

**ECOLOGICAL REHABILITATION OF THE RIVERS RHINE AND MEUSE:
NETHERLANDS RESEARCH PROGRAM 1992-1995**

Publications and Reports Vol - 1992 - 40

to be cited as: Admiraal, W., G.M. van Dijk, W.B. Harms, A.J. Hendriks, L.W.G. Higler, E.C.L. Marteiijn, H. Pieters, J.A.W. de Wit, 1992. Ecological Rehabilitation of the Rivers Rhine and Meuse: Netherlands Research Program 1992-1995. Report of the project "Ecological Rehabilitation of the Rivers Rhine and Meuse". Report nr 1992-40, 15 pp.

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INTRODUCTION

The joint research program on the ecological rehabilitation of the rivers Rhine and Meuse finds its basis and aims in the Rhine Action Program and furthermore in the Nature Development Plans for the rivers.

According to the Rhine Action Program the ecosystem of the Rhine should be improved in such a way that higher species (e.g. salmon) become indigenous again. This ecological objective has been elaborated in an Ecological Masterplan for the Rhine. Furthermore in the 3rd National Policy Document on Water Management in the Netherlands objectives and actions are specified for the Dutch part of the international river.

An international action program for the river Meuse is lacking at present. The ecological condition of the river Meuse would certainly justify an action program. To anticipate future developments it is necessary to collect information on the ecosystem of the Meuse.

The growing importance of ecosystem management and nature development in the policy plans for the rivers Rhine and Meuse makes a better understanding of the ecosystem of these rivers indispensable. This is even more the case as the development of the ecological infrastructure is now in the phase of design, implementation of plans and evaluation of measures.

In the first phase the joint research program has proved its value. Research findings e.g. on monitoring, and quality objectives found their way to the policymakers on a national and international level. Different ways to support policy actions have been developed. Within the Netherlands research program on the river Rhine the direct participation of members of the research group into the Subcommissions of the IRC has led to dissemination of newly developed insights into the functioning of the river ecosystem, and this has stimulated the formulation of international proposals on e.g. the restoration of fish populations, on the protection of "stepping stones" for ecological recovery, and on the installation of ecological monitoring methods. It appeared that the contacts between the researchers and their ministries, the latter being formally responsible for the national policy, were rather intense. Furthermore researchers were involved in local restoration projects in the flood plains and provided information to municipal and regional authorities.

The knowledge on the Rhine has been summarized through a national symposium and by review papers dealing with the application in the Rhine Action Program. The integration of knowledge and support of the policy actions on the basis of the research findings of the first phase will be elaborated by publishing a summary report (in 1992) and by organizing an international congress (in 1993).

The co-operation of the institutes in the program resulted in a harmonization of their activities and thus in a higher effectiveness of their research efforts.

The co-operation of ecologists and ecotoxicologists must also be mentioned in this respect. The publication series became recognized as an interesting medium for exchanging information.

The second phase of the Netherlands research program (1992-1995) will focus on supporting rehabilitation measures and evaluating actions taken to see if and to

what extent they contribute to the goals.

In the international context of the Rhine Action Program an important question is whether the ecotoxicologically based water quality criteria are sufficient for the rehabilitation of the ecosystem of the Rhine, with special emphasis on the restoration potentials of the flood plains, considering the pollution with micropollutants and the nutrient load.

The plan for the return of migratory fish species poses many questions. Little is known about the migratory routes in the delta region and the possibilities to enter the river from the sea. The Netherlands must take part in the internationally coordinated actions for the return of migratory fish, the evaluations of the success and the assessment of important loss factors.

Restoration of the flood plains e.g. by increasing river dynamics in the flood plains is found to be of vital importance for the rehabilitation of the river and therefore is a main topic in the Ecological Masterplan for the Rhine. The aim should be to recreate an international ecological infrastructure. Local initiatives must be stimulated and evaluated to get a better understanding of the possibilities and the necessary conditions for success. Concepts must be developed for the interdependence of the stepping stones, nationally and internationally.

Research is emerging to support local and regional authorities in decision making about rehabilitation programs. This kind of studies contents scenario development for nature restoration and modeling decision support systems both linked to Geographical information systems.

For the river Meuse basic ecosystem studies are necessary to get a better knowledge of the present state and give a basis for an internationally co-ordinated monitoring program, once a Meuse Action Plan is established. For the Netherlands part of the river Meuse a problem analysis has been completed. A more specific knowledge of the impact of the water quality and discharge conditions on the Meuse ecosystem seems necessary. The plans for the bordering Meuse to combine gravel extraction with nature development are promising. Elaboration of these concepts are necessary though on the basis of specific studies of reference situations and evaluation studies in the Meuse itself.

In the first period the co-operation was limited to three governmental institutes (RIZA, RIVM, RIVO-DLO). A more basin-wide approach seemed necessary. Therefore in the second phase the aspect of terrestrial nature of the river system is strengthened by the joining of the IBN-DLO and the SC-DLO in the joint research program.

The collaboration with the ministries on the Rhine Action Plan will be continued with the same intensity but additional efforts will be made to disseminate information to the public: a film and accompanying leaflet are in preparation and the publication of articles in periodicals on popular science will be stimulated.

A more active participation of non-governmental institutes (e.g. drinking water companies) is needed and shall be promoted.

Next to the Rhine the object of this program is extended to the Meuse. Co-operation with Belgian and French research institutes will be stimulated. In general exchange of information and research findings with other countries and other river

basins seems very useful for all parties. Publication of research findings in international journals shall in this respect receive more attention.

The project will be open to exchange of information and researchers with other (European) river basins. This aspect may benefit the Rhine Action Program as well as promote the establishment of European policies as to the management of river basins.

In the next chapters the selected themes of the joint research program are presented, together with a selection of the products of the first two years of the second phase of the program.

2. ANALYSIS OF RIVER ECOSYSTEMS

Thorough knowledge of the ecological functioning of river ecosystems is a prerequisite to formulate and implement measures and to evaluate their impact. The first phase of the ecological research program was focused on the functioning of the river Rhine ecosystems. It mainly included field studies on the composition and seasonal development of the biota (e.g. plankton, invertebrates, fish, macrophytes), an analysis of the food web under various conditions and studies on the hydrographical conditions. Special attention was paid to the primary production and consumption, key-species such as *Dreissena polymorpha*, feeding behaviour of fish, and the menu of birds predating on fish. The first phase has resulted in a start for an ecological simulation model of the river Rhine ecosystem.

Extension of the developed simulation model requires submodels of some selected processes. A need is felt for more definite ecological studies with the aim to quantify the importance of selected ecological processes. Furthermore, it is necessary to extend the ecological knowledge of rivers with the study of the river Meuse and possibly other European rivers.

The second phase of the ecological analysis of rivers includes process studies on primary production, development of submerged vegetation in relation to habitat requirements, and the functioning of the foodchain. Special attention will be paid to benthic filter feeders, because of their importance in numbers and biomass in the downstream regions of the river systems. Studies will be carried out on the autecology and feeding habits of some selected species (*Corophium*, *Corbicula*). The results of these studies will be used to develop submodels which simulate selected ecological processes such as feeding rate and growth and development of benthic filter feeders and their impact on the plankton community.

These submodels will be incorporated into a simulation model of the river ecosystems as far as feasible. The simulation model to be developed is expected to be a useful tool for developing and evaluating retrospective and prospective scenarios. The second phase of ecological analysis of rivers aims at development of ecological objectives and standards for river systems on a national and later international scale. Co-operative actions will be initiated to include the river Meuse and eventually other European rivers.

Products:

Feeding habits, growth and development of *Corophium curvispinum* (1992-1993)
 Growth, density and filtration capacity of *Corbicula* (1993)
 A follow-up of the first version of the simulation model on C-fluxes (1992-1993) through the river Rhine ecosystem.

3. ECOLOGICAL AND ECOTOXICOLOGICAL MONITORING

Monitoring is necessary to determine whether ecological objectives are met and to signal and evaluate developments. In the period 1988-1991 the actual status of the different components of the Rhine ecosystem were monitored e. g. fish, macro-zoobenthos, algae, zooplankton, vegetation, amphibians. Information about the historical reference situation was collected and ecological and ecotoxicological objectives were formulated. In general it showed that the situation in the Rhine is poor, although some improvements can be seen. The information also resulted in possibilities for further improvements.

In co-operation with German institutes a program of implementing and testing early-warning systems was started. Some of these systems have been implemented at monitoring stations. This resulted in operational fish monitoring systems in Lobith and Eijsden.

For the international river regular inventories at 5-year intervals have been agreed upon for the years 1990 and 1995. For the Meuse monitoring until now is rather incomplete, less systematic and on an international level non existing.

In the period 1992-1995 an extensive biological monitoring program for Rhine and Meuse will be carried out by RIZA in co-operation with RIVM and RIVO. This is part of the national biological monitoring program for the main waters. Monitoring of plankton, macro-zoobenthos and fish will be continued. Monitoring of vegetation, birds and ecotoxicological parameters (c.q. bio-assays) are added to it. Special emphasis will be given to method evaluation and development. Also methods may have to be harmonized internationally, based on the experience of 1990.

Monitoring results of 1990 will be reported in international co-operation. Historical developments will be analyzed in view of what may be expected in future.

Increase of river dynamics in flood-plains are important features of existing restoration plans. To get a better knowledge of the effect on flora and fauna, monitoring of these nature-development projects is necessary. The EHR program may participate in these projects, if of national interest.

The implementation of bio-alarm systems will be extended with Daphnia, not only for the Rhine (1992) but also for the Meuse (1993). A further extension of the bio-alarm systems (e.g. algae systems) may be considered, depending on the results of the international program.

Products

Status report for the Rhine in 1990 (1992)

Development of macro-zoobenthos of the river Rhine. (1992)

Changes in macro-zoobenthos in the nature development project Duursche Waarden. (1992).

Actual status of flora and fauna in the river Meuse (1993)

Macro-zoobenthos in the sedimentation area of the Rivers Rhine and Meuse (1993)

Implementation of Daphnia bio-alarm system in Lobith (1992) and Eijsden (1993)

4. ECOTOXICOLOGICAL STUDIES

Concentrations of some micropollutants in water and organisms have decreased substantially during the last decade. In the seventies, test organisms that were exposed to Rhine water immediately died, but recently water had to be concentrated to induce acute effects in bacteria and waterfleas. Unfortunately, other bottle-necks remain. Sediments are still of poor quality, as is indicated by laboratory assays and field observations on e.g. mosquito larvae. Residues of some compounds, especially highly chlorinated biphenyls, chlorodibenzodioxines and chlorodibenzofuranen and methyl-mercury, are still at a troublesome level in higher species. Some of these compounds have been studied with regard to impaired breeding success of fish-eating top predators, especially cormorants. Preliminary estimations from literature data on less well-known taxa, indicate that other compounds, in particular cadmium, are still important.

The general aim of the ecotoxicological studies is to evaluate whether objectives in emission reductions are sufficient for ecological rehabilitation. Not only the emission levels of chosen priority substances are subject of study, but also other potentially priority substances.

Trends in less polluted water can be monitored by a combination of concentration techniques and short-term assays. The application of different techniques and more sensitive assays will be further explored. As the overall water quality improves, local problems, like those in the dilution zones of large discharges, will become more important.

Results of field experiments and surveys in water will be evaluated to detect field effects. In future, field investigations will be extended to flood plains. These flood plains will be used for many purposes in the near future, including nature development, so that indicators for pollution must be developed. Effects of toxicants on species at the beginning of the flood plain food chain will receive special attention. Preliminary methods for hazard assessment will be refined to improve integration of laboratory and field observations and extrapolation to less well-known compounds and species. The link to emission objectives will be continued by implementation of results from fate modelling. In particular, concentrations of accumulating compounds along the aquatic food-chain will be compared to model calculations. These investigations will yield priorities for additional selection of critical compounds and development of standards.

Products

Accumulation of several IRC priority pollutants along the aquatic food chain: measurements. (1992) calculations/estimations compared to measurements. (1993)
Toxicity of concentrated and fractionated Rhine and Meuse water. (1992-1993)

5. STUDIES ON NUTRIENTS

Nutrients play a dominant role in the interrelationships between biota of the river ecosystem. They have a direct impact on primary production which may affect other parameters negatively like the underwater light climate and oxygen concentrations. Furthermore nutrients can be inhibitory through the toxicity of high ammonium concentrations. The nutrient conditions of the River Rhine are rapidly changing. Measures to reduce phosphate input in the Rhine basin led in recent years to a drastic decrease in river concentrations. However, due to purification of sewage in the past 15 years the total concentration and oxygenation state of nitrogen in the river increased. As a result the N:P ratio has almost tripled during the last decade. In view of the importance of nutrients in the functioning of the river ecosystem, the ecological consequences for the river communities of the current and future changes in nutrient loads and composition need to be assessed. Additionally, studies on the impact of other non-toxic substances, such as chloride, on the functioning of river ecosystems, will be included as far as feasible. Special attention will be given to macrophytes.

The second phase of the research on nutrients (and other non-toxic substances) includes a desk study on the long term trends in nutrient loads and speciations in the river Rhine basin and additionally in the river Meuse basin (catchment to North Sea). Special emphasis will be put on the N:P ratio, the ammonium:nitrate ratio, and assessment of ecological risk of the current nutrient loads and forms for river and backwater ecosystems. Experimental process studies on the interrelationships between phytoplankton growth and nutrient loads and forms and *vice versa* will be conducted. Special attention will be paid to the question whether the phytoplankton growth in rivers is currently limited by nutrients (N, P and Si) or is likely to become nutrient limited in the near future.

An attempt will be made to study the impact of nutrient concentration in the stream on riparian zones and on backwaters and *vice versa*. Special efforts will be made to study the impact of nutrients on the submerged vegetation in side channels and backwaters.

The results of these studies will be used for extending the ecological simulation model. The nutrient input from the catchment (derived from the Delta Study) and nutrient fluxes through the system will be incorporated. Special efforts will be made: firstly, to model dynamically the nutrient ratios in water and biota and secondly, to include higher trophic levels in the model (*e.g.* benthic filterfeeders). It should be noted that the derived submodels on specific processes (see paragraph 2) will be incorporated into the model. The model will be used to analyze the possible impact of nutrients on the ecological condition of the rivers ecosystems.

Products:

Long-term trend analysis of nutrient concentrations and speciation in the River Rhine (1992).

First results of bio-assay studies on the relationship of nutrient concentrations *in situ* and phytoplankton development (1992-1993).

Limiting factors for macrophytes in the Dutch parts of the Rivers Rhine and Meuse (1993).

6. ANALYSIS AND MODELLING OF GEOGRAPHIC POTENTIALS FOR NATURE DEVELOPMENT

The Ministry of Agriculture, Nature Management and Fisheries has in 1989 published the Nature Policy Plan. According to this Plan 50.000 ha must be withdrawn from agriculture for Nature development purposes. A research programme on nature development has been formulated in order to support the policy plan. The river flood plains constitute one of the priority landscapes concerned. The question arises whether nature development poses the question what nature development is possible in the flood plains, given the necessary constraints or with changing conditions. Also information is needed on the implications of nature development for other river bound functions, e.g. shipping and flood protection.

A model is developed to predict the interaction between the dynamics of the river and the development of the vegetation in the flood plains of the rivers Rhine, Waal and IJssel. A geographical information system will be used to store the necessary data to predict the vegetation development. The most important variables in the model are soil, inundation frequencies and management. Apart from this model an inundation model was developed to calculate the inundation frequencies in the flood plains. When the vegetation model communicates with the GIS, the vegetation development can be predicted for different management scenarios and will function as an input for a hydrological model (WAQUA) to predict the response of the water movement and water heights to increasing resistance of the vegetation. In the next years the model will be tested and implemented in a particular area called the "Gelderse Poort". In this area the effects of different management scenarios on the vegetation development will be predicted and the change in water resistance will be translated by the WAQUA model into the change in water movement and heights.

It is the intention to apply the model eventually to all the flood plains of the rivers, Waal and IJssel up to that area where the tidal effect is noticeable.

The potentials for nature development will be examined in pilot study which aims at a general survey of nature development in flood plains. It concerns formulating habitat references and nature development targets, analyzing of constraints and potentials and mapping suitable locations for nature development. The study involves river dynamics, abiotic site conditions, vegetation dynamics and faunistic habitat requirements of the aquatic and terrestrial ecosystems of the river flood plains. The study also contains a survey of nature-development models with both a temporal and geographical dimension.

Products:

A general framework for a geographical information system of the riversystem in the Netherlands 1993.

"The state of the art" on nature development opportunities of river flood plains; confronted with the gaps in knowledge: a research program for detailed studies (1992).

A map of geographical potentials for nature development in Netherlands flood plains (1992).

7. PILOT STUDIES ON THE REGENERATION OF RIVER BANKS AND FLOOD PLAINS

Several studies have provided thorough up-to-date ecological descriptions of most groups of aquatic biota in the river Rhine and its tributaries. In all studies much attention was paid to the definition of the most determining factors/parameters for the presence or absence of species. The gathered ecological data were used in the design of nature development projects in the flood plains to be implemented in the near future.

First effects of increased river dynamics on the macro-invertebrate community in the ecological rehabilitation project of "Duursche Waarden" were monitored. Morphological and hydraulic model studies were done on the feasibility of man-made creation of side channels in the flood plain, considering the ecological demands. Similar studies have been carried out for the river Meuse to obtain information about the effects of channel widening on the water level and the formation of sand and gravel banks.

A start was made with the study of the application of willows as a natural river bank protection along the river Waal. Three years of intensive studies on the application of rushes and reed have been finished and the results will be published in 1992/1993.

Much effort will be put in the implementation of the recently gathered ecological information and ideas, especially in the field of the aquatic community, in the design of future projects on the improvement of river habitats. This will require cooperation with municipal, provincial and also private organizations dealing with this subject. Monitoring the effects of these habitat improving measures on the aquatic community in new projects has to be a logical result of this cooperation. River morphologists and biologists will intensify the study, especially on willows as river bank protection. Besides the experiments with planted trees, new experiments will be carried out studying the possibilities of natural re-establishment of these plants. Important items to be studied are: viability of several species in relation to hydrological regimes, their effects on erosion and sedimentation and their (ship-) wave reducing effects.

The application of side channels in future nature development projects will be developed further, both in the field of morphology and in the field of ecology.

Products:

Vegetation as a tool for preventing erosion: the application of willow, rushes and reed (1993).

The effects of increased river dynamics on the aquatic macro-invertebrate community (1993).

Changes in macro-zoobenthos in the nature development project Duursche Waarden (1992).

8. STUDIES ON MIGRATORY FISH

During the first research period, research was carried out into the following subjects, related to the EHR program.

Monitoring fish populations in the rivers, anadromous fish species in the Netherlands coastal zone, migration routes of (sea-) trout along the coast and in the rivers and the suitability of some fishpasses for fish migration. About 45 fish species were observed in the rivers Rhine and Meuse, ten diadromous fish and lamprey species living in the Dutch coastal zone (among them sea-trout).

Tagging experiments have been carried out with sea-trout in 1987, 1988 and 1989 in inland waterbodies. Returns only came from inland waters, even one from Gamsheim in Germany. In 1990 a number of 963 sea-trout were tagged in the Haringvliet-estuary. Recaptures demonstrate, that trout over 40 cm (adults) migrate to the rivers Rhine and Meuse, including the German part of the Rhine, while smaller ones stay in the coastal zone, migrating northward.

Thousands of fish reached higher stretches of the rivers through newly built pool-type fishpasses. An automatic fish-sluice in the river Lek has produced poor results.

In the period 1992-1995, fisheries research will still be focused on the state and the needs of the fish communities in the rivers Rhine and Meuse. Environmental demands and shortcomings for the migrating riverine fish populations and the anadromous salmonids, salmon and sea-trout, will be assessed in particular. Ways to improve the possibilities for migration will be indicated.

The following activities will be developed, based upon the research in the previous period, and in co-ordination with investigations carried out Germany and Belgium: determination of the migration routes of anadromous fish species, sea-trout in particular, assessment of the measure in which physical barriers along the North Sea coast and in the rivers obstruct the migration of migratory fish species, evaluating the functioning of the new fish passages in the rivers.

Essential work on quality and improvement of spawning and nursery areas is in Belgium and also will be continued in Germany.

Products:

The migration of sea-trout (*Salmo trutta trutta* L.) along the Netherlands coast and in the lower part of the Rhine (1992).

The results of the monitoring of fish-populations in the rivers (1992, 1993).

Fish migration through a fishpass in the river Meuse (1992).

9. PARTICIPATION OF THE RESEARCH INSTITUTES

The participating support the policies of their respective ministries with regard to the Rhine Action Programm as well as the joint actions of the ministries and the IRC. The research programme will be carried out by the institutes that take responsibility for certain aspects as specified below.

RIZA	2, 3, 4, 5, 6, 7
RIVM	2, 3, 4, 5
RIVO-DLO	3, 4, 8
IBN-DLO	4, 6
SC-DLO	4, 6

The program is supervised by a steering committee composed of three representatives of the ministries involved and representatives from the participating institutes. The secretariat will be fulfilled by RIZA. The research program is coordinated by a team of five representatives of the participating institutes. This team is responsible for the integration of the results and the dissemination of information. It organizes inter-institute presentations and discussions, issues a series of reports and organizes an international symposium.

The personnel and financial input is specified below

	Institute pers. my/y	Project pers. my/y	external projects Kfl
RIZA	10		940
RIVM	4	2,5	53
RIVO-DLO	3,5	1	90
IBN-DLO	5,3	2	145
SC-DLO	2	2	-

PUBLICATIES EN RAPPORTEN VAN HET PROJECT "ECOLOGISCH HERSTEL RIJN"

- 1 - 1988 Ecological rehabilitation of the river Rhine: a proposal for a Netherlands research programme. (RIZA, RIVM, RIVO-DLO)
- 2 - 1988 Fish and their environment in large European river ecosystems; the Dutch part of the river Rhine. W.G. Cazemier, Science de l'Eau 7, 95-114 (1988). (RIVO-DLO)
- 3 - 1988 High rates of denitrification in a storage reservoir fed with water of the river Rhine. W. Admiraal and J.C. van der Vlugt, Arch. Hydrobiol. 113, 593-605 (1988). (RIVM)
- 4 - 1988 Impact of biological activity on detritus transported in the lower river Rhine: an exercise in ecosystem analysis. W. Admiraal en B. van Zanten, Freshwater Biology 20, 215-225 (1988). (RIVM)
- 5 - 1988 Continue signalering van toxische stoffen in het aquatische milieu met behulp van biologische bewakingssystemen - literatuurstudie. J. Botterweg, 31 pp., Den Haag (1988). (RIZA)
- 6 - 1988 Environmental stress in five aquatic ecosystems in the floodplain of the river Rhine. W. Admiraal, E.D. de Ruyter van Steveninck en H.A.M. de Kruijf, The Science of the Total Environment 78, 59-75 (1988). (RIVM)
- 7 - 1989 Bioaccumulation in yellow eel (*Anguilla anguilla*) and perch (*Perca fluviatilis*) from the Dutch branches of the Rhine- mercury, organochlorine compounds and polycyclic aromatic hydrocarbons. F. van der Valk, H. Pieters en R.C.C. Wegman. (RIVO-DLO)
- 8 - 1989 Beoordeling en evaluatie van biologische alarmeringssystemen op het meestation Lobith. Bio-alarm project fase I. J. Botterweg. (RIZA)
- 9 - 1989 Ecologisch herstel Rijn - beleid en onderzoek. Symposium- verslag 26 mei. E.C.L. Martelijn (red.) (RIZA)
- 10 - 1989 Summary of results and conclusions from the first phase (1988-1989) of the Netherlands research programme "Ecological Rehabilitation Rhine". J.A.W. de Wit, W. Admiraal, C. van der Guchte and W.G. Cazemier. (RIZA)
- 11 - 1989 Literature survey into the possibility of restocking the River Rhine and its tributaries with Atlantic salmon (*Salmo salar*). S.J. de Groot. (RIVO-DLO)
- 12 - 1989 Literature survey into the possibility of restocking the River Rhine and its tributaries with sea trout (*Salmo trutta trutta*). S.J. de Groot. (RIVO-DLO)
- 13 - 1989 Water- en oeverplanten in het zomerbed van de Nederlandse grote rivieren in 1988. Hun voorkomen en relatie met algemene fysische en chemische parameters. M.M.J. Maenen. (RIZA)
- 14 - 1989 Ecologisch herstel van de Rijnmakrofauna. B. van Dessel. (RIZA)
- 15 - 1989 Comparison of nitrification rates in three branches of the lower river Rhine. Biogeochemistry 8, 135-151. W. Admiraal and Y.J.H. Botermans. (RIVM)
- 16 - 1990 Vegetatie in de uiterwaarden: de invloed van hydrologie, beheer en substraat. M.C.C. de Graaf, H.M. van de Steeg, L.A.C.J. Voeselek en C.W.P.M. Blom. (RIZA)
- 17 - 1990 Chemicals affecting the spawning migration of anadromous fish by causing avoidance responses or orientational disability, with special reference to concentrations in the River Rhine. T.C. van Brummelen. (RIZA)
- 18 - 1990 Biomonitoring met de larven van Chironomiden en kokerjuffers. F. Heinis en T. Krommentuijn. (RIZA)
- 19 - 1990 Changes in plankton communities in regulated reaches of the lower River Rhine. E.D. de Ruyter van Steveninck, W. Admiraal and B. van Zanten. (RIVM)
- 20 - 1990 Fixation of dissolved silicate and sedimentation of biogenic silicate in the lower River Rhine during diatom blooms. W. Admiraal, P. Breegem, D.M.L.H.A. Jacobs and E.D. de Ruyter van Steveninck. (RIVM)
- 21 - 1990 On the potential of basing an ecological typology of aquatic sediments on the nematode fauna: an example from the River Rhine. T. Bongers and J. van de Haar. (RIVM)
- 22 - 1990 Monitoring the toxicity of organic compounds dissolved in Rhine water. D. de Zwart and A.J. Folkerts. (RIVM)
- 23 - 1990 The kinetics of the degradation of chloroform and benzene in anaerobic sediment from the River Rhine. P. van Beelen and F. van Keulen. (RIVM)
- 24 - 1990 Phases in the development of riverine plankton: examples from the rivers Rhine and Meuse. E.D. de Ruijter van Steveninck, B. van Zanten and W. Admiraal. (RIVM)
- 25 - 1990 Typologie en waardering van stagnerende wateren langs de grote rivieren in Nederland, op grond van waterplanten, plankton en macrofauna, in relatie tot fysisch-chemische parameters. F.W.B. van den Brink. (RIZA)
- 26 - 1990 Ecologische ontwikkelingsrichting grote rivieren. Anzet tot kwantitatieve uitwerking van ecologische doelstellingen voor de grote rivieren in Nederland. J.A.M. Vanhernelinck en A.L.M. van Broekhoven. (RIZA)
- 27 - 1991 Monitoring macroinvertebrates in the River Rhine. Results of a study made in 1988 in the Dutch part. A. bij de Vaate and M. Grijdanus-Klaas. (RIZA)
- 28 - 1991 Voedsel ecologie van vissen in de Nederlandse Rijntakken. P.J.M. Bergers. (RIZA)
- 29 - 1991 Natuurontwikkeling in uiterwaarden. Perspectieven voor het vergroten van rivierdynamiek en het ontwikkelen van oobossen in de uiterwaarden van de Rijn. H. Ducl. (RIZA)
- 30 - 1991 Phytoplankton in the river Rhine, 1989. Comparison between Lobith and Maassluis. R. Bijkerk. (RIVM)
- 31 - 1991 Inventarisatie van en verbeteringsplanning voor de fysiske belemmeringen voor de migratie van vis op de grote Nederlandse rivieren. A.W. de Haas (RIZA)
- 32 - 1991 Visitatie mogelijkheden in de Rijn in Nederland. J.A.M. Vanhernelinck (RIZA)
- 33 - 1991 Nevengeulen - onderzoek naar de mogelijkheden, de consequenties en de te stellen eisen bij de aanleg van nevengeulen in de uiterwaarden. A.W. de Haas (RIZA)
- 34 - 1991 The Asiatic clam, *Corbicula fluminea* (Müller, 1774), a new immigrant in the River Rhine. A. bij de Vaate (ed.) (RIZA)
- 35 - 1991 The effects of micropollutants on components of the Rhine ecosystem. Ed. J.A.W. de Wit et al. (RIZA)
- 36 - 1991 Aquatische makro-eventeraten in de Druische Waarden 1989- 1991. A. Klink, E. Martelijn, J. Mulder en B. bij de Vaate (RIZA)
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- (RIZA): Institute for Inland Water Management and Waste Water Treatment, P.O. Box 17, 8200 AA Lelystad, The Netherlands.
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- (IBN-DLO): Institute for Forestry and Nature Research, P.O. Box 9201, 6800 HB Arnhem, The Netherlands.
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