a simple empirical model linking agricultural practices to diffuse N-loading of surface waters is presented.

The catchments studied

The 6 small catchments studied are part of the Danish Land Monitoring Programme (Grant et al., 1997). Each catchment covers an area of 5-15 km^2 and includes 9 to 28 farms. The catchments have been selected to cover the common soil types, climatic conditions and farming practices in Denmark. Three catchments have been selected to represent the loamy soils of The Islands and East Jutland and 3 catchments to represent the sandy soils of West and North Jutland (Table 1). The catchments thus reflect the general increase in precipitation from the East to the West of Denmark as well as the tendency for a higher number of livestock per unit area from East to West.

Table 1. *Characteristics of the six agricultural catchments studied*

Catchment	Area ha	Soil type	% clay 10-15 cm	Annual precip. [1] mm	% agricultural land	Farming no. of farms[3]	livestock units/ha[2),3]
Højvads Rende	980	loamy	16	614	73	24	0,23
Lillebæk	470	loamy	15	704	89	20	0,73
Horndrup Bæk	530	loamy	16	875	82	21	1,06
Odderbæk	1140	sandy	5	794	98	26	2,05
Barslund Bæk	1470	sandy	4	969	65	9	0,41
Bolbro Bæk	1330	sandy	6	993	99	28	1,04

1) Average for the period 1961 to 1990

2) 1 livestock unit = 1 dairy cow based on a manure N content of approx. 100 kg N yr^{-1}

3) 1996

3. Methods

Questionnaire survey of farming practice

Once a year a questionnaire survey is carried out among the farmers in all 6 catchments. The objective of the survey is to obtain a statistical estimate of the farming practices in each catchment and to collect the information required for modelling N-leaching from the root zone during each agricultural year (September to August). The questionnaire covers at the farm level: livestock units, productions of slurry/manure and storage capacity of manure. At the field level the questionnaire covers soil type, crops, yields, use of crop residues, the date for all field activities and N application in mineral fertiliser and manure.

Modelling N-leaching from the root zone

The N-leaching from the root zone from all the individual fields (about 1200 fields in the six catchments) is estimated with an empirical leaching model which takes into account the actual agricultural practice (Simmelsgaard, 1991). The model is based upon a large number of controlled field and lysimeter experiments (Table 2). N-leaching is described as a function of applied N (mineral fertiliser and manure), percolation through the root zone (i.e. net precipitation), crop and soil type (clay or sand). Leaching at actual fertilisation level and actual manure utilisation is calculated as:

$$Y = (1 + 3.6a) \bullet Y_s \bullet \exp[0.7(^{X}/_{X_s} - 1)] - 1.8 \bullet a \bullet Y_s + 1.875 \bullet (0.4 - {}^{VT}/_{100}) \bullet a \bullet X \; ;$$

Where:

Y: leaching at actual fertilisation, kg N ha^{-1} yr^{-1}

Y_s: leaching at standard fertilisation, kg ha^{-1} yr^{-1}

X: actual fertilisation, effective N, kg N ha^{-1} yr^{-1} , assuming an effective N-value of 40% in manure

X_s: standard fertilisation, effective N, kg N ha^{-1} yr^{-1}

a: 0.4 • (total N in manure)/X
VT: effective N-value in manure, %

Table 2. *Standard N-leaching from major crops expressed at standard fertilisation level for Danish conditions. Experimental data adjusted to standard climatic conditions by means of the relation* $Y_s = Y \bullet (^P/_{Ps})^{-0.8}$, *where* Y_s*: standard N leaching, kg N* ha^{-1} yr^{-1}, *Y: measured leaching, kg N* ha^{-1} yr^{-1}, P_s*: standard percolation, mm* yr^{-1}, *P: actual percolation, mm* yr^{-1}.

Crop	**Sand**		**Clay**	
	no. of expm.	Y_s **kg** ha^{-1} yr^{-1}	**no. of expm.**	Y_s **kg** ha^{-1} yr^{-1}
spring sown cereals	38	65	45	55
winter crops	12	45	15	35
winter rape	0	50	0	40
spring rape	0	70	0	55
Peas	1	75	1	60
fodder beets	1	45	11	30
beets for sugar production	0	40	0	25
Potatoes	0	45	0	30
spring cereal undersown	15	35	26	20
spring cereal for insilling	0	40	0	25
grass field in rotation	11	40	13	25
grass and clover field in rotation[1)]	-	40	-	25
Permanent grassland	0	25	0	15
1 yr. set aside establ. in spring[2)]	-	35	-	20
1 yr. set aside establ. in autumn[2)]	-	50	-	37
Permanent set aside[2)]	-	15	-	10

1) No distinction is made between grass fields and grass/clover fields in rotation

2) Estimates by The National Environmental Research Institute based on *Waagepetersen (1992).*

The model consists basically of 3 elements: (i) A table of standard values for N-leaching from major crops grown on sand and clay, respectively (Table 2); (ii) an exponential function for N-leaching under increasing N-fertilisation rate; (iii) a function for adjusting N-leaching from standard percolation to actual percolation and vice versa (Table 2). The modelled N-leaching values are reduced if a catch crop or a winter crop follows the main crop.

Stream water sampling, analysis and load estimation

Water sampling in the streams draining the 6 catchments is conducted at weekly intervals during the high flow winter period and fortnightly intervals during the low flow summer period. Water samples are immediately transported to regional laboratories and analysed for N-fractions utilising standardised analytical methods as previously described (Kronvang *et al*., 1993). Daily N-concentration is calculated by linear interpolation between each water sampling date. N loading is then calculated by summing the product of daily discharge and daily N concentration over the period in question. The N-loss to surface waters from agricultural areas in the six catchments are calculated as the annual measured total N-loss minus both point source N-loading and the background N-loss from the whole catchment. The latter is obtained from annual measurements in 7 small non-agricultural Danish catchments (Kronvang *et al.*, 1993).

4. Results and discussion

Changes in farming practices

The period from 1990 to 1996 has been characterised by a number of regulations of the agricultural production in Denmark: (I) restrictions in the number of livestock per unit area, i.e. 2.3, 1.8 and 2.0 livestock units per ha for cattle production, pig production and mixed animal husbandry, respectively; (II) demands to the storage capacity of manure (9 months) so that the time of application of manure to the field can be optimised; (III) rules for application methods of manure aiming at minimising gaseous losses of N; (IV) demands to a specific utilisation of N in manure, i.e. for 1996 a first year utilisation of 45%, 40% and 30% of N in manure from pigs, cattle and other manure, respectively, and a demand for a 10% utilisation the following year; (V) EU regulations combining demands for set aside of arable land with subsidies; (VI) a reduction in grain prices. One result of these regulations is a change in the application time of manure. In 1996, nearly 85% of all manure was applied in spring and summer, this being an increase of 30%-points since 1990. The change in the application time of manure has led to an increase from 33% to 43% in the effective N value of manure. Another result of the regulations is that the consumption of mineral fertiliser has declined continuously during the study period corresponding to an average reduction of 23% in the three loamy catchments and 25% in the three sandy catchments (Table 3).

Table 3. *Annual N-balance for 6 agricultural catchments during agricultural years (September 1989 - August 1990 to September 1995 - August 1996) grouped according to soil type. L = loamy soil, S = sandy soil. All figures in kg N* ha^{-1} yr^{-1}.

	Soil type	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Atm. Deposition	L	19	19	19	19	19	19	19
	S	19	19	19	19	19	19	19
N-fixation	L	15	17	12	13	13	7	5
	S	33	22	22	26	28	24	16
Mineral fertiliser	L	133	128	127	120	109	116	102
	S	142	132	125	112	109	103	107
Manure[1]	L	64	69	71	69	74	70	65
	S	69	102	121	120	116	122	120
Total input	L	231	233	229	221	215	212	191
	S	263	275	287	277	272	268	262
Harvest	L	150	142	120	132	116	126	126
	S	169	133	108	132	132	133	130
Net input	L	81	91	109	89	99	86	65
	S	94	142	179	145	140	135	132

1 Data on livestock numbers for 1990 - the first year of monitoring - are questionable.

N-balance at the field level

An average N-balance for the input and output of N at the field level has been calculated for the 3 loamy catchments and the 3 sandy catchments in order to illustrate the potential for N leaching (Table 3). All inputs are quantified, however, outputs in the form of NH_3-evaporation and denitrification are ignored. An average reduction of 17% (1990-1996) and 5% (1991-1996) has been observed in the total N-input to the 3 loamy and 3 sandy catchments, respectively (Table 3). Annual net N-input varies depending on the amount of harvested N, however on average during 1990 to1996 for the loamy catchments and during 1991 to1996 for the sandy catchments reductions of respectively 20% and 7% can be observed (Table 3). The net input of N is closely connected to the number of livestock as revealed by the 50 kg N ha^{-1} yr^{-1} larger net input of N in the 3 sandy catchments than in the three loamy catchments.

N leaching from the root zone

Annual N-leaching at actual climate varies considerably in the three loamy catchments (8-75 kg N ha^{-1} yr^{-1}) being a direct function of annual variations in net precipitation (Fig. 1). Less variation is observed for the N-leaching from the three sandy catchments (71-81 kg N ha^{-1} yr^{-1}) which are located in the more precipitation rich part of the country (Fig. 1). Annual N-leaching at normal climate has also been calculated in order to isolate the effect of changes in farming practice (Fig. 1). In the sandy catchments there is no difference between leaching at actual and normal climate as it has been assumed that net precipitation at all times is large enough to empty the root zone for any N-surplus. On average, N-leaching from the root zone has been reduced by 30% in the loamy catchments and by 9% in the sandy catchments during the seven year study period. On average, a 17% overall reduction has been calculated for the 6 catchments.

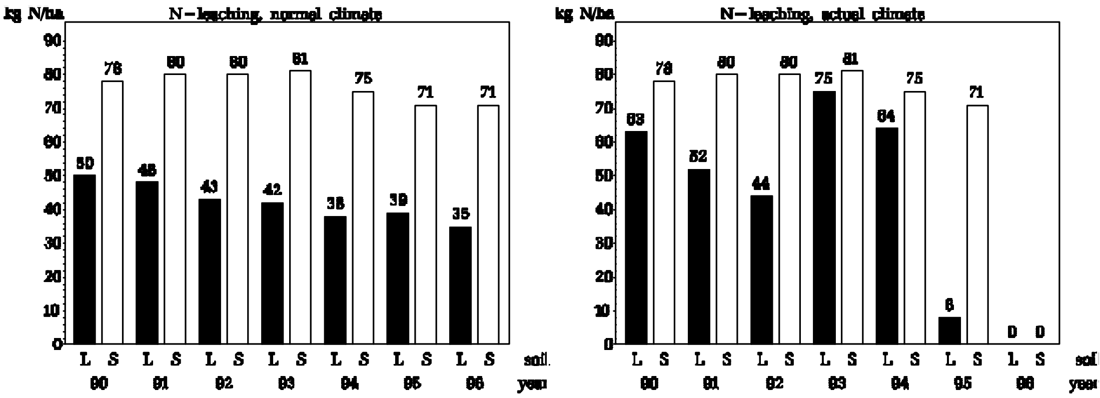

Figure 1. *Annual average N-leaching from the root zone during hydrological years (June 1990 - May 1991 to June 1996 to May 1997) calculated at normal (lines) and actual (bars) climate. The results shown are mean values for the 3 loamy catchments and the 3 sandy catchments, respectively. Since leaching caused by the farming practice in the agricultural year of September 1995 to August 1996 is ascribed to the hydrological year of 1996/1997 calculations at actual climate for 1996 are not carried out due to missing climate data for 1997 at the time of calculation.*

N-loss from agricultural areas to surface waters

The average annual loss of total N to streams from agricultural areas in the 6 catchments are appreciable higher from the three catchments with loamy soils than from the three catchments with sandy soils (Table 4). The annual variation in total N-loss are also much higher in the loamy catchments than in the sandy catchments as revealed by the annual minimum and maximum N-loss during the study period (Table 4). The minimum annual total N-loss was measured during the extremely dry hydrological year of 1995/1996. Annual runoff during this drought year constituted, respectively, 20%, 25%, 46%, 48%, 65% and 66% of the average annual runoff from each catchment during the six hydrological years studied. In comparison, annual total N-loss from agricultural areas to streams in the six catchments during this drought year constituted, respectively, 5%, 11%, 25%, 33%, 54% and 19% of the average annual N-loss during the study period (Table 4).

Table 4. *Average annual, annual minimum and annual maximum total N-loss from agricultural areas in the 6 catchments studied during six hydrological years of 1990/1991 to 1995/1996.*

Catchments	Dominant soil type	Average total N-loss (kg N ha^{-1} yr^{-1})	Minimum total N-loss (kg N ha^{-1} yr^{-1})	Maximum total N-loss (kg N ha^{-1} yr^{-1})
Højvads Rende	Loam	23,7	1,2	38,3
Lillebæk	Loam	34,1	4,0	60,4
Horndrup Bæk	Loam	24,5	6,8	35,1
Odderbæk	Sand	16,3	5,8	22,4
Barslund Bæk	Sand	13,0	7,6	17,9
Bolbro Bæk	Sand	7,7	1,7	12,2

Extreme hydrological years as the drought year of 1995/1996 where the streams were almost exclusively fed by groundwater reveals important information on the lag time for water and N that can be expected in these headwater streams. Thus, it can be assumed that at most 5-25% of the total N-loss to streams experiences a lag time of more than one year for the three loamy catchments, whereas it increases to 19-54% in case of the three sandy catchments. Such information is important when assessing the effects of changes in agricultural practices on N-losses at the catchment scale.

Subsurface N- removal in small catchments

The average annual total N-loss from agricultural areas to surface water constituted only 54% of the annual average N leached from the root zone in the three loamy catchments and 17% in the three sandy catchments during the study period. Subsurface N-removal processes are thus capable of removing large amounts of N leached from agricultural land due to denitrification processes in groundwater and riparian zones. The average annual proportion of N removed during subsurface transport amounted to 36-61% in the loamy catchments and 78-89% in the sandy catchments (Table 5).

Table 5. *Average annual, annual minimum and annual maximum proportion of N removed during subsurface transport as a percentage of annual N-leaching. The figures are calculated as the difference between the N-leaching from the root zone during five agricultural years (1989/1990 to 1994/1995) and the total N-loss from agricultural areas to surface water during five hydrological years (1990/1991 to 1995/1996) for the six studied catchments.*

Catchments	Average N-removal (%)	Minimum N-removal (%)	Maximum N-removal (%)
Højvads Rende	36	8	54
Lillebæk	39	21	57
Horndrup Bæk	61	56	69
Odderbæk	78	70	82
Barslund Bæk	81	74	85
Bolbro Bæk	89	85	96

Both the proportion and the quantity of N removed during subsurface transport is highest in the sandy catchments of which two (Odderbæk and Barslund Bæk) experience long lag times for water and N (Table 4). The proportion and quantity of N removed during subsurface transport is lowest in two tile drained loamy catchments (Højvads Rende and Lillebæk) (Table 5). The relatively high proportion of N removed in the loamy Horndrup Bæk catchment can possibly be explained by the fact that this catchment is not artificially drained and therefore may reveal a reasonably high runoff and N-loss even during the drought year of 1995/1996 (Table 4). Denitrification in riparian areas can be a possible explanation for the high proportion of N removed in the sandy Bolbro Bæk catchment as it experiences a permanently high ground water table.

A lumped empirical N-loading model

A lumped empirical model for the annual diffuse total N-loss to surface water from small catchments is developed based on one year data from 27 small Danish agricultural catchments which vary in climate, soil type, land use and agricultural practices. Annual N-loss to surface water during a calendar year can be predicted as a function of the average annual total N-input in the catchment during the corresponding agricultural year (October to September), and total annual runoff from the unsaturated zone in the catchment during the calendar year:

$N_{loss} = 1{,}13 \bullet e^{0{,}00452 \bullet F} \bullet Q^{0{,}4973}$; where

N_{loss} is the annual total N-loss to surface water in a calendar year in kg N ha^{-1} yr^{-1} measured at the outlet of the catchment and corrected for point source loading,

F is the total average N-input in the catchment in kg N ha^{-1} yr^{-1} (mineral fertiliser and manure, atmospheric deposition and fixation) in the agricultural year (October to September) based on information derived from the questionnaire survey (uncultivated catchments are assumed to receive 20 kg N ha^{-1} yr^{-1} by atmospheric deposition as the only input) and

Q is the estimated total annual runoff from the unsaturated zone in the calendar year in mm year calculated by use of a baseflow separation technique (BFI-index: Institute of Hydrology, 1993).

The model explains 78% of the variation in the diffuse N-losses from the 27 small catchments during the calendar year of 1994 and was highly significant ($p<0{,}01$). The model is at this stage restricted to be used in simple scenarios on the short-term effect of changes in agricultural practices on diffuse N-losses to streams. Longer-term data on agricultural practices and N-loss for the catchments is needed to cope with the difficulties of subsurface lag times for water and N.

5. Conclusions

A combination of detailed questionnaire surveys of agricultural practices at the field level, modelling of N-leaching from the root zone at the field level and monitoring of total N-loss from agricultural areas to surface water within six small catchment which differ in soil types and climate has revealed important information on the state, trends and subsurface N-removal in typical Danish agriculture during recent years.

Although the average annual N leaching from the root zone is 1,5 times higher in the 3 sandy catchments investigated than in the 3 loamy catchments the average annual N-loss from agricultural areas to surface water is 2,2 times higher from the loamy catchments than from the sandy catchments. The discrepancy between N-leaching from the root zone and N-loss to surface waters in sandy and loamy catchments reflects the differences in subsurface N-removal processes.

On average, the proportion of leached N from the root zone that is removed during subsurface transport to surface waters amounts to 36-61% in the loamy catchments and 78-89% in the three sandy catchments. Subsurface N-removal processes in groundwater and riparian zones is therefore of great importance for the diffuse N-loading of surface waters and has to be considered in assessments of the ecological effects of changes in agricultural practices at the catchment scale.

A lumped empirical model for the annual diffuse total N-loss to surface water from small catchments has been developed which incorporates two simple variables, one variable for the agricultural pressure within the catchment (total N-input to soils) and a descriptive variable for the hydrogeology in the catchment (runoff from the unsaturated zone). The model needs, however, to be further developed in order to cope with the problem of subsurface lag times for water and N. Longer-term integrated studies of the N-cycling in small agricultural catchments with different physical properties will enable us to further investigate the linkage between agricultural practices, N leaching from the root zone and N-loss to surface waters.

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Annex IV: Example of methodology in the Netherlands: Surface water pollution from diffuse agricultural sources at a regional scale

Contents

1. Abstract

The approach used in the leaching models to assess the nitrogen and phosphorus load on minor surface water systems at the regional scale in the Netherlands is presented in this Annex. Regional spatially distributed patterns of soil type, land use and hydrology are schematised by a number of homogeneous subregions. In the model a sub-region is represented by a single vertical soil column. Lateral groundwater fluxes are used to compose a regional average discharge concentration. Results of the model approach are discussed for the study on the quantification of the nitrogen and phosphorous load on surface waters at a national scale, as has been conducted in the framework of the Fourth National Policy Document on Water Management in the Netherlands. The aim of the study was to analyse the impact of fertiliser management on N and P discharges to Dutch surface waters. It was concluded that hydrological insight into the system and an associated understanding of the relation between groundwater flow and the loading of surface water are of utmost importance.

2. Introduction

Mathematical models play an important role in the assessment of pollution and the evaluation of intended measures. Trends in water quality parameters as a consequence of fertilisation reduction can be predicted. The far-reaching effects of the intended fertilisation measures on agricultural production justify a thorough examination of the relationship between environmental compartments. In regions with shallow groundwater tables and water discharge towards surface water, residence times are strongly influenced by the drain spacing and the depth of the local flow system. A sound description of the link between the local system and the regional system is of great importance for water quality simulations, because the greater part of the final discharge concentration depends on processes within the upper layer of the top system. In the relation between groundwater and surface water pollution, the schematisation of the hydrological system is of utmost importance.

3. Description of the ANIMO model for nitrogen and phosphorus leaching

The ANIMO model (Rijtema *et al.*, 1999) aims to predict the nitrogen and phosphorus load on surface water systems and the nitrate concentrations in the upper groundwater zone. The model can be used at the field plot scale as well as at the regional scale. Besides the uptake of mineral N and P by crops and displacement of dissolved compounds, the model includes the cycles of soil organic matter, nitrogen and phosphorous and takes account for the following transformation processes:

- Mineralisation and immobilisation of mineral compounds in organic forms;
- Nitrification and denitrification;
- Sorption of ammonium;

• Reversible and irreversible non-linear sorption and chemical precipitation of phosphate.

Transformation of organic materials in soil can be influenced by partial and temporal anaerobic conditions as a consequence of unfavourable aeration. Optimal values of the rate coefficients are corrected for the pH-value of the soil and the actual soil temperature.

Transport routes are related to surface runoff, leaching to groundwater and leaching to surface water systems (Figure 1).

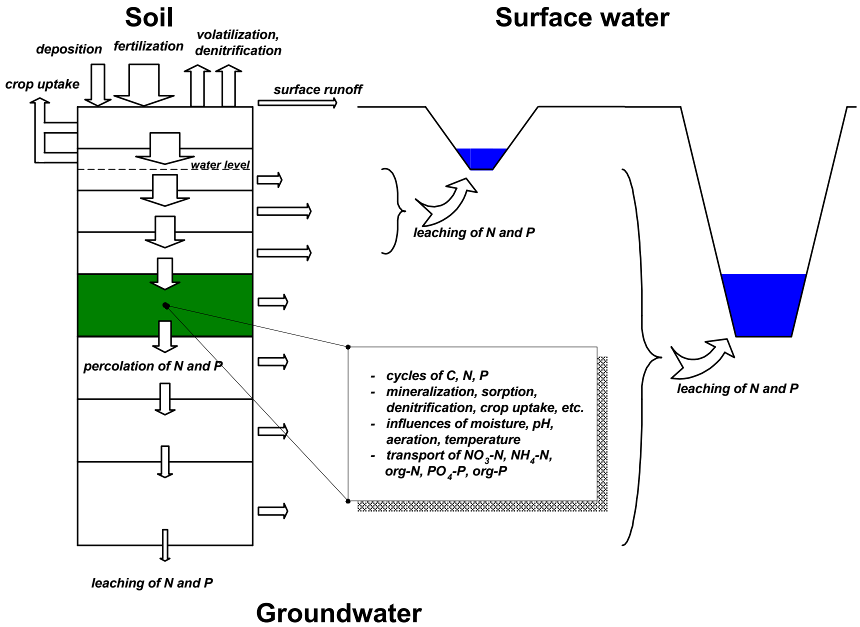

Figure 1. *Transport routes and nitrogen and phosphorus related processes included in the ANIMO model*

4. Hydrological schematisation

Water discharge to groundwater and surface water is schematised by a pseudo-two-dimensional flow in a vertical soil column with unit surface. The ground level provides the upper boundary of the model and the lower boundary can be found at the hydrological basis of the system defined. The lateral boundary consists of one or more different drainage systems. The position of lower and lateral boundaries depends on the scale and type of model application.

Hydrological data, such as water fluxes and the moisture content of the distinct soil layers, are supplied by an external field plot model (Feddes *et al.*, 1978, Van Dam *et al.*, 1997) or a regional groundwater flow model (Querner & Van Bakel, 1989). The schematisation of the soil profile and the main terms of the water balance for a particular drainage situation are depicted in Figure 2.

In regions with high groundwater levels and water discharge towards surface water, residence times are strongly influenced by the size and depth of the drainage system. In non-point water quantity models, the extent of water flows to each of the drainage systems must be calculated by using drainage formulae applicable to the local flow.

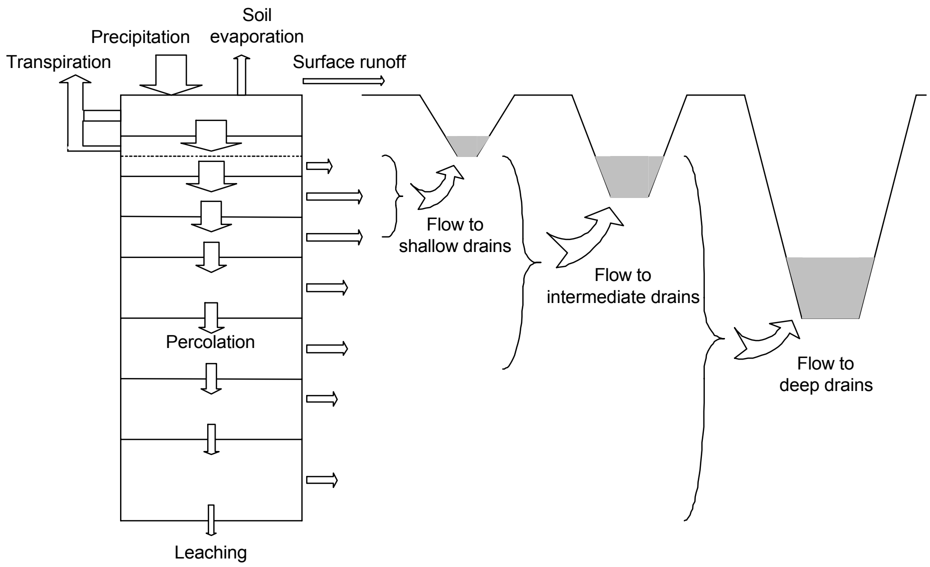

***Figure 2**. Schematisation of water flows in a soil profile and the main terms of the water balance.*

In the non-point water quality models, regional spatially distributed patterns of soil type, land use and hydrology are schematised by a number of homogeneous subregions. The size of a subregion depends on the heterogeneity of these factors and on the ultimate goal of the model application. The boundary between local and regional flow can be defined as the depth below which no discharge to local surface water occurs. Above this depth, the greater part of the precipitation surplus flows to water courses and other drainage systems. This depth depends on the deepest streamline discharging water to the drainage systems.

Once the regional and local flow have been segregated by the position of the boundary surface, the streamline pattern within the top system is schematised into vertical fluxes between soil layers and into lateral fluxes in the saturated zone. Information on water discharges and drainage distances is used to simulate residence times of water and solute in the saturated zone.

Regional flow patterns generally result in a non-linear relation between the discharges measured and the groundwater elevation. This non-linear relation can be described by a set of distinct homogeneous regional drainage systems (Ernst, 1978). Assuming a linear behaviour of the regional drainage discharge, fluxes can be derived by superposition of the different subsystems. A non-linear relation between the regional averaged groundwater elevation and drain discharge can be linearised into a number of drainage systems with linear behaviour. The total regional drain discharge $q_{d,r}$ (m.d^{-1}) is calculated using the following equation:

$$q_{d,r} = \sum_{i=1}^{n} \frac{h - h_d(i)}{\Upsilon_d(i)}; \qquad h \geq h_d(i) \tag{1}$$

Where
n is the number of the drainage systems modelled;
$h_d(i)$ is the drainage level of system i; and
$\Upsilon_d(i)$ is the drainage resistance of system i.

Lateral fluxes can be used to compose a regional average discharge concentrations. Model discharge layers should be identified to describe the vertical and lateral fluxes as a function of depth.

5. Regional travel time distribution approach

In the ANIMO model (Rijtema *et al.*, 1999, Groenendijk & Kroes, in press), pseudo-steady groundwater flow and a uniform distribution of recharge rates are assumed as well as a constant thickness of the aquifer. The sum of all discharges of groundwater Q_i from drainage system i equals the total recharge rate q_d, multiplied by the recharge area A_i. The occupied flow volumes V_i in the flow domain are assumed to be proportional to the discharge flows.

For convenience, only three levels of drains are considered, although the concept discussed here is valid for a system having less or more drainage levels. The superposition principle of drainage systems is applied. First order drains are supposed to act also as field ditches and trenches and next higher drains act partly as third order drains. The schematisation of the regional groundwater flow including the occupied flow volumes for the nested drain systems is depicted in Fig. 3. The occupied flow volume V_i consists of summed rectangles L_iD_i of superposed drains. In a homogeneous soil profile, the lateral flux relation per unit soil depth shows a uniform distribution. Heterogeneity is taken into account calculating the lateral drainage fluxes $q_{i,k}$ to drainage system *i* per computation layer *k* by:

$$q_{1,i} = q_1 \frac{k_{h,i}\ \Delta z_i}{\sum_{i_z=\phi_3}^{i_{z=D_1+D_2+D_3}} k_{h,i}\ DELTA z_i} \qquad for \qquad \phi_3 < z < D_1 + D_2 + D_3$$

where $k_{h,k}$ is the horizontal conductivity ($m.d^{-1}$) per compartment,

Δz_k is the thickness of a compartment (m) and

N represents the number of compartments with complete water saturation.

Solute discharge from each compartment to a certain drainage system results from the multiplication of water flux and solute concentration.

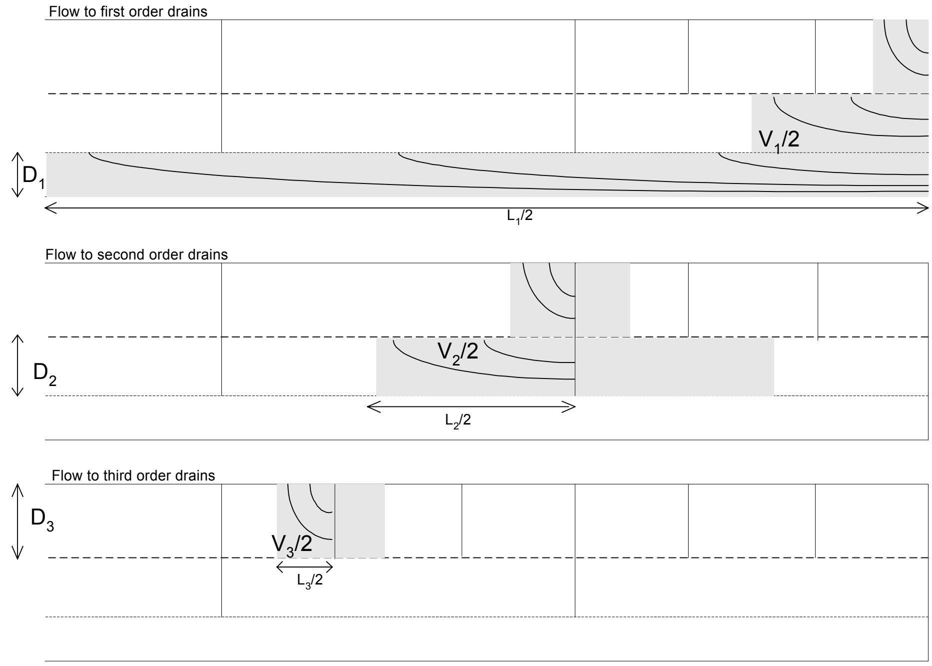

***Figure 3**. Schematisation of regional groundwater flow through discharge layers with occupied flow volume V and thickness D.*

6. Model application at regional scale

In the framework of the Policy Analysis of Water Management in the Netherlands, the ANIMO model was applied for the Fourth National Policy Document (Boers & Noij, 1997, Kroes *et al.*, 1997). The model was used to analyse the impacts of different fertiliser management scenarios on nitrogen and phosphorous leaching into surface water systems. The set of simulation models presented in Fig 4, consisting of a schematisation procedure, a static model for fertiliser additions and dynamic models for water transport in soil and nitrogen and phosphorus leaching to groundwater and surface water was implemented in a software shell for information exchange and direction. The fertiliser distribution model predicted the impact of policy alternatives on the short term and long term fertiliser additions. Dynamic models for water and nitrogen and phosphorus behaviour in soils were inevitably required because of the combined impact of seasonal variations in meteorology, hydrology and timing of fertiliser applications, which is essential for the leaching of N and P to surface waters. The first step in the application of the model instrument was the determination of a spatial schematisation. Basic data related to meteorology, geo-hydrology and drainage conditions and data related to soil physics, soil chemistry and land use were used to arrive at a set of calculation units (plots).

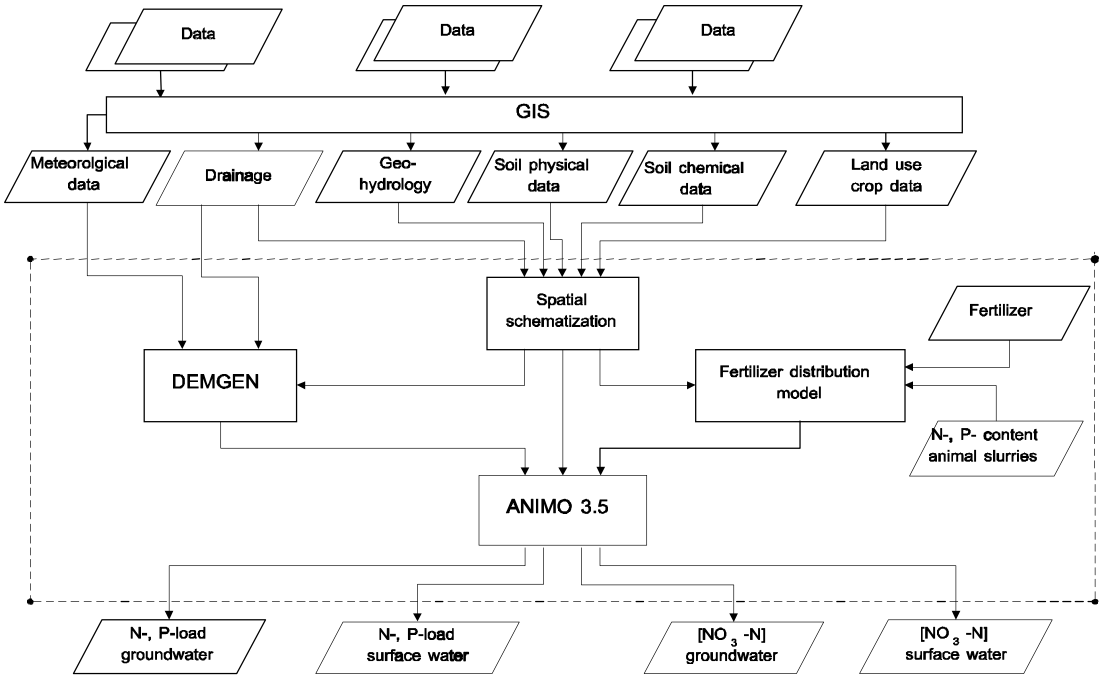

Figure 4. *Set of models used for the simulation of regional nitrogen and phosphorus leaching (between the dotted lines) and main data flow.*

Results of the hydrological model, based on the spatial schematisation, and results of the fertiliser distribution assessment were transmitted to the ANIMO model. These simulations generated N and P mass balances of each plot. The N and P loads towards surface water systems were derived on the basis of these results.

The ANIMO model requires a good estimate of the initial distribution of N, P and C compounds in the solid and liquid phase of the soil system, because poor initial conditions will cause error propagation. However, it is almost impossible to estimate the initial penetration of N and P fronts in the soil and the distribution of compounds over different pools of soil organic matter (including characteristic C/N and C/P ratios and decay rates). By simulation of a historical period from 1940 until the present situation, the initial conditions with respect to soil organic matter quality were determined by the model itself. Results of the evaluation were used to verify the initial conditions by making a tentative comparison between measured and simulated data and were utilised as initial conditions for future scenarios (until 2045). Results from the hydrological model for the period 1971 to 1985 were used as input for nitrogen and phosphorus simulations of history and scenarios. The fertiliser distribution model produced types and level of annual fertiliser applications.

7. Results

Validation of initial simulations to assess the environmental pollution and the storage of minerals in soils was conducted by comparing simulated and measured concentrations in groundwater and surface water systems.

Three regions with different soil units were selected: a clay, a peat, and a sandy region. During the winter period, low temperatures will prevail and process rates will be low. Relatively high discharges in winter cause low residence times and will minimise the influence of processes in the surface water. Consequently, a comparison of winter discharges to the surface water system with measured concentrations in the surface water system can be made more safely than a comparison with summer discharges.

The consequences of some fertiliser scenarios were simulated. One extreme scenario represents a continuation of the fertiliser use in 1993 (scenario: *present*), another extreme scenario represents a prohibition of fertiliser use (scenario: *zero*). The scenario *policy* is aimed at reaching a balance between fertiliser levels, crop uptake and environmental acceptable nitrogen and phosphorus excesses (Boers & Noij, 1997). In the fertiliser distribution model these acceptable excesses were converted into fertiliser levels by assuming some levels of nitrogen and phosphorus uptake by crops.

The difference between the nitrogen discharge of the scenarios *present* and *zero* is large. Results from scenario *present* for 2045 show a leaching of nitrogen which is six times higher than the leaching from *zero*. The same scenarios show that the leaching of phosphorus in scenario *present* is about twice as high as that of scenario *zero*. These results indicate the maximum reduction that can be achieved after a complete fertilisation prohibition. In 2045, the scenario *policy* resulted in a leaching of nitrogen of about 50% of the leaching that resulted from scenario *present*. The phosphorus leaching from scenario *policy* is about 70% of the leaching from scenario *present*. The phosphorus leaching from the scenario *policy* is almost constant from 1985 onward.

8. Discussion

The approach for loads on surface waters at a regional scale is based on the assumption of complete drainage and horizontal discharge layers. For diffusely scattered, low-adsorptive substances the relation used is considered valid. However, for distributed inputs at field level, or high-adsorptive components in the presence of drainage tubes at a certain depth, the schematisation may produce results of insufficient accuracy. The regional streamline pattern has been schematised to block shaped flow volumes, while in reality the flow paths shows a pattern of arched curves. Under certain conditions, this may lead to unreliable predictions.

Correction of the lateral flux distribution with depth in the one dimensional column approach can result in more reliable drainage concentrations. Such a correction should account for the contraction of streamlines in the vicinity of drains and the influence of the regional groundwater flow on depth of streamlines concerning the fast water displacement through shallow soil layers. The overall residence time of drainage water is more or less proportional to the saturated depth of the soil column (Van Ommen, 1986). Appropriate values should be derived from geo-hydrological information at first instance.

Validation of the approach by comparing model results with field data can only yield a global judgement, due to the large number of uncertainties. For the near future, the verification on results generated by three dimensional models can provide a first assessment.

The uncertainty of the regional travel time distribution is a part of a number of shortcomings which affect the reliability of environmental model predictions. Integration of knowledge, as has been achieved in the model instrument for nitrogen and phosphorus leaching at a regional scale, requires also an integrated approach with respect to the enhancement of a part of a set of modules. Sensitivity and uncertainty analysis can aid the choice on which subject priority should be given.

9. Conclusions

The pseudo-two dimensional approach as outlined in this paper has resulted in an operational model instrument for regional predictions of average drainage concentrations. By the classification of surface water systems and the application of the discharge layer approach, one can take account for the response time of the groundwater system. Validation of the approach by comparing with data generated by three dimensional groundwater models and with field data should result in more reliable predictions.

Combined with the impact of solute transport via soil cracks and preferential flow, approximation of these problems in regional load models is considered to be an important challenge for further research. The study on emission of N and P from agriculture to Dutch surface waters has shown a difference between nitrogen and phosphorous behaviour in soils. This implies that the nitrogen leaching reacts more directly to changes of manure policies than does the leaching of phosphorous. The combined effect of vulnerable soils, high fertilisation levels and specific hydrological factors, which result in inadmissible emission to groundwater and surface water systems, could be identified. Exfiltration areas characterised by shallow groundwater tables are most vulnerable to contamination of surface water with phosphate, because the P-excess accumulates in the first decimetres of the topsoil. These areas do also contribute to eutrophication by nitrogen discharge, but to a lesser extent, due to more favourable denitrification conditions in soil. Leaching of ammonium and dissolved organic matter at high groundwater tables depends on the composition of the animal manures applied.

Simulation models have proved to be effective tools for acquiring insight into the relation between groundwater and surface water pollution. Trends in water quality parameters as a consequence of fertilisation reduction, land use and water management measures can be predicted. However a number of uncertainties should still be resolved, the model instrument has the ability to assess the effects of various scenarios with respect to climatic factors, soil conditions, hydrological regimes and agricultural developments.

10. References

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Annex V: Self-developed Procedure for Quantifying Nutrient Losses from Agriculture into Surface Waters (Irish Approach)

Contents

1. Introduction

The recommended methodologies (draft Guideline 6) for quantifying nutrient losses from diffuse anthropogenic sources are based either on measurements or upon objectively determined loss coefficients for different types of land cover. The land cover data is normally derived from satellite imagery such as CORINE. An intensive catchment-level investigation is presently underway on Ireland's largest catchment, the Lough Derg and Lough Ree catchment. Application of the loss coefficient procedure to this catchment was considered but deemed inappropriate because measured agricultural losses from grasslands, the principal landuse in the catchment, varies significantly due to factors such as topography, drainage, soil characteristics and agricultural practices.

All existing (inland) water quality management plans in Ireland are designed on a catchment basis. A standard feature of the catchment based approach is the inclusion of a co-ordinated monitoring and management system for the relevant catchment. The monitoring systems place considerable emphasis on identifying and assessing point and diffuse sources of pollution, in particular from the agricultural sector. This approach has required the collection of data from a wide range of sources, including information on soil types, topography, precipitation patterns, permeability and land use together with data on point source discharges. This information can be related to phosphorus and nitrogen loadings in inflowing streams enabling the quantification of nutrients from subcatchments.

The self-developed procedure for estimating nutrient losses from agriculture in Ireland is based on actual measurements obtained from the Lough Derg and Lough Ree Catchment Monitoring and Management System. The procedure takes on board detailed knowledge of physical conditions and farming practices in the catchment. Percentage loss figures, initially derived from detailed agricultural studies at mini-catchment and subcatchment level are linked to an agricultural risk map. Estimated nutrient percentage loss figures can then be applied to the total agricultural import to produce an overall estimate for total agricultural nutrient losses to surface waters.

2. Quantification method

Implementation of the self-developed procedure involved the following steps.

Step 1: Estimation of nutrient losses from agricultural mini-catchment studies

Detailed agricultural investigations have been underway in three selected mini-catchments, which are representative of the typical range of farming activities and physical conditions within the Lough Derg and Lough Ree catchment (Attachment 1). Farm survey data and water quality monitoring results enabled a direct calculation of nutrient inputs to the mini-catchment and percentage loss of nutrients to surface waters. The Bellsgrove mini-catchment analysis focused on Molybdate Reactive

Phosphate (MRP), the soluble form of Phosphorus most readily available for uptake by aquatic plants and algae. Nitrogen measurements have not yet been processed.

The Bellsgrove stream monitoring results from September 1996 to September 1997 estimated a total MRP export rate of 236,1 kg/year. Phosphorus imports to the mini-catchment were derived from imported chemical fertiliser usage and pig slurry application. This information was obtained from farm surveys undertaken by Teagasc[1] (Ireland's Agricultural Advisory Service) in 1997 and was calculated to be 15 784 kg P/yr.

$$\text{Agricultural \% Loss} = \frac{\text{MRP Export}}{\text{P Import}} = \frac{236{,}1}{15784} = 1{,}5\ \%\ \text{loss}$$

Farming management practices in the Bellsgrove have been regulated for many years due to water quality problems in Lough Sheelin. It is accepted that management practices in the Bellsgrove catchment are generally better than similar farmed areas elsewhere in the catchment and therefore that the loss ratio is likely to be low in comparison to the overall catchment.

Step 2: Estimation of nutrient losses from subcatchment studies

The following special study areas were selected to estimate agricultural loss rates at subcatchment level for a range of representative agricultural activities:

- Nenagh subcatchment;
- Camlin subcatchment;
- Brosna subcatchment.

Monitoring programmes within the study areas were developed as part of the Catchment Monitoring and Management System, to assess the sectoral contributions to the nutrient pollution load from urban agglomerations, industry and agriculture.

Agricultural nutrient loss rates were estimated as follows:

1. Total Dissolved Inorganic Nitrogen and Total Phosphorus stream loadings were measured at selected water quality monitoring points downstream of predominantly agricultural areas for the period April 1998 – March 1999. The N and P input from significant upstream point discharges was deducted from the measured N and P to separate agricultural losses. The input from septic tanks was also taken into consideration.

2. Agricultural imports (chemical fertiliser usage and pig slurry application) were quantified using Teagasc data for chemical fertiliser (N and P) on a DED basis and surveys of pig numbers. The Department of Agriculture and Food supplied N and P production rates for pigs (Table 1).

3. From the information provided from steps 1 and 2 above, it was possible to calculate an agricultural nutrient loss rate for each of the three special study areas. A summary of the data is presented in Table 2.

Table 1. *Nitrogen and Phosphorus Production from Pigs*

Type of Pig	Nitrogen kg/head/year	Phosphorus kg/head/year
Sow (to Weaner)	29	9
Sow (to finish)	67	22
Finishing Pig	8,8	3

Table 2. *Nitrogen and Phosphorus % Loss from Agriculture in Selected Subcatchments*

Special Study Area	Agricultural In-stream Measurement		Chemical Fertiliser		Piggery input		Total Input		% Loss	
	Tonnes/year		Tonnes/year		Tonnes/year		Tonnes/year		Tonnes/year	
Sub-catchment	Total N (DIN)	Total P	Total N	Total P	Total N	Total P	Total N	Total P	Total N	Total P
Nenagh Point 1	340,7	5,7	1154,9	174,9	0,0	0,0	1154,9	174,9	29,5	3,3
Point 2	378,6	11,3	1028,0	158,0	224,5	74,6	1252,5	232,6	30,2	4,9
Camlin	377,1	18,2	1533,0	218,0	365,0	132,0	1898,0	350,0	19,9	5,2
Brosna Point 1	457,0	5,7	3304,0	480,0	25,0	8,0	3329,0	488,0	13,7	1,2
Point 2	407,3	11,9	2125,0	356,0	17,0	6,0	2142,0	362,0	19,0	3,3

Step 3: Extrapolation to the Overall Catchment

Agricultural nutrient loss rates were extrapolated to the overall catchment as follows:

1 An Agricultural Risk map was developed for the catchment using the Geographical Information System (GIS) to investigate the relationship between a set of agricultural indicators and water pollution potential (Attachment 2);

2 Relationships were derived between the percentage agricultural loss rates calculated at mini-catchment and subcatchment level and the agricultural risk category;

3 The percentage loss factors derived from step 2 were applied to the overall catchment using the agricultural risk map. The results are summarised in Table 3;

4 The estimated N and P percentage loss for each of the subcatchments were applied to the total agricultural N and P import from chemical fertiliser usage and pig slurry production. The results are presented in Table 4.

Table 3. *Nitrogen and Phosphorus Percentage Loss from Agriculture*

Subcatchment	% Area in High Risk	% Area in Low Risk	Total P % Loss	Total N % Loss
Ballyfinboy	58,71	41,29	4,1	26,7
Brosna	12,57	85,16	2,4	17,2
Camlin	56,77	35	3,8	25,1
Graney	10,6	89,4	2,4	17,1
Hind	1,71	98,29	2,1	15,3
Inny	42,44	55,1	3,4	23,1
Kilcrow/Cappagh	5,64	94,35	2,2	16,1
Little Brosna	35,41	64,59	3,2	22,1
Nenagh	57,88	40,79	4,0	26,4
Rinn	26,67	72,69	2,9	20,2
Shannon (at Roosky)	9,45	89,9	2,3	16,8
Shannon Corridor	15,43	82,41	2,5	17,8
Suck	1,37	98,58	2,1	15,3
Woodford/Coos	27,13	72,87	3,0	20,4

Table 4. *Quantification of Nutrient Losses from Diffuse Anthropogenic (Agricultural) Sources*

Subcatchment	Agric. Input Total P (Tonnes/ year)	Agric. % Loss Total P	Agric. Loss Total P (Tonnes/ year)	Total Agric. Phosphorus Loss kg/ha/year	Agric. Input Total N (Tonnes/ year)	Agric. % Loss Total N	Agric. Loss Total N (Tonnes/ year)	Total Agric. Nitrogen Loss kg/ha/year
Ballyfinboy	146,3	4,1	5,9	0,5	828,6	26,7	221,6	16,7
Brosna	1123,6	2,4	26,9	0,2	7179,9	17,2	1232,8	9,7
Camlin	470,4	3,8	18,0	0,5	2695,8	25,1	677,2	17,2
Graney	170,2	2,4	4,0	0,1	1130,7	17,1	193,6	6,7
Hind	111,3	2,1	2,3	0,2	792,9	15,3	121,6	11,5
Inny	1320,9	3,4	45,4	0,4	8045,9	23,1	1860,2	15,5
Kilcrow/Cappagh	322,6	2,2	7,1	0,2	2173,4	16,1	350,6	8,8
Little Brosna	613,3	3,2	19,9	0,3	3569,3	22,1	788,1	13,3
Nenagh	308,2	4,0	12,3	0,4	1964,5	26,4	518,2	16,1
Rinn	265,3	2,9	7,8	0,3	1711,7	20,2	346,4	11,2
Shannon (at Roosky)	1090,6	2,3	25,3	0,1	7663,2	16,8	1286,6	6,7
Shannon Corridor	1790,9	2,5	44,8	0,2	11549,0	17,8	2051,1	9,2
Suck	1270,7	2,1	26,1	0,2	8526,4	15,3	1302,0	8,4
Woodford/Coos	38,1	3,0	1,1	0,1	255,4	20,4	52,2	4,7
Overall Catchment	9042,4	2,9	246,8	0,3	58086,7	20,0	11002,2	11,1

A summary of the self-developed procedure for estimating nutrient losses from agriculture is presented in Figure 1.

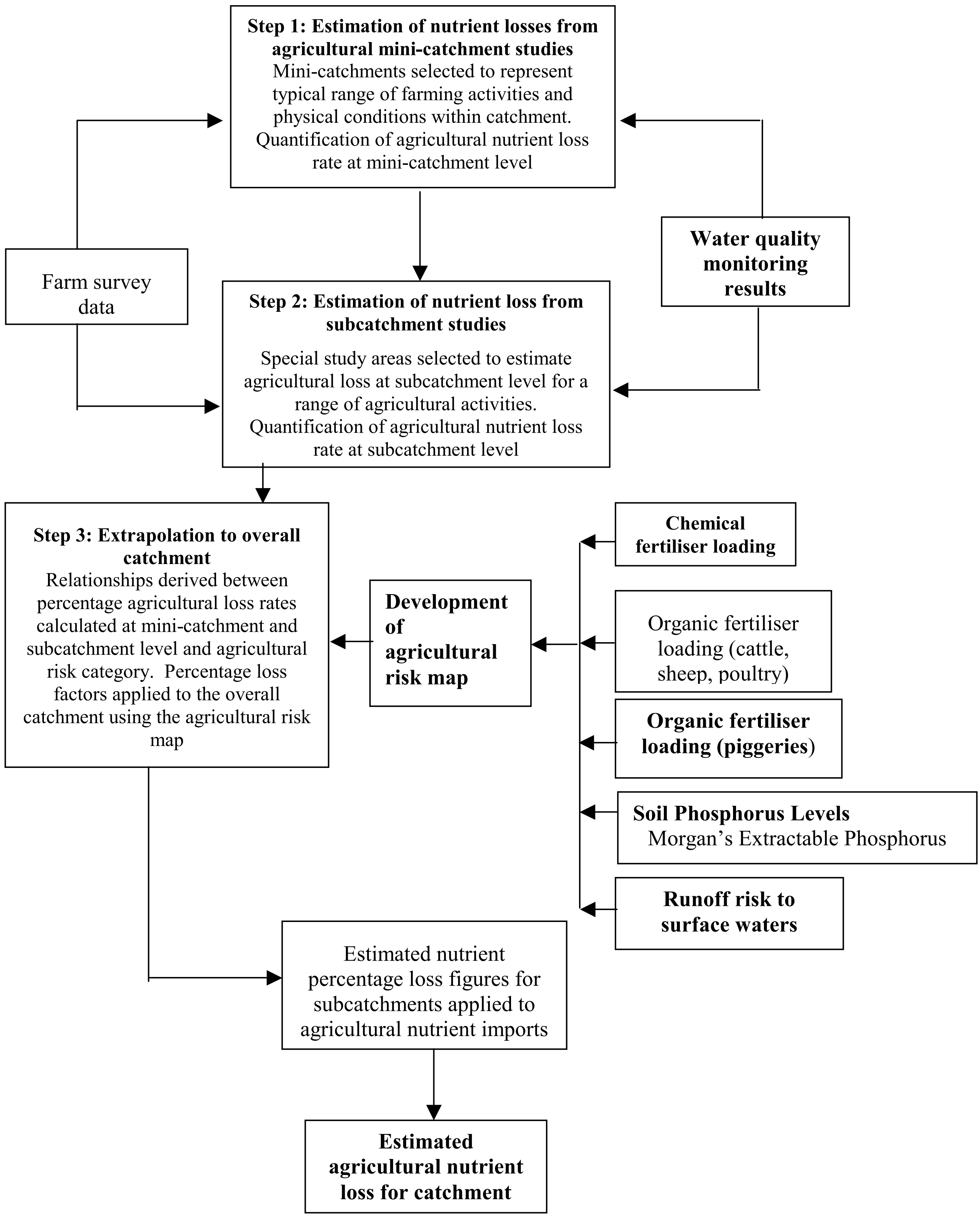


Figure 1. *Elements of the self-developed procedure to estimate nutrient losses from agriculture to surface waters*

Attachment 1: Agricultural Mini-Catchments

An essential requirement to the self-developed procedure for estimating nutrient losses from agriculture is the provision of detailed information derived at mini-catchment level. This attachment details mini-catchment studies in the Lough Derg and Lough Ree Catchment that have been developed to achieve agricultural objectives of the Catchment Monitoring and Management System.

Agricultural Objectives

The objectives of the agricultural element of the Catchment Monitoring and Management System are:

- to quantify agricultural nutrient loss to surface water under varying conditions and to add to the body of existing knowledge regarding the factors implicated in agricultural nutrient loss;
- to promote, implement and evaluate the concept of Nutrient Management Planning at farm level;
- using the information and experience derived at mini-catchment level, to develop strategies that may be promoted on a catchment-wide basis both in Lough Derg and Ree and other lake and river catchments for the reduction of agricultural nutrient losses.

The above objectives are being developed and evaluated in three selected areas, representative of the typical range of farming activities and physical conditions within the Lough Derg and Lough Ree catchments. Agriculture is the sole industry in each mini-catchment and there are no significant municipal discharges. The areas are:

- Bellsgrove Mini-catchment, Co Cavan 12,5 km^2
- Clarianna Mini-catchment, Co Tipperary 28,0 km^2
- Grange-Rahara Mini-catchment, Co Roscommon 11,9 km^2

Methodology

Each mini-catchment was studied in detail to evaluate physical characteristics (geology, soil, drainage, climate, etc.), farm practices, nutrient budget, receiving water flow and quality. Soil Phosphorus levels were also investigated to determine the mechanisms of MRP loss and investigate relationships between nutrient export and stream flow and to evaluate the effectiveness of Nutrient Management Plans.

The findings and analysis of the mini-catchment studies are available in the report entitled “Low Level Trial – Implementation of Draft OSPAR Guidelines for Harmonised Quantification & Reporting Procedures for Nutrients” – September 1999 – Contribution by Ireland (Kirk McClure Morton).

Attachment 2: Computerised Information System

A computerised information system has been developed for the Lough Derg and Lough Ree catchment. The system comprises a series of databases coupled with a Geographical Information System. Information is held on the following topics:

- Geology/geopmorphology
- Landuse
- Soil characteristics
- Hydrology and hydrometry
- Agriculture and forestry
- Peat milling operations
- Fishery resource
- Municipal, industrial and other significant discharges
- Recreation and amenity resources
- Nature conservation and cultural heritage
- River and lake water quality

The Geographical Information System (GIS) has been used to investigate the relationship between a set of agricultural indicators and water pollution potential. Variation in both physical (land) characteristics and usage (management) practices are considered to influence the risk of nutrient loss to surface waters. The factors considered in evaluating the potential for *loss* and *transport* of diffuse nutrients from agricultural systems are:

(a) Chemical Fertiliser Loading

Chemical fertiliser loading has been estimated for the year 1995 based on cropping rates (1991 census) and the 1995 fertiliser use survey (Teagasc).

(b) Organic Fertiliser Loading (cattle, sheep, poultry)

The organic fertiliser loading associated with cattle, sheep and poultry has been established based on livestock numbers (1991 census) and animal nutrient production rates.

(c) Organic Fertiliser Loading (piggeries)

The organic fertiliser loading associated with the 68 pig units within the catchment has been established based on pig numbers (1998) and nutrient production rates. A map showing areas where pig slurry is potentially landspread has been developed in the absence of specific information on actual disposal outlets.

(d) Soil Phosphorus Levels

Soil Phosphorus levels (Morgan’s Extractable Phosphorus) (1991-1995) have been estimated for each District Electoral Division (DED) within the catchment based on the mean results of soil samples received by Teagasc.

(e) Runoff Risk to Surface Waters

The physical characteristics which influence the transport of Phosphorus to surface waters (soil type and by inference, drainage density, slope and rainfall) have been combined in a runoff risk map developed by Gleeson, 1992. Gleeson's original eight risk classes have been simplified into high, medium, low and very low runoff risk. All other factors being equal, '*the greater risk of P-loss will coincide with those combination of factors that create a higher risk of runoff*', Magette, 1998.

Other factors that have a significant bearing on nutrient loss from agriculture include farmyard condition and the management of landspreading activities. An equal bias for these factors has been assumed across the catchment in the absence of quantitative information of this nature on a catchment-wide basis. However, it is considered that the organic loading data, (b) and (c) above, in part reflect this variation in that greater volumes manure are generated, stored and disposed of in areas of higher stocking density.

A ranking scheme, Table 5, was developed whereby each of the Phosphorus loss indicators is subdivided into zones of relative risk, each of which has a numerical value for scoring purposes. The relative importance between factors is also represented by a further scoring system or 'weighting'.

A 'score' or 'rank' for a given combination of factors affecting loss and transport of nutrients is developed in two steps:

1. Multiply the weight of each factor by the relative risk associated with the magnitude of each factor; and

2. Sum all of the products derived in step 1.

The result is then presented in the form of a composite map which highlights priority areas to be at high or very high potential risk (respectively indexes 3 and 4 of four potential risk classes).

Table 5. *Phosphorus Ranking Scheme*

Factor	Factor Weighting	Risk Class	Score
(a) Chemical Fertiliser Loading	12	1. (0-9 kg/ha) 2. (10-11 kg/ha) 3. (12-14 kg/ha) 4. (15-19 kg/ha) 5. (20+ kg/ha)	0,8 1,6 2,4 3,2 4,0
(b) Organic Fertiliser Loading (cattle, sheep, poultry)	24	1. (0,0-1,0 LU/ha)* 2. (1,0-1,5 LU/ha) 3. (1,5-2,0 LU/ha) 4. (2,0 + LU/ha)	1,0 1,5 2,0 4,0
(c) Organic Fertiliser Loading (piggeries)	24	1. (low potential) 2. (moderately low potential) 3. (moderately high potential) 4. (high potential)	0,8 1,6 3,6 4,0
(d) Soil Phosphorus Levels**	16	1. (0-5 mg/l) 2. (6-9 mg/l) 3. (10-14 mg/l) 4. (15+ mg/l)	1,0 2,0 3,0 4,0
(e) Runoff Risk to Surface Waters	24	1. (very low risk) 2. (low risk) 3. (medium risk) 4. (high risk)	1,0 1,5 2,5 4,0

* Unit LU/ha is livestock units/hectare

** Morgan's Extractable Phosphorus

The results of the water quality monitoring programme (April 1998-March 1999) confirmed a strong correlation between the areas identified as being of high or very high potential risk and poor water quality, Table 6. It is important to note that the agricultural risk map is not steadfast, and will need to be periodically reviewed as knowledge regarding the factors influencing agricultural nutrient loss improves. The approach presented is based upon current best understanding and will benefit from the ongoing work in the agricultural mini-catchments, and from research undertaken by others.

Table 6 *Comparison Between Identified Agricultural Risk Areas and Surface Water Quality*

Risk Category	Number of Sampling Stations*	Number Satisfactory	Number Unsatisfactory	Average MRP Concentration (mg P/l)
Very High	13	7	6	0,054
High	45	27	18	0,035
Medium	125	110	15	0,019
Low	7	6	1	0,015

*Sampling stations immediately influenced by point discharges have been excluded.

References

DEPARTMENT OF THE ENVIRONMENT AND LOCAL GOVERNMENT (1997). Managing Ireland's Rivers and Lakes: A catchment-based Strategy against Eutrophication**.**

GLEESON, T. (1992). Runoff Risk Categories for Soils. Teagasc.

KIRK McCLURE MORTON (1999). Low Level Trial – Implementation of Draft OSPAR Guidelines for Harmonised Quantification & Reporting Procedures for Nutrients" – September 1999 – Contribution by Ireland.

MAGETTE, W. L. (1998). Factors affecting losses of nutrients from agricultural systems and delivery to water resource. Draft Guidelines for Nutrient Use in Intensive Agricultural Enterprises, Teagasc.

TEAGASC (1998). Nutrient Advice for Phosphorus and Potassium Fertiliser. Teagasc Research Centre. Johnstown Castle, Wexford.

NOTE:

Teagasc is the Agriculture, Food and Development Authority in Ireland and was established under the Agriculture (Research, Training and Advice) Act 1988. Teagasc's statutory functions are defined mainly in terms of promoting various aspects of agricultural research and development.

Annex VI: PARCOM Guideline for Calculating Mineral Balances

Contents

Introduction

PARCOM 1988 agreed on PARCOM Recommendation 88/2 on the Reduction of Nitrogen and phosphorus to the Convention Area. It was agreed to achieve a substantial reduction (of the order of 50%) in inputs of phosphorus and nitrogen between 1985 and 1995 into areas where these inputs are likely, directly or indirectly to cause eutrophication.

There is a lack of appropriate direct measurements in order to evaluate whether progress is made in the reduction of emissions from agriculture to the maritime area. Furthermore the timelag between the application of measures and their effects on inputs to the maritime area is a complicating factor to evaluate the progress made.

In order to assess the effectiveness of the nitrogen and phosphorus reduction measures taken within the agricultural sector the Paris Commission considers the evaluation of mineral balances a helpful tool.

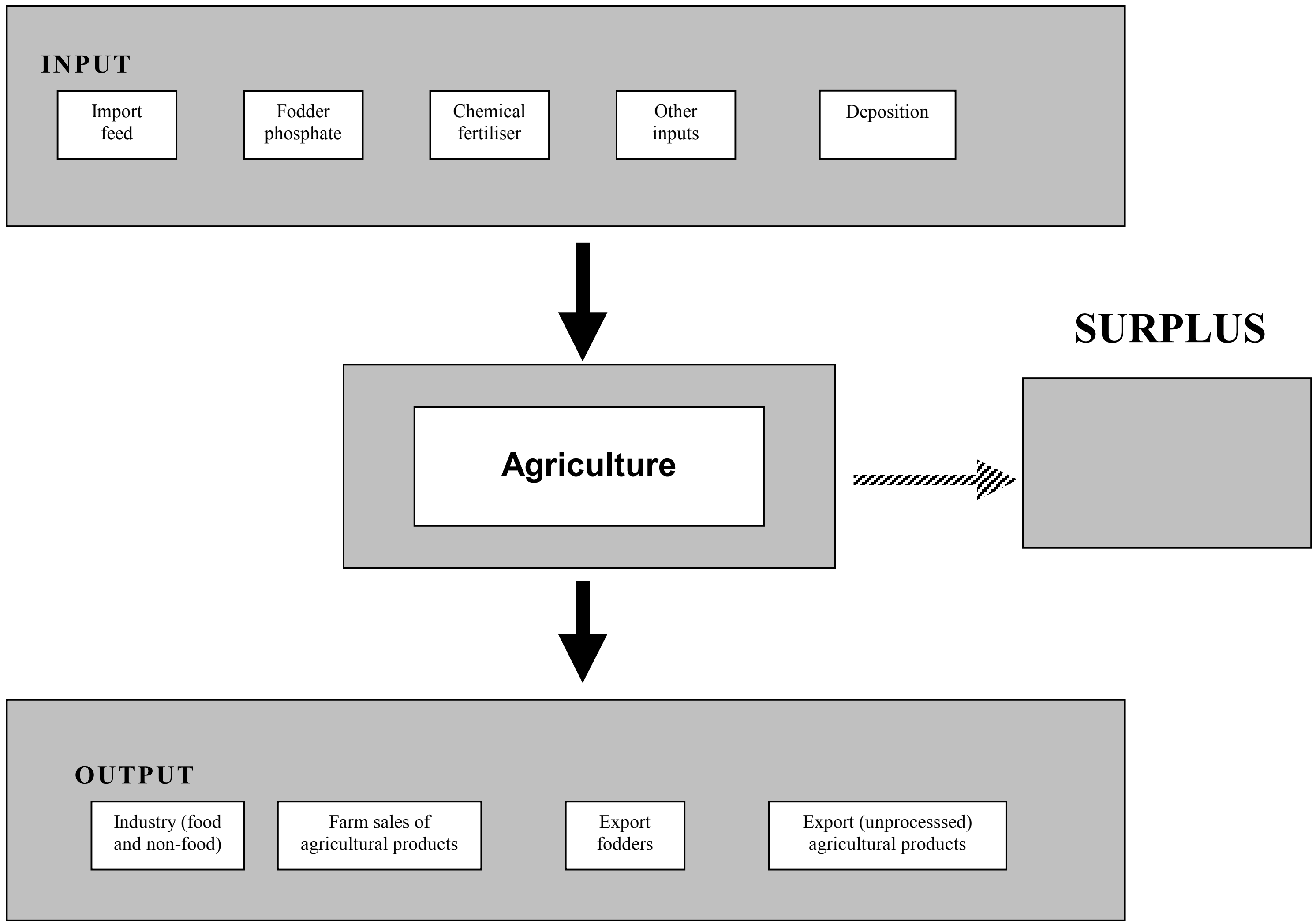
The frequent calculation of a national (or where appropriate regional) agricultural nitrogen and phosphorus balance on nitrogen and phosphorus provides an estimate of overall surplus from agricultural production. The surplus contains all losses to the environment in any form. The changes over the years of the surplus can provide an overall estimate of the effects obtained by the measures taken. For comparison of the progress achieved in the different Contracting Parties a common basis for calculation is needed. The method described below makes, where possible, reference to the data reported to the EC (Eurostat).

In the second part a description of a more detailed mineral balance is given, in which it is possible to countercheck parts of the more general balance.

Calculation of the basic national mineral balance

The basic national mineral balance for phosphorus (P) and nitrogen (N) is presented as a flow chart in Figure 1. The agricultural production system is essentially considered to be a "black box", and only data for INPUT (import from abroad and other sectors) and OUTPUT (export of agricultural products and consumption) have to be provided; the SURPLUS is calculated as the difference between these two.

Figure 1


INPUT
Import feed
Fodder phosphate
Chemical fertiliser
Other inputs
Deposition
Agriculture
SURPLUS
OUTPUT
Industry (food and non-food)
Farm sales of agricultural products
Export fodders
Export (unprocesssed) agricultural products

In formula (for N and P):

AGRICULTURAL SURPLUS = INPUT - OUTPUT

INPUT:

IMPORT FEED
FODDER PHOSPATE
CHEMICAL FERTILIZER
OTHER INPUTS (return from food industry, sewage sludge, N-binding)
DEPOSITION (for nitrogen exclusive NH_3-emissions from agriculture that returns)

OUTPUT:

INDUSTRY (FOOD and NON-FOOD)
FARM SALES OF AGRICULTURAL PRODUCTS
EXPORT FODDERS
EXPORT (UNPROCESSED) AGRICULTURAL PRODUCTS

Source of data

Most quantitative data for the calculation are obtained from national economic statistics, which are reported annually to Eurostat, the statistical office of the EC (for EC-members; EFTA-countries have a similar annual report). Countries are advised to contact their statistical institutes to obtain these data. If necessary, most data can be obtained from the references mentioned (Eurostat 5A-Agriculture, 6C-Foreign trade; OECD food consumption statistics; FAO Statistics 102-Trade, 104-Production, 106-Fertilisers).

Data of nitrogen and phosphorus contents in products are obtained from analysis of manufacturers/importers (actual figures[63]), agricultural[64] and environmental research institutes (measurements and estimates), or, only if no other source available, estimates from literature. See Appendix 1.

The use of the most recent and accurate nitrogen and phosphorus contents in products involved is essential for obtaining reliable balances. With changing supply and demands from e.g. the market of feed resources and animal feed industry, the (average) mineral contents in imported feed compounds may change drastically. However, the average contents of minerals and the variation therein that can be expected, depending on source and country of origin, is well known for most raw materials. Depending of country of origin and treatment given for most compounds a reliable estimate can be made[65].

[63] This may include both public and confidentially provided information available in Statistical offices.

[64] This may include both incidental and frequently updated research;
eg., a continually updated table with composition of all available feedstuffs is available from the Dutch "Central Bureau of Feedstuffs".

[65] Data used in these calculation will be available in most countries.

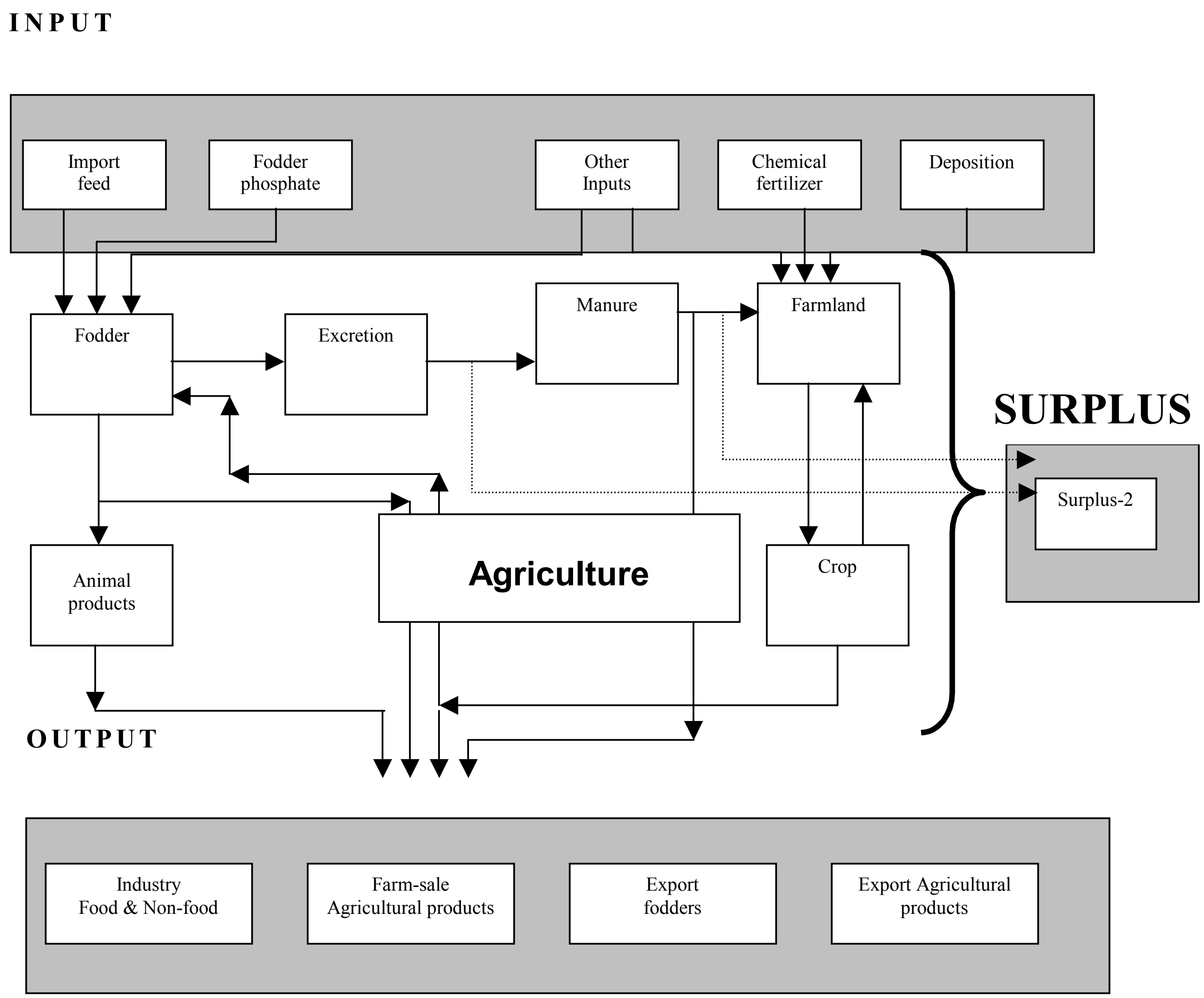
The complete national mineral balance

The complete national mineral balance is presented as a flow chart in Figure 2. It can be considered an expansion of Figure 1, to which an internal agricultural balance is added. This added (sub)balance can be utilised for ***control purposes***, but is ***not needed for the calculation of the basic balance***. However, it is worthwhile to add this information, because of the relative ease of calculation, and the countercheck this can provide on the basic balance. The required data are presented in Appendix 2.

In addition, several data on nitrogen and phosphorus content are required. eg., in manure (ex-animal, ex-storage), in roughage, in animal etc. These contents may vary considerably between (and within) countries, depending on housing type, feeding regimes, animal genetics and production levels, abatements measures taken, etc. Therefore year-to-year estimates per country (region) should be made. It should be stressed, however, that these estimates affect the *internal* balance only; *not* the basic balance as described above.

Several checks on the accuracy of the data can be established. eg., comparison of data presented as INPUT for food industry versus data provided as OUTPUT from agriculture to industry. But more interestingly: - measured and/or estimated environmental losses (NO_3, NH_3, phosphate leaching) indicated as **Surplus-2**, versus the overall SURPLUS. Year-to-year changes in the overall surplus can easily be detected, and can be traced to their source.

Figure 2


INPUT
Import feed
Fodder phosphate
Other Inputs
Chemical fertilizer
Deposition
Fodder
Excretion
Manure
Farmland
SURPLUS
Surplus-2
Animal products
Agriculture
Crop
OUTPUT
Industry Food & Non-food
Farm-sale Agricultural products
Export fodders
Export Agricultural products

Summarising

- The basic mineral balance as described can easily be calculated for all Contracting Parties, using already available data, either from national institutes or, in many cases, international statistics.
- If appropriate, a comparable regional balance can be calculated similarly. Data therefore will probably be available in national statistical institutes.
- The comparison of year-to-year data of the basic balance can provide an accurate estimate of the effectiveness of total reduction measures taken in the agricultural sector as a whole; particularly since only anthropogenic activities are involved, and no retention time influences data.
- The more detailed mineral balance sheet described in the second part can probably be calculated for most Contracting Parties, using already available data.
- The more detailed mineral balance sheet provides several counterchecks and insight in location of losses.

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Eurostat *Series C:* Accounts, surveys and statistics, *Theme 6:* Foreign trade, *Chapters 1-24:* Agriculture and foodstuffs.

OECD - Food consumption statistics (by year).

FAO - *Statistics No. 102:* Trade (yearbook).

FAO - *Statistics No. 104:* Production (yearbook).

FAO - *Statistics No. 102:* Fertilizer (yearbook).

PARCOM *Emission Factors Manual.*

Appendix 1: Data for the basic balance sheet are obtained as follows (see figure 2):

BASIC MINERAL BALANCE	Source composition data	Source quantitative data	Reference
INPUT			
• **Import feed**			
Import concentrate (compounds)	AR, IND	IT, IND	EC, OECD, FAO
Import roughage (grass-silage, maize)	AR	IT	EC, OECD, FAO
• **Fodder phosphate**			
Import fodder phosphate	IND, AR	IT, IND	
Input phosphate industry	IND	IND	
• **Chemical fertilizer**			
Import chemical fertilizer	IND, (AR)	IT, IND	FAO
Input from fertilizer industry	IND, (AR)	IND, NT	FAO
• **Other inputs**			
Returns from food industry	AR, IND	NT, AG	
Sewage sludge[1)]	AR	NT, AG	
Organic (household) waste[1)]	AR	NT, AG	
Animal manure imports	AR	IT, AG[2)]	
N-binding papillonaceae	AR	AG	
• **Deposition**			
Deposition by air mainly NH_3 and other N- deposition (including border crossing imports, excluding NH_3 remaining within agriculture)		ER	EMEP, Atmos
OUTPUT			
• **Industry**			
Products delivered to food and non-food processing industry (for national use and export)	AR, IND	NT, IND, AG	-
• **Farm-sales agricultural products**			
On farm sales agricultural products for human consumption	AR, IND	NT, AG	-
• **Export fodders**			
Export raw and processed fodders for animal production	AR, IND	IT, IND, AG	EC, OECD, FAO
• **Export agricultural products**			
Export unprocessed agricultural products	AR, IND	IT, IND, AG	EC, OECD, FAO

Information provided by:

AR	Agricultural Research institutes
AG	Agricultural Statistics
ER	Environmental Research institutes
ES	Environmental Statistics
IND	Industry
IT	International Trade statistics
NT	National Trade statistics

1) Analysis of composition by certified laboratories and registration obliged for producers and users per 1/1/93 in the Netherlands.

2) Registration for users is mandatory in the Netherlands.

Appendix 2

Complete mineral balance sheet: in addition to the "Basic balance" data the following information is required (see figure 2)

COMPLETE MINERAL BALANCE	**Source composition data**	**Source quantitative data**	**Reference**
AGRICULTURE			
• **Fodder**			
Total fodder production, and consumption in animal production	AR	AG, NT	(EC, OECD, FAO)
• **Excretion**			
Total excretion from animal production	AR	AG, (NT)	
losses (NH_3)	AR, ER	AG, ES	
• **Manure**			
Total manure application to field	AR	AG	
losses ($NH_3 + NO_3 + P + K$)	AR, ER	AG, ES	
• **Farmland**			
Total application of fertilizer	AR	AG, (NT)	
• **Crop**			
Total harvested product; losses returning as "fertilizer"	AR, IND	AG, NT	EC ,OECD, FAO
• **Animal products**			
Primary production: Meat, milk, etc.	AR, IND	AG, NT	EC, OECD, FAO
SURPLUS			
• **Overall SURPLUS**			
calculated as mentioned in table 1	*	*	
• **SURPLUS-2**			
Detailed surplus from known loss sources e.g. NH_3, NO_3 measurements, etc.	AR, ER	AG, ES	

Information provided by:

AR	Agricultural Research institutes
AG	Agricultural Statistics
ER	Environmental Research institutes
ES	Environmental Statistics
IND	Industry
IT	International Trade statistics
NT	National Trade statistics

National Reports on Agricultural Mineral Surpluses of Nitrogen and Phosphorus

Reporting Format

Country:	
Year /Economic Year:	

1. Catchment Area Approach: Surface balance from the agricultural land area (has to be filled in separately for each catchment area)

Name: Size of agricultural land (without set aside areas) in ha:	

1.1 Nitrogen Surplus

Values	kg N / ha x year
INPUT	
Mineral fertiliser	
Agricultural organic manure	
Atmospheric N-deposition (net)	
NH_3-deposition to the agricultural land area (return flow)	
Input due to symbiontic and asymbiontic nitrogen fixation	
Input due to sewage sludge and compost application	
Total INPUT	
OUTPUT	
Total harvested crops	
Total OUTPUT	
Agricultural SURPLUS = INPUT - OUTPUT	

1.2 Phosphorus Surplus

Values	kg P / ha x year
INPUT	
Mineral fertilizer	
Agricultural organic manure	
Input due to sewage sludge and compost application	
Total INPUT	
OUTPUT	
Total harvested crops	
Total OUTPUT	
Agricultural SURPLUS = INPUT - OUTPUT	

2. Approach for the whole country

2.1 Farm gate balance

Size of agricultural land (without set aside areas) in ha:

2.1.1 Nitrogen Surplus

Values	kg N / ha x year
INPUT	
Fodder from countries food industry	
Animal food from net import	
Mineral fertilizer	
Atmospheric N-deposition (net)	
Input due to symbiontic and asymbiontic nitrogen fixation	
Input due to sewage sludge and compost application	
Total INPUT	
OUTPUT	
Livestock market products	
Crop market products (without animal food)	
Total OUTPUT	
Agricultural SURPLUS = INPUT - OUTPUT	

2.1.2 Phosphorus Surplus

Values	kg P / ha x year
INPUT	
Fodder from countries food industry	
Animal food from net import	
Mineral fertilizer	
Fodder phosphate	
Input due to sewage sludge and compost application	
Total INPUT	
OUTPUT	
Livestock market products	
Crop market products (without animal food)	
Total OUTPUT	
Agricultural SURPLUS = INPUT - OUTPUT	

2.2 Surface balance from the agricultural land area

Size of agricultural land (without set aside areas) in ha:

2.2.1 Nitrogen Surplus

Values	kg N / ha x year
INPUT	
Mineral fertilizer	
Agricultural organic manure	
Atmospheric N-deposition (net)	
NH_3-deposition to the agricultural land area (return flow)	
Input due to symbiontic and asymbiontic nitrogen fixation	
Input due to sewage sludge and compost application	
Total INPUT	
OUTPUT	
Total harvested crops	
Total OUTPUT	
Agricultural SURPLUS = INPUT - OUTPUT	

2.2.2 Phosphorus Surplus

Values	kg P / ha x year
INPUT	
Mineral fertilizer	
Agricultural organic manure	
Input due to sewage sludge and compost application	
Total INPUT	
OUTPUT	
Total harvested crops	
Total OUTPUT	
Agricultural SURPLUS = INPUT - OUTPUT	

Annex VII: Examples of figures on background losses of nitrogen and phosphorus

Background losses monitored in different countries. For Denmark, the results are the average of median monitored values for 10 years (1989-98) ± 2 times standard error (corresponding to the 95% confidens interval) in 7 small catchment without or with very low human activities. For the other countries, the figures given are related to the period 1990-1995 and are also measured in forested catchments and/or catchment with very low human impact (besides the impact on atmospheric deposition).

Country	Total nitrogen kg/ha	Total Nitrogen mg/l	Total Phosphorus kg/ha	Total Phosphorus mg/l	Discharge l/s km^2
Denmark	2,15± 0,74	1,52±0,13	0,071±0,02	0,048±0,004	5,4±1,1
Estonia	4,3		0,12		
Finland	2,5 (south) 1,7 (north)		0,1 (south) 0,1 (north)		
Germany		2,0		0,025	
Latvia	0,5-1,0		0,1-0,6		
Lithuania		0,32-0,8		0,05-0,09	
Norway					
Sweden	2-7				

Guideline 7:
Quantification and Reporting of the Monitored Riverine Load of Nitrogen and Phosphorus, including Water Flow Normalisation Procedures

Guideline 7: Quantification and Reporting of the Monitored Riverine Load of Nitrogen and Phosphorus, including Water Flow Normalisation Procedures

Contents

1. Objectives

1.1 To describe procedures for the quantification of the total riverine load of nitrogen and phosphorus, including methods for the normalisation of riverine loads.

1.2 To list the type of data to be reported on in addition to those on annual figures on nitrogen and phosphorus loads.

2. Introduction

2.1 The RID monitoring programme enables a quantification of all riverborne and direct inputs of selected pollutants to the Maritime Area. Figures on the total riverine loads of nitrogen and phosphorus are important as background data for assessments of the eutrophication in marine areas. They are also the basis for the source apportionment approaches (c.f. Guideline 8 on Principles for Source Apportionment).

2.2 Time series of water quality data are often strongly dependent on climatic factors such as precipitation and runoff. Thus, the inter-annual variations in nitrogen and phosphorus load can vary substantially and cause spurious trends and lead to misinterpretation. This calls for harmonised procedures for the reporting of normalised annual riverine loads.

2.3 This Guideline describes procedures for:

- The quantification and reporting of the total riverine load of nitrogen and phosphorus (c.f. section 3); and
- The normalisation of riverine loads (c.f. section 4).

3. Quantification of the total riverine load of nitrogen and phosphorus

3.1 The RID Programme

3.1.1 The river-load data should be collected through the relevant parts of 'Principles of the Comprehensive Study on Riverine Inputs and Direct Discharges' (RID monitoring programme), see Annex 1 for the nutrient-related sections. Inputs from lakes, polders and storm water overflows are to be included where information is available. The sampling and reporting procedures are defined in the RID programme. The application of the part of the RID Programme that concerns direct discharges from point sources and direct losses from diffuse sources is not part of the scope of this Guideline. They are covered in Guidelines 2 to 5 and in draft Guideline 6.

3.1.2 In the RID Programme, each Contracting Party bordering the Maritime Area should:

- Aim to monitor, on a regular basis, at least 90% of the inputs of each selected pollutant;
- Provide, for a selection of their main rivers, information on the annual mean/median concentration of pollutants resulting from the monitoring; and
- As far as is practicable, estimate inputs from diffuse sources, direct sources and minor rivers complementing the percentage monitored to 100 %.

3.1.3 When establishing monitoring stations in addition to the current RID stations, Contracting Parties should take account of sections in relevant EC Directives, including the draft Water Framework Directive.

3.1.4 The RID reporting format enables the voluntary submission of supplementary data e.g. concentration ranges, comments and other determinants. The Quality Assurance is a responsibility of each Contracting Party; the reporting format contains an entry for the accuracy of the reported value.

3.2 Monthly data resolution

3.2.1 Where appropriate and practicable, the following riverine time-series data, covering the period from 1985 onwards, should be calculated on the basis of:

- Time-series of river flow (flow data on a monthly basis, preferably based on daily values); and
- Time-series, with calculated riverine loads of nitrogen (NO_3-N and total-N) and phosphorous (PO_4-P and total-P)- dissolved and particulate- the data resolution should at least be on a monthly basis.

4. Normalisation of riverine load data[66]

4.1 General

4.1.1 The following two major approaches for flow-normalisation are described:

a. Empirical hydrological normalisation (further referred to as category 1); and

b. Model-based hydrological normalisation (further referred to as category 2).

4.1.2 Six different empirical hydrological normalisation methods are described below (further referred to as 1A1, 1A2, 1A3, 1B1, 1B2 and 1C). They should be used for the reporting of annual riverine or stream loads.

4.1.3 Comparative pilot studies in selected rivers should be carried out in order to determine which of the empirical methods is/are the most suitable. Generally, methods 1A1, 1A2 and 1A3 are most suitable when trends in the riverine loads are small, or when the relationship between load and flow, or concentration and flow do not change over time.

4.1.4 Method 1A1 is less suitable when the concentration/flow-relationships are strong (c.f.: example in the Annex). Methods 1B1 and 1B2 are particularly useful in situations where the transport/flow relationship is gradually changing over time (i.e. when diffuse or point sources are increasing or decreasing over time).

4.1.5 Model-based hydrological normalisation should be considered when empirical methods are considered as less suitable.

66 It should be noted that work on normalisation is ongoing within OSPAR/INPUT; hence this issue may require revisions to the current version of the Guideline.

4.1.6 The Annex provides a more detailed description of the methods under category 1, including practical examples.

4.2 Empirical hydrological normalisation (category 1)

General

4.2.1 Category 1 methods concern:

- 1A: Methods that can be applied to systems with random variation around a fairly constant long-term mean;
- 1B: Methods that can be applied to systems with trends; and
- 1C: Methods that can be applied to systems where the flow may be divided between various pathways.

1A. Methods that can be applied to systems with random variation around a fairly constant long-term mean

4.2.2 The three formulas given may be used when the trends in the riverine loads are small. The first method (1A1) represents the easiest approach, where annual normalised loads are estimated by:

$$\tilde{L}_i = L_i \frac{\bar{q}}{q_i} \quad \text{(1A1)}$$

Where

L_i denotes the mean annual load the *ith* year;

q_i is the mean annual flow in the *ith* year; and

$\bar{q}$ the long-term mean annual flow (calculated over the time period from 1985 onwards).

4.2.3 The disadvantage with this method is the rather inefficient use of the statistical information in the concentration and flow data. This is particularly true in situations with dependency between concentration and water discharge (c.f.: example in Annex). It is therefore recommended to use this method only if the other proposed methods are considered to be inadequate.

4.2.4 Method 1A2 uses the normally good relationship that exists between riverine loads and flow (*i.e.* water discharge). The relationship may be modelled by a simple regression equation of the following form:

$$L_{ij} = \alpha + \beta \; q_{ij} + \varepsilon_{ij}, \quad i = 1,2,\ldots,n, \quad j = 1,2,\ldots,m, \quad \text{(1A2)}$$

Where

L_{ij} denotes the load during the *j*th season (normally monthly or fortnightly point samples) of the *i*th year;

q_{ij} is the flow during the same period; and

ε_{ij} is a random error term: α (intercept) and β (slope) are model parameters.

4.2.5 For the sake of simplicity, this approach is exemplified with a linear model. Any model-function (not necessarily linear) is, however, possible. With this model-structure, flow-normalised seasonal values may be calculated according to the equation:

$$\tilde{L}_{ij} = L_{ij} - (q_{ij} - \bar{q}_{..})\hat{\beta}$$

Where

$\hat{\beta}$ is the estimated slope parameter; and
$\bar{q}_{..}$ the average flow for a reference period.

In order to reduce the risk of obtaining negative loads, one can also apply a flow-normalisation, according to the equation:

$$\tilde{L}_{ij} = L_{ij} \cdot \frac{\hat{\alpha} + \hat{\beta}\bar{q}_{..}}{\hat{\alpha} + \hat{\beta}q_{ij}},$$

Where
$\hat{\alpha}$ is the estimated intercept parameter.

4.2.6 Annual flow-normalised values are also obtained by simple aggregation of the seasonal values according to the equation:

$$\tilde{L}_i = \sum_j \tilde{L}_{ij}$$

4.2.7 If the relationship between nitrogen and phosphorus load and flow shows seasonality, the regression model 1A2 can be extended to the equation:

$$L_{ij} = \alpha_j + \beta_j q_{ij} + \varepsilon_{ij}, \quad i = 1,2,\ldots,n, \quad j = 1,2,\ldots,m, \qquad \text{(1A3)}$$

Where
L_{ij} denotes the load during the jth season (month) of the ith year;
q_{ij} the flow during the same period; and
ε_{ij} is a random error term: α_j and β_j are model parameters.

In such cases, flow-normalised values can be calculated according to the equation:

$$\tilde{\hat{L}}_{ij} = L_{ij} - (q_{ij} - \bar{q}_{.j})\hat{\beta}_j$$

Where
$\hat{\beta}_j$ denotes the estimated slope parameter for the jth season; and
$\bar{q}_{.j}$ is the average flow during the jth season.

Annual flow-normalised values are obtained in a similar way as for method 1A2.

1B. Methods that can be applied to systems with trends

4.2.8 The 1A methods described above are relevant for situations whereby the momentary concentration or riverine load is a time-independent function of the simultaneous flow or of time-lagged runoff values. However, concentration-flow and load-flow relationships may change gradually over time. Two flow-normalisation methods, which can accommodate gradual changes in transport-flow relationships, are described below.

4.2.9 Method 1B1 represents basically an extension of methods 1A2 and 1A3. The time series are divided into separate time periods (1985-1989 and 1990-1994) and then analysed separately according to methods 1A1, 1A2 or 1A3.

4.2.10 Method 1B2 accomplishes gradual and smooth changes in relationships between load and runoff. More precisely, it describes a semi-parametric regression model on the following form

$$\boxed{L_{ij} = \alpha_j + \beta_{ij} q_{ij} + \varepsilon_{ij}, \quad i = 1,2,\ldots,n, \quad j = 1,2,\ldots,m,} \quad \text{(1B2)}$$

in which the variation of slope parameters β_{ij} from season to season and year to year is only restricted by non-parametric constraints.

4.2.11 The model parameters are estimated by minimising an expression of the form:

$$\boxed{S(\alpha,\beta) = \sum_{i,j} (L_{ij} - \alpha_j - \beta_{ij} q_{ij})^2 + \lambda_1 \sum_{i,j} (\beta_{ij} - \frac{\beta_{i+1,j} + \beta_{i-1,j}}{2})^2 + \lambda_2 \sum_{i,j} (\beta_{ij} - \frac{\beta_{i,j+1} + \beta_{i,j-1}}{2})^2,}$$

Two penalty factors λ_1 and λ_2, are used to define a desired compromise between overfitting and specification errors. This semi-parametric regression approach is also referred to as a roughness penalty technique. Suitable levels of the penalty factors λ_1 and λ_2 can be established by undertaking a cross-validation study of relationships between L_{ij} and q_{ij}. One may also apply further restrictions: the generalised degrees of freedom of the model could be a constant or the ratio $\frac{\lambda_1}{\lambda_2}$ of the penalty factors could be a constant.

4.2.12 Seasonal flow-normalisation could be accomplished in an additive way by employing the formula:

$$\boxed{\hat{L}_{ij} = L_{ij} - (q_{ij} - \bar{q}_{.j})\hat{\beta}_{ij},}$$

or by multiplication by employing the formula:

$$\boxed{\tilde{L}_{ij} = L_{ij} \cdot \frac{\hat{\alpha}_j + \hat{\beta}_{ij}\bar{q}_{.j}}{\hat{\alpha}_j + \hat{\beta}_{ij} q_{ij}}}$$

Where

$\hat{\beta}_{ij}$ and $\hat{\alpha}_j$ depict parameter estimates obtained by employing the roughness penalty approach described above.

Annual flow-normalised values are obtained in a similar way as for method 1A2. Method 1B2 cannot be run automatically in standard software packages.

4.2.13 Method 1B2 can be extended with regard to:

- The parameterisation of the intercept parameter α, which may vary from year to year; and
- Further normalisation variables, e.g. the temperature.

This requires an extension of the penalty expression in section 4.2.12 and appropriate restrictions to the penalty factors.

5. Reporting

5.1 The following figures should be reported for each catchment (sub-catchment), in order to allow transparent comparisons of the results:

a. Annual loads of nitrogen and phosphorus, calculated on the basis of the measurements at the selected measurement site for the time period 1985 onwards:

(i) without normalisation (specific year); and

(ii) with flow-normalised loads (L_{river}).

b. Description of the methods used for the normalisation of riverine load data.

6. References

BEHRENDT, H., 1997. ‘Detection of anthropogenic trends in time series of riverine load using windows of discharge and long- term means’, ICES-Report cm1997/env: 11 of the ICES/OSPAR workshop on the identification of statistical methods for temporal trends, Annex 5, 20-29, 1997.

OSPAR, 1996. ‘Principles of the Comprehensive Study on Riverine Inputs and Direct Discharges (RID)’.

STåLNACKE, P. AND GRIMVALL, A. 1997. Semi-parametric approaches to flow-normalisation and source apportionment of substance transport in rivers. Environmetrics (accepted).

7. HARP Reporting Format

Catchment (No. and name)	Annual load of total nitrogen (tonnes per year)		Annual load of total phosphorus (tonnes per year)		Description of alternative method(s) or deviations from the standard methods used, and assessment of their comparability with the recommended methods
	Specific year ± %	Flow-normalised ± %	Specific year ± %	Flow-normalised ± %	
National figure[3]					

To Summary Reporting Format in Guideline 1

± %: Wherever possible, the accuracy of the figures should be indicated.

[3] Sum of the figures from all the catchments/coastal areas given above.

Annex I: Principles of the Comprehensive Study on Riverine Inputs and Direct Discharges (RID)[67], nutrient related sections

1. Objectives of the Comprehensive Study

1.1 To assess, as accurately as possible, all riverborne and direct inputs of selected pollutants to Convention waters on an annual basis. Inputs from lakes, polders and storm overflows are to be included where information is available.

1.2 To contribute to the implementation of the JAMP by providing data on inputs to Convention waters on a sub-regional and a regional level.

1.3 To report these data annually to the Paris Commission and:

a. to review these data periodically with a view to determining temporal trends; and

b. to review, on the basis of the data for 1990 to 1995 whether the Principles of the Comprehensive Study on Riverine Inputs require revision.

1.4 Each Contracting Party bordering the maritime area and excluding the EC should:

a. aim to monitor on a regular basis at least 90% of the inputs of each selected pollutant;

b. provide, for a selection of their main rivers, information on the annual mean/median concentration of pollutants resulting from the monitoring according to paragraph 1.4a; and

c. as far as is practicable estimate inputs from diffuse sources, direct sources and minor rivers complementing the percentage monitored (cf. paragraph 1.4a) to 100 %.

2. Determinants to be monitored

2.1 The following determinants are to be monitored on a mandatory basis:

• Ammonia expressed as N	• Total P
• Total N • Nitrates expressed as N	• Orthophosphates expressed as P

3. Monitoring and reporting

3.1 All major load bearing rivers and direct discharges to the maritime area (identified at Annex 1[68]) are to be monitored every year in accordance with the objectives of the comprehensive study as set out at paragraph 1.4.

3.2 Diffuse and direct inputs and inputs from minor river systems not included within the monitoring programme (which may account for up to 10% of the total pollution load from each Contracting Party) should be assessed using "best estimates" of concentrations and flow, and should be reported to the Secretariat on an annual basis. Actual measurements (flows and concentrations) are to be carried out on the minor river systems at a frequency to be determined by each Contracting Party in the light of knowledge of the river system concerned.

67 Ireland and Spain hold study reservations. Germany lifted its study reservation on 21 March 1996.

68 Contracting Parties may propose additions or changes to this list, taking into account the requirements of paragraphs 1.3 and 5.2, in particular the objective to assess trends.

3.3 The RID results are to be reported to the Secretariat by 30 September (30 November for Denmark only) each year and reviewed by the Working Group on Inputs to the Marine Environment (INPUT).

4. Reporting Format

4.1 The text-reporting format is at Annex 2. Data should be submitted to the Secretariat on floppy disk but the Secretariat will accept data using a paper reporting format (available from the Secretariat). The Secretariat will provide to Contracting Parties floppy disks containing templates for data submission before 30 June of the reporting year. Contracting Parties are required to describe the methodology used in assessing the input load from each source category.

4.2 Contracting Parties are asked to provide, as far as is practicable, statistical information on river catchment areas e.g. on population in the catchment area, long term average flow data and/or other relevant information of the same type. This information should be supplied once and updated periodically (at least every five years).

5. Methodology for assessing riverine inputs

Definition

5.1 A riverine input is a mass of a determinant carried to the maritime area by a watercourse (natural river or man-made watercourse) per unit of time.

Objective

5.2 To obtain:

a. As accurate an estimate as possible of the input load per annum.

b. Information on the long-term trends in inputs, and of trends in contaminant concentrations of such inputs where such information might provide an additional or a better basis for a trend assessment.

Sampling strategy

5.3 The sampling strategy should be designed on the basis of historical records. It should aim to cover the whole flow cycle but should concentrate on periods of expected high river flow. Experience has shown that there is a positive correlation between periods of high river flow and high input load, especially for suspended solids, heavy metals, and nitrates. Most monitoring effort should be directed towards those rivers with the highest input load.

Sampling frequency

5.4 In order to estimate the annual input for the major load bearing rivers (cf. paragraph 3.1), there should be a minimum of 12 datasets, collected within a 12-month period. The datasets need not be collected at regular monthly intervals but can be collected at a frequency, which appropriately reflects the expected river flow pattern.

5.5 For those rivers carrying the heaviest contaminant loads the sampling frequency may be increased beyond the minimum 12 datasets. However for such rivers, it should not be necessary to take samples more than once per week.

5.6 For rivers where, on the basis of past knowledge, the concentrations are at or below the limit of detection for the specified determinants, the requirement for 12 datasets may be too stringent. In such cases, the Contracting Party concerned should ensure that sufficient samples are taken to obtain a “best estimate” of the pollution load. This “best estimate” should be compatible with the requirement of paragraph 7.3.

5.7 Thus for some rivers it may be necessary to monitor certain determinants at the "standard" frequency of 12 datasets per annum where concentrations are significantly above the detection limit, but to monitor other determinants at a reduced frequency.

5.8 All rivers with a significant contaminant load should be gauged for river flow on a routine basis.

Site selection (cf. also “measurements in tidal areas”)

5.9 The measurement site should be in a region of unidirectional freshwater flow.

5.10 The site should be an area where the water is well mixed (such as at or immediately downstream of a weir) and hence of uniform quality, otherwise it would be necessary to establish the relationship between the concentration at the sampling point and at a representative number of sampling points over the whole river cross section (established by weighting the concentrations at each sampling point by the volume of water per unit time at that point).

Estimation of annual load

5.11 The load of a specific determinant transported by a river should be estimated by taking the product of the mean flow-weighted concentration and the total flow, expressed by the following formula:

$$\frac{Qr. \sum_{i=1}^{n} (Ci\ Qi)}{\sum_{i=1}^{n} (Qi)}$$

Where

Ci is the concentration measured in sample i;

Qi is the corresponding flow for sample i;

Qr is the mean flow rate for each sampling period; and

n is the number of samples taken in the sampling period.

5.12 In those cases where insufficient information is available to use the above formula, the pollutant load should be estimated by taking the average of the product of flow and concentration for a series of measurements, as expressed by the following formula:

$$\frac{\sum_{i=1}^{n} (C_i \; Q_i)}{n}$$

5.13 For minor load bearing rivers, for which 12 data sets per annum will not be obtained, the best available estimates of flow and flow-weighted concentration should be used to estimate contaminant loads. Tributaries, which discharge directly into the saline estuaries of major river systems, may fall into this category. In the absence of estimates of flow and flow-weighted concentration, estimates of contaminant loads based on per capita or per hectare calculations may be used.

Measurements in tidal areas

5.14 Some Contracting Parties may consider that, given the circumstances of their particular river system, it may be preferable to take measurements in the tidal area rather than upstream of any tidal influence as advocated in paragraph 5.9. The rationale may be that such an approach would provide the best estimate of :

a. The true determinant load of a river taking into account point source discharges in an estuary;

b. Discharges from diffuse sources between the sampling area and the tidal limit;

c. Removal of sediment to landfill.

5.15 Measurements in the tidal area may need to be supplemented by measurements of inputs from the point sources downstream of the sampling area.

5.16 If the assessment of annual input loads is based on measurements made in the tidal regions of an estuary, the assessment should be corroborated by the results of mass balances[69].

6. Methodology for assessing direct discharges

Definition

6.1 A direct discharge is a mass of a determinant discharged to the maritime area from land-based sources (sewage effluents, industrial effluents or other) per unit of time at a point on a coast or to an estuary downstream of the point at which the riverine estimate of input is made.

6.2 For all significant inputs where estimates are not based on measurement of flow and concentration, it is necessary to corroborate, periodically, the reported inputs with estimates based on actual measurements.

[69] A mass balance would show how the various components (e.g. main riverine input, secondary point and diffuse inputs, “negative inputs” relating to sinks of material, dredging, etc.) combine to give the reported (net) input.

Sewage effluents

6.3 Where possible the annual load should be estimated as the product of the annual flow and the flow-weighted concentration. In some cases the only flow data available will be dry weather flow. Dry weather flow should be multiplied by 1,7, to give average flow data. Where there are flow data but no water quality data, the following example of typical water quality data may be used to estimate loads:

	SPM (mg/l)	**Total N** (mg N/l)	**Total P** (mg P/l)	**BOD *** (mg O/l)
Crude sewage	350	55	15	*350*
Partially treated sewage	100	40	10	*100*
Treated sewage	30	30	7	*20*
Treated sewage with nutrient removal	10	8-10	0,5-1	*15*

*: For reference purposes only

6.4 Where only population data is available for estimating crude (untreated) sewage discharges, the following per capita loads based on the above water quality data and a flow of 180 1/person/day may be used to estimate nutrient loads :

SPM	0,063 kg/person/day
Total N	0,009 kg N/person/day
Total P	0,0027 kg P/person/day
BOD	0,063 kg O/person/day

If more specific data are available based on knowledge of local conditions, these may be preferable to the example given above.

6.5 For metals in sewage discharges the loads should be calculated from monitoring and flow measurements wherever possible. When such information is not available, it is necessary to estimate the metal inputs. For Contracting Parties where the consents for discharges from sewage works are set as maxima, estimates based on the consent conditions may be calculated as follows:

0,5 x maximum flow permitted x 0,5 x maximum permitted concentration.

Stormwater overflows

6.6 Whenever possible, Contracting Parties should make estimates of the pollution load in stormwater discharges. Where estimates are provided, a description of the methodology used should be given.

Industrial effluents

6.7 Where direct measurements of industrial effluents are not available and in the absence of a more appropriate formula the same formula as proposed for assessing metal loads from sewage discharges may be used (paragraph 6.5).

7. Limits of detection

7.1 It is necessary to choose a method which will give at least 70 % of positive samples (i.e. those above the detection limit). In all cases, the total concentration should be determined.

7.2 In those cases where the results recorded are less than the limits of detection, two load estimates should be supplied, one assuming that the true concentration is zero and the other assuming that the true concentration is the limit of detection. This will provide maximum and minimum concentrations within which the true estimate will fall. When used to estimate inputs these data will then provide upper and lower bounds for the estimate.

8. Quality assurance

8.1 In 1990, the Oslo and Paris Commissions adopted the following policy of quality assurance (OSPAR 12/16/1, § 8.12):

a. Contracting Parties acknowledge that only reliable information can provide the basis for effective and economic environmental policy and management regarding the Convention area;

b. Contracting Parties acknowledge that environmental information is the product of a chain of activities, constituting programme design, execution, evaluation and reporting, and that each activity has to meet certain quality assurance requirements;

c. Contracting Parties agree that quality assurance requirements be set for each of these activities;

d. Contracting Parties agree to make sure that suitable resources are available nationally (e.g. ships, laboratories) in order to achieve these goals;

e. Contracting Parties fully commit themselves to following the guidelines adopted within the framework of the Commissions in accordance with this procedure of quality assurance.

8.2 In the context of RID's aims and objectives appropriate quality assurance (QA) procedures should be applied to field and laboratory work. For example it is important to apply QA to the measurement of river flow and discharges, and to the collection and storage procedures for samples as well as to the laboratory measurements. In the laboratory work the analysis should be done by experienced analysts using analytical procedures with the required accuracy and precision. Analytical measurements should be carried out under appropriate internal quality control schemes, and periodically validated e.g. through participation in relevant national or international intercomparison exercises.

9. Changes in methodology

9.1 If in future surveys there are significant changes of methodology, these should be reported to the Secretariat by Contracting Parties, together with any re-assessment of previously reported data.

Annex II: Examples of Hydrological Normalisation Procedures of Riverine Nitrogen and Phosphorus Loads

1. General

1.1 The following illustrates the outcome of the proposed flow-normalisation methods described under method-category 1. Time series were collected from the monitoring programme in the (hypothetical) River HARP. Water quality data with nitrogen concentrations is based on monthly sampling frequency and water discharge figures on data from 1985 onwards. Monthly riverine loads of nitrogen, for the time period 1985-1994, were then calculated according to a standard national procedure. There seems to be a slight decline in both the flow and riverine loads over the study period, as shown by raw-data figures in Figure 1.

1.2 The seasonal variability is also distinct with pronounced lower loads and discharges during summer and early autumn, compared to rest of the year; particularly the late winter and early spring periods. It shows that flow-normalisation is necessary, the flow is substantially lower during 1991-1994 compared to the first six-year period, i.e. 1985-1990 (Table 1).

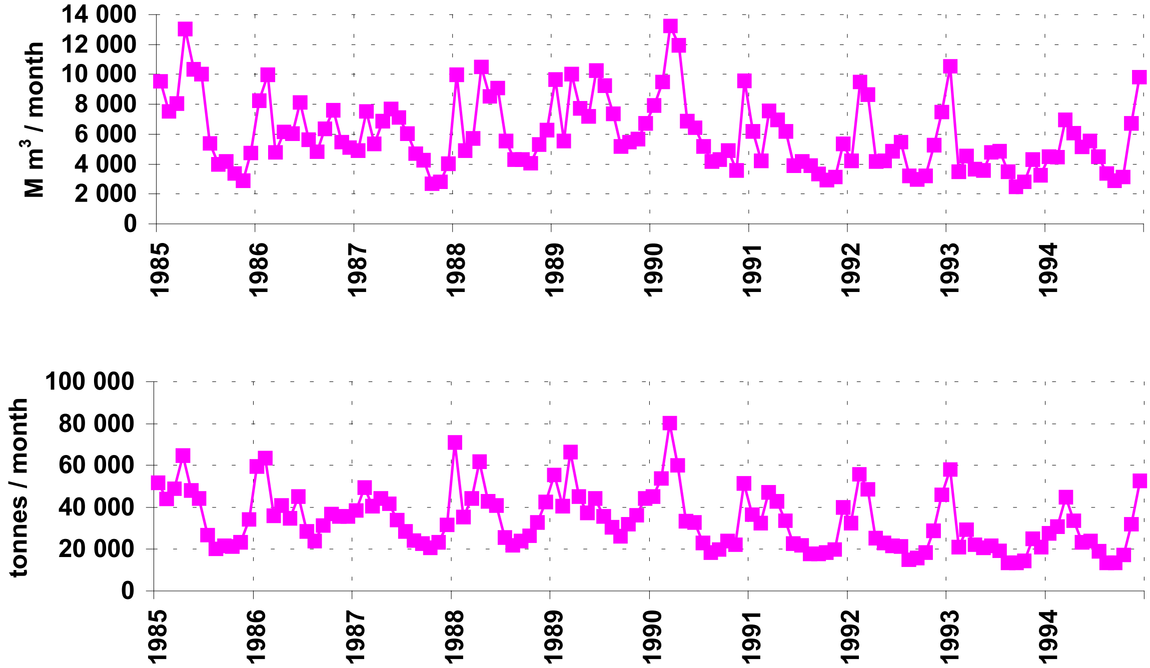

Figure 1. *Time series with monthly water discharges (upper) and monthly nitrogen load (lower) in the River HARP 1985-1994.*

2. Method

2.1 Method 1A1

2.1.1 The results with flow-normalisation method 1A1, show that a substantial part of the inter-annual variability in loads can be explained by flow-variability, and that the trend becomes much less pronounced compared to the 'observed' riverine loads (Table 1). However, the remaining normalised load still shows a relatively high inter-annual variability.

2.2 Method 1A2

2.2.1 The monthly load and monthly flow show a relatively good linear relationship (Figure 2). The parameters α (the intercept) and β (the slope) are estimated with standard least-square linear regression and used to fulfil the requirements for flow-normalisation according to formula 1A2. α and β are given in Figure 2.

2.2.2 The results show that a substantial part of the inter-annual variability in riverine loads is explained by river flow. The flow-normalised inter-annual loads show a slightly lower variability compared to method 1A1 (Table 1 and Figure 6).

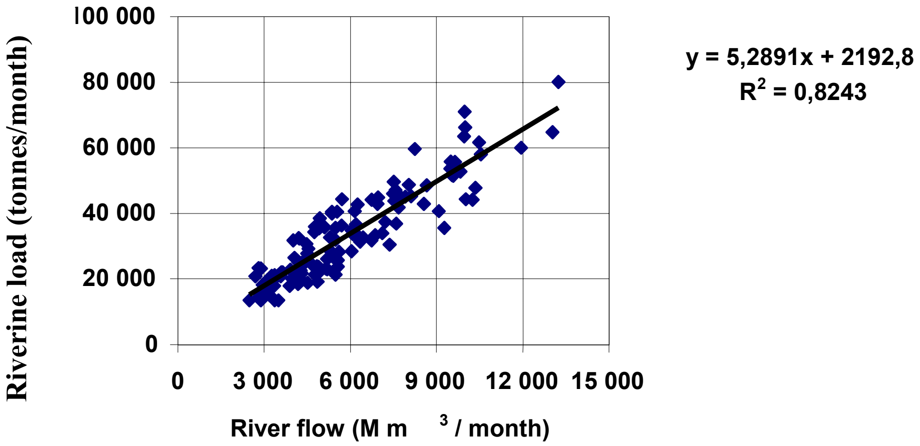

Figure 2. *Scatter plot of the relationship between monthly nitrogen loads and monthly runoff in the River HARP. Data from the time period 1985-1994*

2.3 Method 1A3

2.3.1 The time series in this example were divided into the following four different seasons: November-February, March-May, June-August and September-October.

2.3.2 They were analysed separately in a similar way as method 1A2. An analysis using the original monthly seasons is also possible; the number of observations will be low in each regression analysis (n=10), and thus regarded as less suitable in this particular case. The scatter plot of load and flow in the respective seasons shows a good relationship (Figure 3). Particularly noteworthy is the difference in intercepts and, to some extent, the slopes between the four seasons. The flow-normalisation method 1A3 produces very similar values to these of method 1A2 (Table 1 and Figure 6).

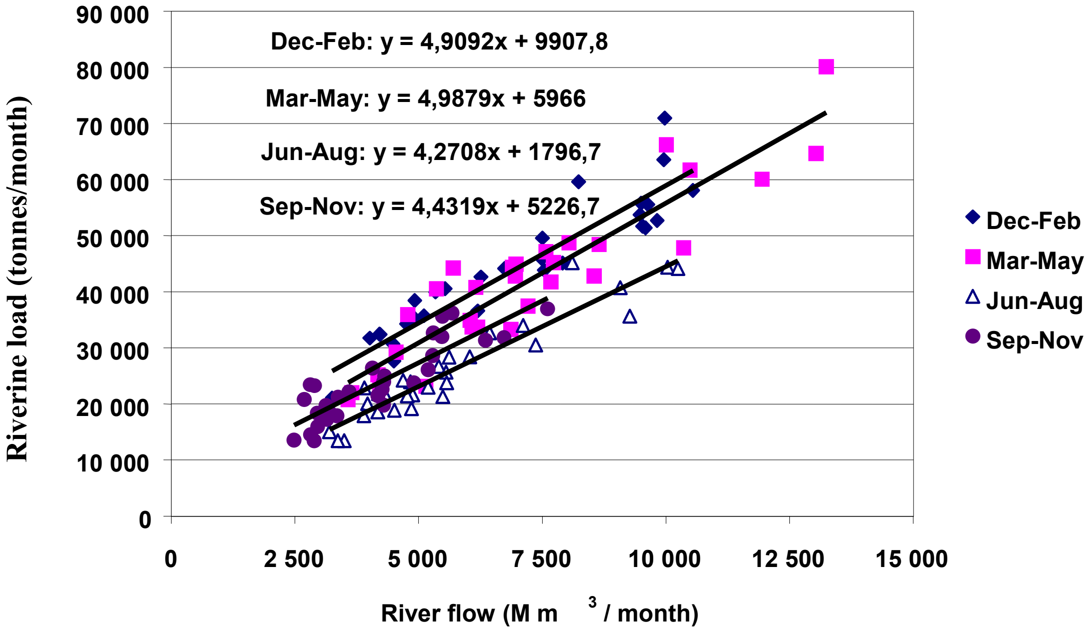

Figure 3. *Scatter plots of monthly riverine loads of nitrogen vs. monthly river flow, divided into four seasons.*

2.4 Method 1B1

2.4.1 The time series were split into two time periods (1985-89 and 1990-94) and analysed separately, according to method 1A2. As seen from Figure 4, the two regression equations are somewhat different for the two analysed time periods. The flow-normalised values have less inter-annual variability compared to the three methods under category 1A (i.e. 1A1, 1A2 and 1A3).

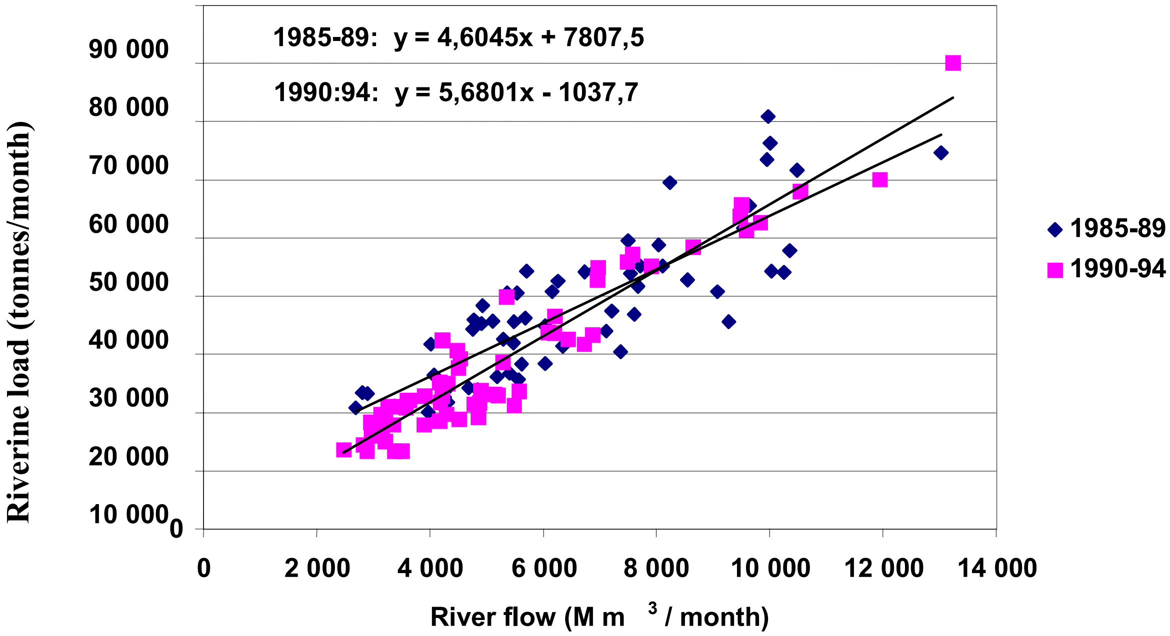

Figure 4. *Scatter plot of monthly riverine loads of nitrogen vs. monthly river runoff divided into two time periods.*

2.5 Method 1B2

2.5.1 This method uses a semi-parametric regression technique for the parameter-estimates, which allows *e.g.* gradual change in the slope-parameters. This is different from standard parametric regressions where only one slope parameter, or alternatively one slope parameter for each season, is feasible. The estimated slope parameters in this example have increased over the years. The flow-normalised nitrogen loads aggregated on years have the lowest inter-annual variability of all proposed methods.

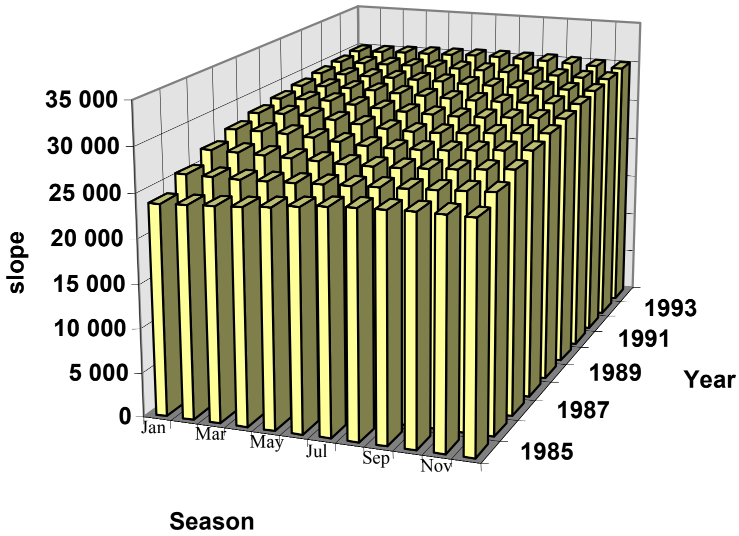

***Figure 5**. Estimated slopes in a semi-parametric model of the relationships between the riverine loads of nitrogen and the flow in the River HARP*

3. Summary and concluding remarks

3.1 The exceptionally low loads in 1991-1994 and high loads in 1988-1990 seem, to a large extent, to be explained by respectively lower and higher water discharges. However, the different flow-normalisation methods seem, at a first sight, to have produced very similar results on an annual basis (Figure 6). A more thorough analysis shows some differences. Method 1A1 and, to some extent also method 1A2, produces results with higher inter-annual variability than the other methods. Method 1B2 produces results with the lowest inter-annual variability.

3.2 Although this example with data from the River HARP showed that the differences in annual nutrient loads between the proposed normalisation methods are small (Table1), there are situations when the deviation are more substantial. For example, Figure 7 shows such a case, where the difference between methods 1A1 and 1A2 is substantial. The underlying data shows that there is a good relationship between the concentration and flow (Figure 8). This, in combination with the pronounced trend in flow (and concentration) (Figure 6), will consequently, with method 1A1 applied, lead to a spurious upward trend in the normalised loads. Method 1A2 on the other hand, uses load and flow relationships, which enable the removal of the flow-induced trend in a much more efficient way.

Table 1. *Annual riverine loads (L_i), water discharge (q_i), and flow-normalised loads according to methods 1A1, 1A2, 1A3, 1B1 and 1B2*

Year	Runoff (q_i)	Load(L_i)	1A1	1A2	1A3	1B1	1B2
1985	83 108	448 181	387 059	388 225	392 330	395 986	406 044
1986	78 275	471 784	432 601	437 292	444 552	441 843	445 401
1987	63 980	399 816	448 517	441 027	437 441	435 693	432 593
1988	78 482	468 825	428 752	433 335	437 447	437 929	440 388
1989	90 091	493 735	393 349	396 844	411 702	409 386	414 379
1990	87 619	463 540	379 713	379 725	384 312	390 574	392 487
1991	57 912	351 084	435 116	424 389	414 540	414 901	413 637
1992	63 272	351 579	398 817	395 534	390 990	390 716	390 426
1993	51 785	279 408	387 260	385 123	374 472	371 440	372 205
1994	63 213	331 344	376 214	376 612	371 501	370 752	371 692
Average	71 774	405 930					

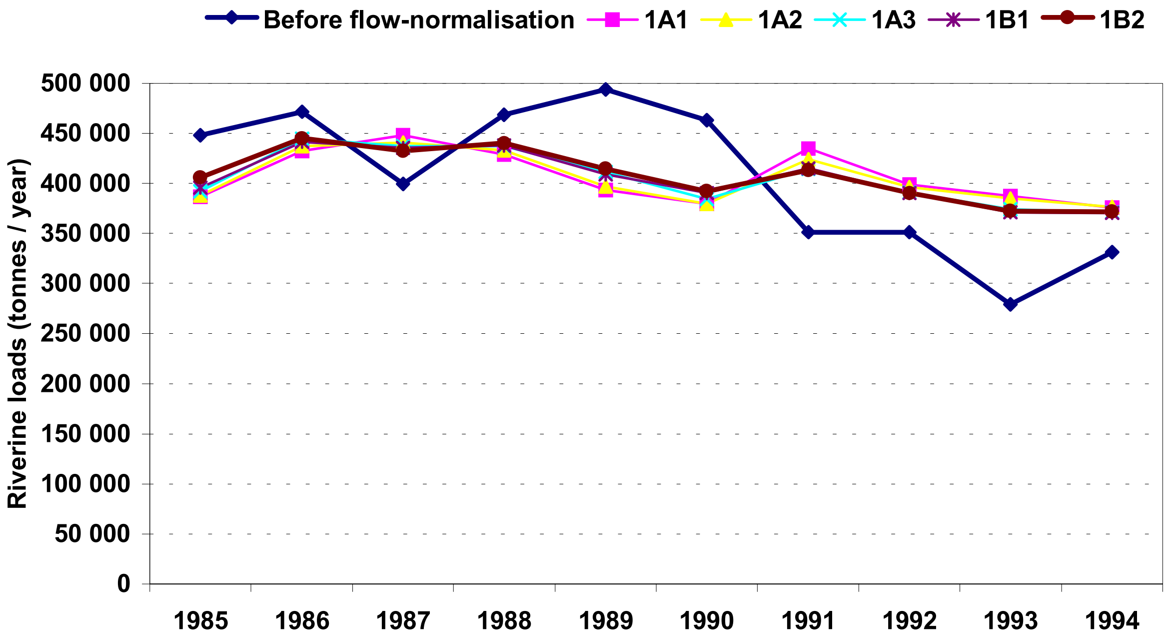

Figure 6. *Annual riverine loads of nitrogen, with and without flow-normalisation. The flow-normalisation is based on methods 1A1, 1A2, 1A3, 1B1 and 1B2.*

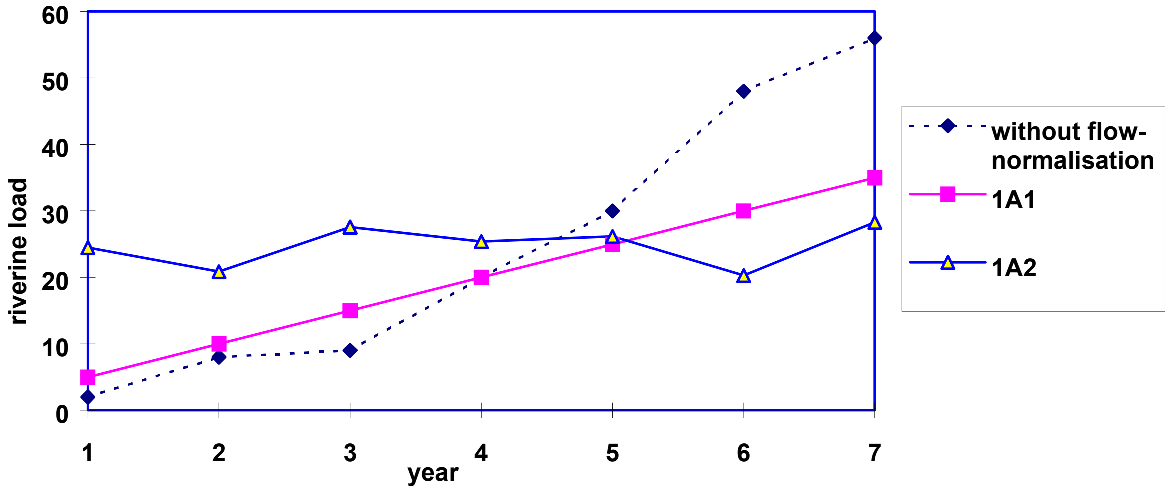

Figure 7. *Annual riverine loads with and without flow-normalisation (according to methods 1A1 and 1A2). Hypothetical data is used (see raw data in Figure 8).*

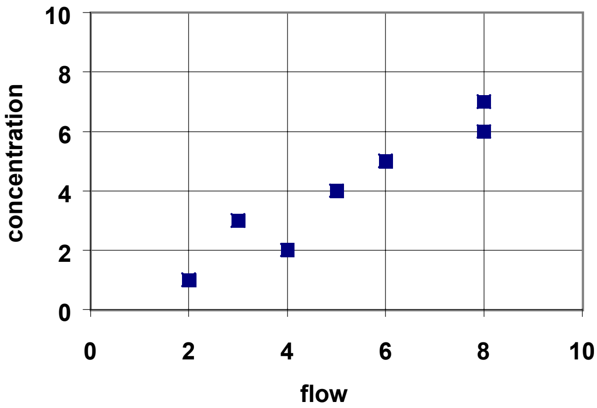

Figure 8*. Scatter plot of the relationship between concentration and flow. The data is hypothetical.*

Guideline 8:
Principles for Source Apportionment for Quantifying Nitrogen and Phosphorus Discharges and Losses

Guideline 8: Principles for Source Apportionment for Quantifying Nitrogen and Phosphorus Discharges and Losses

Contents

1. Objectives

1.1 To describe the Source apportionment approach as a tool for evaluating the contributions of point and diffuse sources to the total riverine nitrogen and phosphorus load per catchment and on a total national basis.

1.2 To enable the use of the Source apportionment approach to facilitate comparisons with data from previous years; i.e. to enable the application of the source apportionment approach in cases where this approach has been used previously.

1.3 To list the type of data to be taken account of, in addition to annual figures on loads of nitrogen and phosphorus from point sources, diffuse sources and natural background losses.

2. Introduction

2.1 On the basis of figures on the total riverine load of nitrogen and phosphorus (c.f. Guideline 7), the Source apportionment approach may be used to assess the importance of anthropogenic sources of nitrogen and phosphorus, both point and diffuse sources.

2.2 The following assumptions are made as regards the separation of the total nitrogen and phosphorus load at the selected river monitoring points (normally the lowest freshwater point, i.e. the tidal/freshwater limit in the river) into source categories:

- The nitrogen and phosphorus discharges from most point sources are virtually the same in volume and quality over time. They depend on meteorological factors to a small extent only. The input sites into a water body can usually be clearly identified; and
- The nitrogen and phosphorus losses from diffuse sources are usually variable; the variations may be of several orders of magnitude. The losses are strongly influenced by meteorological factors, such as precipitation. The input sites into a water body can normally not be clearly identified.

2.3 Time series of water quality data are often strongly dependent on variations in water flow. Thus, the inter-annual variations in nitrogen and phosphorus load can vary substantially and cause spurious trends and thereby lead to misinterpretation. This calls for harmonised procedures for normalised annual riverine loads, in order to analyse these trends (c.f. Guideline 7, on Monitored Riverine Load of Nitrogen and Phosphorus).

3. Quantification principles

3.1 General requirements

3.1.1 In general, the starting point for the source apportionment approach should be data on water flow and nitrogen and phosphorus concentrations at the tidal/freshwater limit in the rivers. The measurement site should ideally be chosen according to the "Principles of the Comprehensive Study on Riverine Inputs and Direct Discharges" (RID monitoring Programme). As regards transboundary rivers, the last monitoring point on the river before the national boundary should be reported on. For catchment areas larger than 20 000 km^2, the source apportionment should also be performed for sub-catchments.

3.1.2 The difference in behaviour towards meteorological factors is one important issue in the separation of the nitrogen and phosphorus loads from diffuse and from point sources. In order to make a differentiation, the various natural and anthropogenic components of the discharge/loss regime prevailing in the river system should be considered.

3.1.3 Nitrogen and phosphorus discharges/losses from anthropogenic and natural sources are affected by temporary and more permanent sinks, as well as by cyclical and removal processes (e.g. denitrification, retention in lakes and flooded riparian areas). To assess the importance of the different nitrogen and phosphorus sources, these river-internal retention processes should be taken account of. If the retention is not considered in the source apportionment quantification, the initial diffuse nitrogen and phosphorus losses from agriculture and other diffuse sources will be underestimated.

3.1.4 Nitrogen and phosphorus discharges/emissions/losses from unmonitored parts of the river catchment area, as well as from unmonitored rivers and coastal areas, should not be taken into account in the source apportionment assessment. The nitrogen and phosphorus load from these areas should be determined separately on the basis of the respective HARP guidelines, viz. the Guidelines on:

- The quantification of the nitrogen and phosphorus discharges from point sources (Guidelines 2, 3 and 4);
- Nitrogen and phosphorus losses from diffus anthropogenic sources, and natural background losses (draft Guideline 6); and
- Nitrogen and phosphorus retention in freshwater bodies (Guideline 9).

3.1.5 Hydrological normalised annual riverine load data should be used for the source apportionment. Hence, the data obtained in the RID monitoring programme, which is based on minimum 12 samples per year for the main load bearing rivers, should the basic data to be normalised (c.f. Guideline 7 on the Monitored Riverine Load of Nitrogen and Phosphorus). The RID monitoring programme, which provides an assessment of all riverborne and direct inputs of selected pollutants to Convention waters on an annual basis, is insufficient when it comes to separate the total nitrogen and phosphorus load measured at the tidal/freshwater limit in the river into the load from different sources (source apportionment). For that purpose, additional information about the measurements at the tidal/freshwater limit, as well as about the point and diffuse sources located within the whole river catchment area, is necessary.

3.2 Quantification methods

3.2.1 A source apportionment approach is based on the assumption that the total nitrogen and phosphorus loads at the selected river measurement site (L_{river}) represent the sum of the various components of the nitrogen and phosphorus discharges from point sources (D_P), the nitrogen and phosphorus losses from diffuse sources (LO_D) and the natural background losses of nitrogen and phosphorus (LO_B). Furthermore, it is necessary to take into account the retention of nitrogen and phosphorus in the catchment (R). This may be expressed as follows:

$$L_{river} = D_P + LO_D + LO_B - R \quad (1)$$

3.2.2 The aim of the source apportionment is to evaluate the contributions of point and diffuse sources of nitrogen and phosphorus to the total riverine nitrogen and phosphorus load, i.e. to quantify the nitrogen and phosphorus losses from diffuse sources (LO_D) as follows:

$$LO_D = L_{river} - D_P - LO_B + R \quad (2)$$

3.2.3 The importance of the different sources may be expressed as:

$$\text{Proportion of } LO_B = (LO_B / L_{river} + R) \cdot 100\% \quad (3)$$
$$\text{Proportion of } D_P = (D_P / L_{river} + R) \cdot 100\% \quad (4)$$
$$\text{Proportion of } LO_D = (LO_D / L_{river} + R) \cdot 100\% \quad (5)$$

3.2.4 The procedure outlined above requires:

a. Measurements at the selected river measurement site in order to determine L_{river}, which represents the riverine load after normalisation (see Guideline 7 on Monitored Riverine Load of Nitrogen and phosphorus); and

b. The determination of the nitrogen and phosphorus point source discharges (D_P) and natural background losses of nitrogen and phosphorus (LO_B) in the river catchment area concerned, as well as the quantification of the river-internal retention of nitrogen and phosphorus (R). For this purpose, there are different methodologies available.

3.3 Data requirements

3.3.1 There are different source apportionment approaches being used to provide figures on annual point source discharges (D_P) (Quantification of the Nitrogen and Phosphorus Discharges from Point Sources, Guidelines 1,2,3 and 4), losses from diffuse sources (LO_D) (Nitrogen and Phosphorus Losses from Diffuse sources, Guideline 5), and natural background losses (LO_B) of nitrogen and phosphorus as totals (draft Guideline 6). Most of them need at least the following information/data, which could be determined following the relevant HARP Guidelines:

a. Time series from the river measurement site for the time-period 1985 onwards.

Data from the RID monitoring programme should be used, but additional national information is required, such as:

(i) Daily water-flow figures;

(ii) Nitrogen and phosphorous concentration figures (determined according to a weekly, fortnightly or monthly sampling frequency); and

(iii) Figures of the nitrogen and phosphorous load.

b. Catchment related data:

The quantification should be done according to the HARP Guidelines, with information such as:

(i) Watershed characteristics such as:

- total catchment area;
- land use;
- soil types;
- total population, population connected to sewage systems and households not connected to public sewerage;

(ii) Point source inventory: annual discharge of nitrogen and phosphorus, annual load of nitrogen and phosphorous from :

- industrial plants;
- municipal waste water treatment plants (WWTPs); and
- aquaculture plants;

(iii) Data from significant unmanaged/natural areas (natural background losses of nitrogen and phosphorus);

(iv) Calculation of retention of nitrogen and phosphorous (retention in rivers and lakes).

4. References

BEHRENDT, H. 1993. Separation of point and diffuse loads of pollutants using monitoring data of rivers. Water, Science and Technology 28: 165-175, 1993.

HELCOM, 1995. Guidelines for estimating natural and anthropogenic contributions to riverine fluxes (source apportionment), TC POLO 3/9 (Summary Record), Annex 5, Riga, 1995.

OSPAR, 1996. Principles of the Comprehensive Study on Riverine Inputs and Direct Discharges (RID).

Guideline 9:
Quantification and Reporting of the Retention of Nitrogen and Phosphorus in River Catchments

Guideline 9: Quantification and Reporting of the Retention of Nitrogen and Phosphorus in River Catchments

Contents

1. Objectives

1.1 To describe procedures for the quantification and reporting of the nitrogen and phosphorus retention in river catchments.

1.2 To list the type of data which should be reported in addition to data on total retention of nitrogen and phosphorus in river catchments.

2. Introduction

2.1 In this guideline, retention of nitrogen and phosphorus is defined as permanent removal of phosphorous and nitrogen in the surface waters of a river systems.

2.2 Retention calculations are necessary in order to enable the quantification of discharges/losses of nitrogen and phosphorus to marine areas from land-based sources (see Guideline 1 Framework and Approach of the Harmonised Quantification and Reporting Procedures for Nutrients (HARP)). It is also necessary to have figures on nitrogen and phosphorus retention to compare and validate the figures on nitrogen and phosphorus discharges/losses from land-based sources with the measurements at the river mouths.

2.3 Retention is, *inter alia*, a function of temperature, physical characteristics of rivers and lakes, such as residence time (lakes) and specific runoff, hydraulic load and bottom characteristics (rivers). Many of these parameters are difficult to measure, and therefore difficult to implement in calculation procedures. In general, nitrogen retention is more influenced by biological processes than the phosphorus retention, whereas the phosphorus retention is more influenced by sedimentation processes than the phosphorus retention.

2.4 Parameters influencing nitrogen and phosphorus retention are, *inter alia*, renewal time in lakes, input of nitrogen and phosphorus to freshwater systems, trophic level, oxygen condition, volumes of lakes, temperature, nitrogen fixation, general water chemistry, water vegetation and human activity in the catchment.

3. Quantification

3.1 General

3.1.1 Factors such as topography and climate vary considerably amongst European countries, and even between regions within the same country. This makes it difficult to fully harmonise the methods of quantifying the nitrogen and phosphorus retention in freshwater systems. Furthermore, many countries will have their own national specific methods.

3.2 Classification of methods

3.2.1 In most cases, nitrogen and phosphorus retention is quantified on the basis of the mass balance of investigated lakes and rivers. The different methods may be divided into the following categories:

- Models of nitrogen and phosphorus retention based, on the mass balances of river systems (including both rivers and lakes), c.f. example in Annex 1;
- Models of nitrogen and phosphorus retention based on mass balances of lakes and transformation of these findings related to the whole river system, c.f. example in Annex 2; and
- *In-situ* measurements or other types of measurements that provide retention coefficients for nitrogen removal in streams and rivers.

3.2.2 The following factors are considered to be important when quantifying the retention of nitrogen and phosphorus in a river catchment:

- The portion of lakes, river stretches and wetland in each catchment;
- The hydrological and morphological conditions within the river system; and
- The development of retention coefficients or methods f6r both nitrogen and phosphorus should be based on national and/or international research on retention in different freshwater systems.

4. Reporting

4.1 The report should include the characteristic parameters of the catchment such as catchment size, water flow, area of surface waters and the figures for the quantified retention according to the Reporting Format in Section 5. If national procedures for the quantification of nitrogen and phosphorus retention are used (other that the methods/procedures in the Annexes), the procedures/methods and the results should also be reported for transparency purposes.

4.2. Since the nitrogen and phosphorus retention rate varies considerably during a year, it should be reported as a yearly or longer than yearly average.

5. HARP Reporting Format

Catchment/Coastal area	Lake water Surface	River Water Surface	Annual water flow	Total retention (tonnes/year) accuracy ± %[70]		Description of method(s) used
No. and Name	**km²**	**km²**	**mill m³/year**	**Tot-P ± %**	**Tot-N ± %**	
National figures[71]						

To Summary Reporting Format in Guideline 1	To Implementation **Format in Guideline 1**

70 Wherever possible, the accuracy of the figures should be indicated, e.g. 5 tonnes (+14 %).

71 Sum of the figures from all the catchments/coastal areas.

Annex I: Nitrogen and phosphorus mass balance models for river systems, a German Approach

The knowledge about the pathways of nitrogen and phosphorus discharges/losses from point and diffuse sources enables the quantification of the total discharges/losses of nitrogen and phosphorus into a river system. If the nitrogen and phosphorus discharges/losses are known, the retention can be quantified approximately as the difference between the discharges/losses and the monitored load at the river mouth. This approach entails errors due to 'upscaling' and insufficient knowledge about the hydrological processes in the catchment. In the following, it is assumed that retention processes are the main reasons for the difference between the observed load (L) and total discharges/losses (D).

In Germany, an analysis has been carried out with data on the discharges/losses and riverine loads of nitrogen and phosphorus in 100 different rivers, located in different parts of Europe. The geographical region covered by these rivers ranges between la Loire in France (west), the Drau in Austria (south) and Vataanjoki in Finland (north and east) (c.f. Behrendt & Opitz, 1999). River catchments smaller than 100 km² have not been considered.

The models requires the following parameters for the quantification of the retention:

a. The catchment area (A in km²);

b. The water-flow (Q in m³/s); and

c. The area of surface waters within the river catchment (A_s in km²).

The area of the surface waters in the catchment (A_S) can be calculated from detailed statistics on land use or by using the surface area of the lakes and reservoirs (A_{Lake}), on the basis of land use maps (e.g. CORINE Land-cover) and the river surface according to the following equation:

$$A_S = A_{LAKE} + 0{,}001 \cdot A^{1.185} \quad [\text{km}^2] \qquad (1)$$

Where;
As = area of surface waters;
A_{LAKE} = area of lakes in the catchment; and
A = catchment area.

The second part of the sum is derived from the analysis of different river systems according to stream order (Billen et. al., 1992; Billen et al., 1995) and measurements in rivers of different size (c.f. also Behrendt & Opitz , 1999). The parameters in this equation should be developed specifically for the region/catchment under consideration.

As shown by Vollenweider & Kereekes (1982), the relationship between the discharges/losses of nitrogen and phosphorus into the lake and the state of the lake may be described by the following equation:

$$\frac{C_{N,P}}{C_{INPUT_{N,P}}} = \frac{1}{1 + R_{SN,SP}} \qquad (2)$$

Where:
$C_{N,P}$ = the nitrogen and phosphorus concentration observed in the lake;
$C_{INPUT\ N,P}$= the nitrogen and phosphorus concentration in the inflow; and
$R_{SN,SP}$ = the specific retention of nitrogen and phosphorus.

The specific retention ($R_{SN,SP}$) is estimated by the statistical analysis of lakes in different regions of the world, and appears to be dependent on the residence time of the lakes. Equation (2) may be generalised for a river system with or without lakes by the following equation:

$$\frac{L_{N,P}}{D_{N,P}} = \frac{1}{1 + R_{SN,\,SP}} \qquad (3)$$

Where:
$L_{N,P}$ = the nitrogen and phosphorus load at a specific monitoring station;
$D_{N,P}$ = the sum of all nitrogen and phosphorus discharges/losses within the catchment area upstream of the said monitoring station; and
$R_{SN,SP}$ = the specific retention of nitrogen and phosphorus.

The specific retention is a quantity without dimensions. To date, there appears to be no estimations of the residence time of the water in a whole river system. The quantification of nitrogen and phosphorus retention in the freshwater system (both lakes and rivers) is therefore derived from other relevant parameters. Kelly *et al.* (1987) and Howarth *et al.*(1996) have shown that the nitrogen retention of lakes and rivers is dependent on the hydraulic load (HL: defined as the annual runoff divided by the water surface of the river basin). In the form of equation.3, this model can be characterised by the following equation:

$$\frac{L_N}{D_N} = \frac{1}{1 + \frac{S_N}{HL}} \qquad (4)$$

Where:
S_N = the average mass transfer coefficient given in m/a.

Behrendt & Opitz (1999) found that the specific nitrogen and phosphorus retention of river systems depends on the hydraulic load and/or specific runoff (q: defined as the runoff divided by the area of the river basins). The following relation between the specific retention of the hydraulic load and specific retention were proposed:

$$\frac{L_{N,P}}{D_{N,P}} = \frac{1}{1 + a \cdot HL^b} \quad \text{or} \quad \frac{L_{N,P}}{D_{N,P}} = \frac{1}{1 + a \cdot q^b} \qquad (5)$$

The coefficient of the model of Eq.(5) is the same as S_N for nitrogen, if the coefficient b is –1.
The coefficients of both models were estimated on the base of 100 different river basins in Europe. The results are given in Table 1, according to Behrendt & Opitz (1999).

Table 1: *Results of regressions between the nitrogen and phosphorus retention per load (R_L) of river systems and the specific runoff (q) and the hydraulic load for the studied river systems.*

	q	**HL**[72]	**HL**[73]
Phosphorus:			
R^3	0,8090	0,6148	0,6130
N	89	89	89
A	26,6	13,3	16,6
B	-1,71	-0,93	-1
Nitrogen:			
r^2	0,5096	0,6535	0,6173
N	100	100	100
A	6,9	5,9	11,9
B	-1,10	-0,75	-1

The models explain more than 60% of the total variance of the L/D ratio (load/discharge) for both phosphorus and nitrogen. According to equations (4) and (5), the models can be applied to river systems and lakes, if the surface waters area (A_S) and the water flow (Q) are known. Further values of the coefficients for river basins grouped by the basins' size are given in Behrendt & Opitz (1999).

By the comparison of different methods for the quantification of phosphorus discharges, the coefficient A seems to be lower by a factor of 0,49 than the value given in Table 1 (Behrendt;1999). This is because there are indications that the P-load is to a certain level underestimated by "normal" monitoring, and the discharges/losses of phosphorus seem to be partly overestimated.

The procedures described above concern river catchments larger than 100 km². The data set used for the development of the model represents the situation of different river catchments over a longer time period. Therefore, the models cannot be used for the description of inter-annual fluctuations in one river system.

The application of the retention models is only given for freshwater systems with a hydraulic load and a specific runoff higher than 1 m/year and 3 l/km²/s respectively.

Because the availability of data for total nitrogen load has been limited, the coefficients of the models given in Table 1 are based on the load of dissolved inorganic nitrogen (NO_3 + NH_4 + NO_2) and the data for the discharges inputs have been based on total nitrogen.

Equation (4) and (5) enable the estimation of the nitrogen and phosphorus load in cases where the area is unmonitored and the discharges/losses are calculated at source, according to the relevant HARP Guidelines. The total nitrogen and phosphorus retention in a freshwater system ($R_{N,P}$) can be estimated by multiplication of the observed or calculated nitrogen and phosphorus loads with the specific retention of nitrogen and phosphorus; according to equations (3) and (4) and/or (5).

$$R_{N,P} = R_{SN,SP} \cdot L_{N,P} \qquad (6)$$

Where;
$R_{N,P}$ = total nitrogen and phosphorus retention in freshwater system;
$R_{SN,SP}$ = the specific retention of nitrogen and phosphorus; and
$L_{N,P}$ = the nitrogen and phosphorus load at a certain monitoring station.

72 Results of a model according to Eq. (5).
73 Results with a constant mass transfer coefficient - a, according to the model approach of Kelly *et al.* (1987).

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Annex II: Nitrogen and phosphorus mass balance models for lakes, a Danish Approach

1. Introduction

Mass balance models for lakes have been developed by Vollenweider & Keerekes (1982) for phosphorus and Kelly et al. (1982) for nitrogen (see also Equation (4)). These Models can be applied, in particular for phosphorus, in cases where the residence time of the water in the lake or lakes is known. In Denmark special mass balance models have been developed for the specific conditions of shallow lakes.

2A. The Danish model for Phosphorus retention in shallow lakes

The model "P2" has only two state variables: total phosphorus in lake water (P_l) and exchangeable total phosphorus in sediment (P_s). The driving variables in the model are the monthly inlet concentration of total phosphorus (P_i), the corresponding monthly water discharge (Q) and the lake water temperature (T).

In Danish streams the fraction of the total phosphorus transport contributed by the particulate total phosphorus transport are generally high (Svendsen *et al*., 1995; Kronvang & Bruhn, 1996). The proportion of the particulate total phosphorus transport in such streams increases with increasing water discharge in the individual stream (Svendsen *et al*., 1995; Kronvang & Bruhn, 1996). The input of particulate phosphorus will settle instantly in the lakes and therefore not contribute to the phosphorus pool in the lake water immediately. In the P2-model, this is simulated by dividing the input of total phosphorus between the lake water pool of phosphorus and the sediment pool of total phosphorus. The fraction of the total phosphorus input forwarded to the lake water pool is given by the factor 'k', thus the fraction of the total phosphorus input forwarded to the sediment pool is given by '1-k'. The actual values of 'k' have been related to water discharges by the following empirical relation:

$$k = \frac{1}{1 + \sqrt{\dfrac{V}{365 \cdot Q}}}$$

Where
k is the fraction of input total phosphorus input to lake water;
(1-k) is the fraction of input total phosphorus input to sediment;
Q is the water discharge (m^3/day); and
V: Lake water volume (m^3).

In P2 the use of k is optional. If required, all the total phosphorus input is considered to be input to the lake water pool of total phosphorus. This might prove useful when considering lakes where most of the input is dissolved phosphorus.

The dynamics of lake water and total phosphorus is given by the difference between input and output. The sedimentation of total phosphorus is deducted, and the release of total phosphorus from the sediment is added, c.f. below

$$\frac{dP_l}{dt} = \frac{Q}{V} \cdot (k \cdot P_i - P_l) - SED + REL$$

Where
P_l: is lake water total phosphorus concentration (g m^{-3});
P_i is the inlet total phosphorus concentration (g m^{-3});
SED is the sedimentation of total phosphorus from lake water to sediment (g P/ m^2 /day);
REL is the release of total phosphorus from sediment to lake water (g P/ m^2 /day).

Correspondingly, the change of total phosphorus in the sediment is given by the partial input from the inlet. The sedimentation of total phosphorus is added, and the release of total phosphorus from the sediment is deducted.

$$\frac{dP_s}{dt} = \frac{Q}{V} \cdot ((1-k) \cdot P_i) + SED - REL$$

Where
P_s is the sediment total phosphorus concentration (g/m^3, in output converted to g/ m^2).

The sedimentation of total phosphorus is given by a constant sedimentation rate, times the lake water pool of total phosphorus. In order to have the same units of sedimentation in the different lakes, the equation is adjusted by the lake mean depth. The temperature dependence of this process is modelled by a standard Van Hoff's equation as follows:

$$SED = bS \cdot (1 + tS)^{T-20} \cdot \frac{P_l}{Z}$$

Where
BS is the sedimentation rate of total phosphorus;
TS is the temperature correction for bS;
T is the lake water temperature (°C); and
Z is the mean water depth (m).

The sedimentation of total phosphorus is given by a constant sedimentation rate, times the lake water pool of total phosphorus. In order to have the same units of sedimentation in the different lakes, the equation is adjusted by the lake mean depth. The temperature dependence of this process is modelled by a standard Van Hoff's equation.

$$REL = bF \cdot (1 + tF)^{T-20} \cdot P_s$$

Where
BF is the release rate of total phosphorus; and
TF is the temperature correction for bF.

An estimate of lake retention of total phosphorus is thus given by the difference of sedimentation and release (SED-REL).

The calibration of the parameters were done on an eight years series of monthly data on water balance and phosphorus mass balances from 16 Danish lakes; some of these lakes were permanently stratified during summer. They were all quite shallow with a mean depth below 10m and a max depth below 22 m (c.f. Table 1).

***Table 1**. Characteristics of the 16 lakes.*

	Lake area (km^2)	Mean depth (m)	Max depth (m)	Water retention time (days)	Lake P-conc. (year) (mg P l^{-1})	Inlet P-conc. (year) (mg P l^{-1})	Lake P-conc. (summer) (mg P l^{-1})	Chlorophyll a (summer) (µg l^{-1})	Secchi depth (summer) (m)
Min	0,05	0,9	1,5	7	0,090	0,094	0,086	38	0,4
Median	0,34	1,8	3,2	30	0,220	0,148	0,286	113	0,6
Mean	0,91	2,5	5,3	70	0,249	0,211	0,322	132	0,8
Max	6,62	9,9	21,7	266	0,849	0,963	0,991	350	2,0

The results of the calibration of the model, on basis of the data from the 16 lakes, is given in Table 2.

***Table 2**. Calibrated parameter values for the P2-model.*

Parameter	Calibrated value
Sedimentation rate (bS)	0,0470
Temperature dependence of P-sedimentation (tS)	0,0000
Sediment release rate (bF)	0,000595
Temperature dependence of P-release (tF)	0,0800

As a consequence of the value of tS calibrates to 0, the equation for the sedimentation can be reduced to:

$$SED = bS \cdot \frac{P_l}{Z}$$

The initial values of PS (t=0) were calibrated for each lake, reflecting differences in the development of phosphorus loading in the past years and, consequently, in the actual sediment pool of total phosphorus.

Since the model is calibrated by using shallow Danish lakes, caution should be applied when using the model under other circumstances, especially if the lake characteristics differ (c.f. Table 1). The most crucial factor is stratification, as the model will not perform very well for permanently stratified lakes.

2B. The Danish nitrogen model for lakes (Jensen *et al.* 1994)

The aim of this study was to elucidate the seasonal dynamics of nitrogen retention in lakes differing in hydraulic and N loading. In addition, besides the annual models, the first simple model capable of accurately predicting seasonal variation in lake water concentration of total nitrogen and retention of total nitrogen is presented.

The model of lake retention of total nitrogen on a monthly basis is given by:

$$N_{ret}(\%)=a*\theta^{(T-20)}*N_{retmax}$$

Where
T is water temperature; and
N_{retmax} is given by the sum of the inflow of total nitrogen and the pool of total nitrogen in the lake water.

The parameters have been calibrated to 0,455 and θ to 1,087 on the basis of data from 16 shallow Danish lakes (Windolf *et al.* 1996).

The model of lake retention of total nitrogen on a yearly basis is given by:

$$N_{ret}(\%)=a*tw^b$$

The parameters have been calibrated to 78 and b to 0,48, on the basis of data from 16 shallow Danish lakes (Windolf *et al.* 1996).

The calibration of the parameters was done on a 3-4 years series of monthly data on water balance and phosphorus mass balances from 16 Danish lakes. Some of these lakes were permanently stratified during summer and they were all quite shallow (mean depth below 6m), c.f. Table 1.

***Table 1**. Characteristics of the 16 lakes.*

Lake	**z** (m)	**TP** (ug P/ 1)	**Chla** (ug /1)	**Secchi depth** (m)	**TN** (mg N /1)	**N02 + N03** (mg N /1)	**n**
Vesterborg sø	1,4	241 (27)	105	0,70 (0,04)	5,21 (0,45)	3,70 (0,55)	4
Søgård sø	1,6	272 (34)	153	0,58 (0,05)	6,69 (0,61)	4,67 (0,79)	4
Lemvig sø	2,0	239 (11)	45 (4)	0,74 (0,05)	4,30 (0,48)	3,10 (0,36)	4
Hejrede sø	0,9	123 (6)	75 (10)	0,65 (0,05)	4,34 (0,29)	2,18 (0,36)	4
Fuglesø	2,0	256 (22)	75 (4)	1,12 (0,03)	4,18 (0,37)	2,39 (0,41)	3
Fårup sø	5,6	92 (5)	37 (4)	1,77 (0,08)	1,51 (0,05)	0,79 (0,02)	4
Langesø	3,1	279 (30)	62 (8)	1,24 (0,04)	3,80 (0,15)	2,39 (0,13)	4
Kilen	2,9	187 (17)	103 (22)	0,68 (0,09)	2,17 (0,07)	0,76 (0,06)	4
Jels Oversø	1,2	273 (26)	100 (12)	0,85 (0,05)	6,90 (0,18)	5,34 (0,26)	3
Ørn Sø	4,0	108 (2)	36 (2)	1,57 (0,05)	1,43 (0,04)	0,55 (0,02)	4
Hinge Sø	1,2	122 (3)	90 (9)	0,68 (0,03)	4,44 (0,20)	2,95 (0,17)	4
Dons Nørresø	1,0	216 (29)	251	0,56 (0,04)	5,05 (0,08)	3,05 (0,11)	4
Borup Sø	0,9	150 (10)	78 (9)	0,92 (0,04)	4,93 (0,46)	2,97 (0,36)	4
Gundsømagle	1,2	1127	276	0,55 (0,02)	5,92 (0,42)	2,85 (0,44)	4
Store Søgård	2,7	465 (53)	41 (1)	0,79 (0,05)	6,27 (0,32)	3,33 (1,65)	3
Bryrup	4,6	107 (7)	33 (4)	2,10 (0,10)	4,15 (0,11)	3,10 (0,11)	4

Since the model is calibrated on shallow Danish lakes, caution should be applied when using the model under other circumstances, especially if the lake characteristics differ (c.f. Table 1). The most crucial factor is stratification, since the model will not perform very well for permanently stratified lakes.

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Development of HARP Guidelines;
Harmonised Quantification and Reporting Procedures for Nutrients

Summary
The Norwegian Ministry of Environment initiated the project 'Harmonised Reporting Procedures for Nutrients' (HARP) in 1996, as a follow-up Ministers at the 4th North Sea Conference's invitation to Norway to develop a transparent and harmonised quantification and reporting system. The development programme, which was organised as a project led by Norway, involved a large number of civil servants and scientific researchers in Europe. The product is the nine HARP Guidelines, which were adopted on a trial basis by OSPAR in 2000. The Guidelines will be used for the reporting on nutrient discharges/losses to the 5NSC and the 2003 OSPAR/MMC. The Guidelines will be reviewed within the OSPAR framework in due time, on the basis of experiences acquired during the said reporting exercises.

Subject words	
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