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REVISTA CIDOB d'AFERS INTERNACIONALS 45-46.

Water and Development.

Water in Europe. Research Achievements and Future Perspectives within the Framework of European Research Activities in the Field of Environment.

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Afers Internacionals, núm. 45-46, pp. 59-78

Water in Europe

Research Achievements and Future Perspectives within the Framework of European Research Activities in the Field of Environment

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Water represents a vital strategic resource for human society. Not only is it used to produce drinking water, food, energy, industrial products, it is used for transportation and amenity and plays an essential part in the sustainable development and protection of the environment.

Nowadays, in particular in view of the increasing population and the associated expansion of urbanisation and economic activities, it is more and more widely recognised that the scarcity, mismanagement and pollution of water pose a serious and growing problem. A problem for the quality of life and human health, a problem for the preservation of the environment and, ultimately, a problem for the economic development of various regions of the world.

European water resources, both in terms of availability and water demand, are extremely diverse and variable in space and time. Recent results for research projects supported by the European Union in the framework of the various European Commission's RTD activities, indicate significant impacts of climate change on both water availability and demands. In particular, the results show major regional impacts on precipitation variability and increase frequency of floods and droughts. Changes in land use due to the expansion of various economic activities (urbanisation, afforestation, farming, etc) exacerbate the problem of water shortages and affect the quality of both surface and groundwater resources. The

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situation is expected to worsen due to population growth and the associated increase of urban water infrastructure, which critically affect both water demand and consumption.

The management of water resources in the coastal zone of the Mediterranean basin is particularly problematic. Over the past 30 years the amount of irrigation from ground water has increased in the Southern European countries. This is due, on the one hand, to the strong disequilibrium between water supply and water demand and, on the other, the lack of an integrated approach of water resources management which takes into consideration the use of alternative water resources, the socio-economic development of those countries and an appropriate water prices policy. As a result, water resources are being heavily overexploited, thus leading to a drying of wetland habitats and terrestrial ecosystems, saline intrusion, and the degradation of ground water quality.

Water pollution also constitutes a major environmental problem across Europe, which calls into question the long-term reliability of many sources of drinking water. Pesticide pollution constitutes a threat to Europe's groundwater pollution. Disposal sites for industrial and municipal waste are potential sources of contamination. The pollution trends and impacts of other hazardous pollutants, such as heavy metals, organic micropollutants and pathogens, on water resources are largely unknown, and so are their impacts on health.

It is thuswise in the economic interest of all European countries to establish appropriate water policies and to support a multidisciplinary research effort to address these continuing and emerging water problems.

EUROPEAN COMMUNITY WATER POLICIES

Water is an essential element of the European Union's environmental policy. Community water policy has evolved over more than twenty years, reflecting the changes of focus and the environmental challenges facing Member States, the Community, as well as the international system. Early European water legislation began with standards for the rivers and lakes used for drinking water abstraction in 1975, and culminated in 1980 in setting binding quality targets for our drinking water. This legislation also included quality objectives for fish waters, shellfish waters, bathing waters and groundwaters. Over this period, progress has been made in understanding the key issues that need to be addressed and, as a result, a fundamental rethinking of Community water policy took place in mid-1995. Thus, a new Water Framework Directive was proposed to be the operational tool by which Community members would set the objectives for water protection well into the next century.

Under the proposed directive, the focus of the current Community water policy goes beyond quality aspects, since it is becoming increasingly clear that questions of water quantity management are inseparable from questions of quality. It also recognises that water policy must take into account the interaction between surface waters and groundwaters within the entirety of the respective river basins. More particularly, with regards to the surface waters, the directive aims to protect the aquatic ecology, the drinking water resources and bathing water, providing mechanisms for renewing all the quality standards established for chemical substances at the European level. With regards to groundwater, the directive aims to limit over-abstraction; to prohibit direct discharges to groundwater; and sets a requirement to monitor groundwater bodies so as to detect changes in chemical composition and to reverse any anthropogenically induced upward pollution trend. Another important innovation of the directive is the introduction of the "full cost recovery" pricing. For instance, by 2001 Member States will be required to ensure that the price charged to water consumers for the abstraction and distribution of fresh water and the collection and treatment of waste water is integrated in the true costs. Finally, the directive emphasizes strengthening the role of citizens and the involvement of any interested parties on water policies by establishing a network for the exchange of information and experience among water professionals throughout the Community.

Water is also considered in many other European policies, in particular the Common Agricultural Policy (CAP) and the Regional and Cohesion Policy. In the context of agricultural modernisation in Europe, the CAP is giving increased attention to the role of agriculture in preserving the environment. Agricultural activities have significant effects on water quality and quantity. Pollution from agricultural sources, such as nitrates, phosphorous, pesticides, and runoff of silage effluent and slurry affects both surface water and groundwater. Pesticide residues in the different water bodies may often affect biodiversity, too, especially in the case of aquatic ecosystems and terrestrial ecosystems linked to water. This is also a potential threat for water quality, which leads to increased costs for drinking water distribution. Agricultural activities also have significant effects on the quantity of water available, especially where irrigation is required. In fact, excessive abstraction can lower the water table and increase the land degradation and salinisation by intrusion of seawater, which destroy wetlands and other natural habitats. Moreover, agriculture and other land use practices may contribute to the occurrence of floods. Therefore, the CAP supports measures to develop agricultural production methods that are compatible with the requirements of the protection of environmental protection and natural resources, as well as those of the sustainabilty of the countryside and the landscape.

Spatial planning is becoming an increasingly essential factor to the construction of Europe and the strengthening of its economic and social cohesion. In the framework of the European spatial development policy, the need is recognized to assure a prudent management and development of natural resources, in particular the sound management of water resources.

This calls for the development of integrated strategies for the management of water resources and flood risk in transnational catchment areas of major rivers; an improved balance between water supply and demand in areas prone to drought; the concerted management of major aquifers, especially coastal and transnational ones; and, the preservation and rehabilitation of major wetlands endangered by over-exploitation or water diversion.

The implementation of these policies and the regulations in the field of water resources management need to be based on sound scientific and technological knowledge. It is therefore important to develop multidisciplinary research efforts towards an integrated water management system. Such efforts should also provide for interaction between research and other water policies of the Community to guarantee consistency and compatibility of objectives.

WATER RESEARCH IN THE FRAMEWORK OF EUROPEAN ENVIRONMENTAL RESEARCH PROGRAMMES

The European Union's research and technological policy is implemented through multiannual framework programmes, which define the objectives, the priority lines and the necessary financial means. Environmental research constitutes an important element of past and on-going EU framework programmes.

Past and ongoing EC R&D environmental activities cover a broad range of water related activities in order to provide the scientific basis on which appropriate policies for integrated water resources development and management can be constructed. These activities include studies on water resource assessment and impacts of climate change on water regimes; hydrological and hydrogeological risks; surface and groundwater hydrology; protection of water resources from diffuse pollution; water quality and aquatic ecosystems; and, environmental technologies. Also supported are socio-economic research projects on the development of improved policy and regulatory instruments, work to improve institutional arrangements and efforts leading to the development of tools and frameworks for integrated environmental assessments and integrated resource management.

These research projects have provided the opportunity to strengthen research on water within a broad European context. Major results with important policy implications have been obtained, while continuing and emerging water related problems have been identified. These are briefly highlighted below:

Hydrological regimes and water resources in Europe

Ongoing EU funded projects are examining the implications of climate change for hydrological regimes and water resources in Europe. They are identifying potential impacts on water resource availability, flow regimes, and drought on European and catchments scales, with a view to providing a scientific background for the development of EU policies.

Results from hydrological models using downscaled scenarios have been used to assess impacts on water resources in various river basins in Europe. Although annual rainfall amounts are found to change little, considerable intra-annual variability has been detected, generally showing increased winter rainfall, and longer summer dry-spells with decreased summer discharges.

Although there exist limitations of the predictive capabilities of numerical climate models, their recent results, taking into account newly developed climate change scenarios, suggest that the hydrological regime of the Rhine will shift from a combined rain-snow fed regime to a rain-fed regime. The results indicate that high discharges will increase in peak flows in the winter period and that low flows will become more pronounced and frequent during the summer and autumn seasons. The most dramatic changes in the discharge regime can be expected in the alpine region, which is considered to be the "Water Tower" of Central Europe. New results from Northern Mediterranean show that there is major underestimation of maximum water discharges in rivers and the real amount of expected precipitation, which is based on traditional forecasting techniques. These results could also affect the investigations on the flood regimes in relevant geographical regions.

The implementation of climate change scenarios belonging to different time horizons enables experts to better estimate the vulnerability of river-based dependent activities such as inland navigation, drinking water supply, irrigation and tourism.

Management of coastal aquifers in Europe

Aquifers in coastal Europe are under severe pressure due to human settlement, industry and tourism. Climate change and a likely sea level rise resulting from global warming also threaten them. In fact, groundwater circulation in Europe has been significantly affected during the past 100,000 years by the direct and indirect effects of Late Pleistocene glaciation. Therefore, to improve the management of groundwater resources in coastal areas, it is important to investigate the following: the origins of palaeowaters; their present distribution; their importance both as archives of former climatic and environmental conditions; and, their potential as sources of good quality drinking water, which is unaffected by the industrial era. Integrated geochemical and isotopic investigations and geochemical and hydrological modelling were carried out in 15 aquifers in 9 European countries. Research tried to understand to what extent groundwaters retained the signature of recharge during the late quaternary; to what extent the high quality palaewaters were being impacted by pollution; how much freshwater renewal of coastal aquifers occurred during the period of lower sea levels; and, whether we could use our understanding of past events to increase freshwater storage in coastal aquifers. One of the main results of this research showed that, although continuous recharge may be recognised in southern Europe, distinct recharge gaps are found in northern areas that correspond to the permafrost cover. Clear evidence was also found across Europe indicating cooler climatic conditions during the last glaciation. There is, therefore, a marked contrast between northern and southern Europe in the total mineralisation of palaeowaters, that reflects the different rainfall and recharge conditions. As these palaeowaters represent an important high quality resource, they require special protection and use. Correct management is often needed because of seasonal demands: priority should thus be given for potable use and not for agricultural or idustrial purposes which do not require waters of such high quality.

Parallel modelling work on the climatic variations impact on aquifers in Southern Europe catchments has shown that a doubling of CO2 will essentially result in large increases in potential evapotranspiration leading to a depletion of groundwater aquifers.

Hydrological risks

The risk associated with floods has increased in Europe over the recent decades. EC supported research projects studied floods both as consequence of human activity as well as a result of environmental change. Major advances were made in meteorological and hydrological forecasting modelling, including the understanding of associated uncertainties, in radar hydrology, and in flood risk assessment and mitigation.

In the field of radar hydrology, the limitations of microwave frequency have been investigated and a detailed understanding of data resolution issues in both space and time evaluated. The benefits of the availability of quantitative weather radar in real-time are clearly evident and significant progress has been made in modelling hydrological systems in real-time. Intercomparisons between various methods of real-time rainfall-runoff flood-forecasting in a variety of river catchments have been performed to identify the sensitivity of various simulations. Results show that lumped and semi-distributed approaches offer potential, but that fully distributed models are still too complex to be satisfactorily calibrated in a real-time environment. However, it is quite clear that quantitative weather radar data can be used to great effect in real-time flood forecasting situations. Various approaches to couple meteorological and hydrological modelling were performed. A new technique using real-time data from operational mesoscale models operated by national meteorological services has been developed. This approach promises much in terms of data interpretation and is likely to prove a key feature in developing a flood forecasting system.

In addition, specific concerted action was taken to examine river basin modelling in the context of flood mitigation, and to establish state-of-the-art techniques and identify further research needs. In this context, the need has been highlighted for a catchment view of flood defence activities that take into consideration the physical, ecological and socio-economic processes and their interactions. Better communication is needed between professional communities so that full benefits can be derived from individual scientific advances. More particularly, there is a need for multidisciplinary working approach not only between meteorologists and hydrologists to improve flood forecasting, but also between engineers, planners and ecologists for the design of better flood defences. Essential here, too, is the involvement of the public, as well as politicians and professionals, in working out the sustainable development and management of river basins to improve flood mitigation. Finally, there is a need to broaden economic evaluations to include "intangible" costs and benefits to assess the non-engineering aspects of flood defence activities within a common methodology for the assessment of flood damages.

A major impediment to further understanding flood occurrences and flood impacts and, hence, the basis for flood management, is the lack of data on rainfall — its flows and their effects. Efforts should be made to instigate greater measurement and monitoring and to systematically compile historical data on these events. These need to be public authority functions since academic institutions can rarely sustain such activity over the number of years for which such work requires.

Much more work is needed to study the physical impact of floods and the spatial variability and patterns of flood impacts. More research is needed on the actual nature and frequency of linkage between upstream and downstream areas, between slopes and channels, and into the dynamics and propagation of the runoff and sediment producing zones. Research on modelling flow generation and flood routing should be advanced, but much more research is also needed on modelling sediment dynamics and the sources, transport, deposition and storage of sediment within channel systems that cover a range of magnitude of events.

In continuation, the other areas that call for more investigation are these: research on the impacts of landuse change and of channel management on the characteristics and effects of flooding; detailed work on the physical, social and economic impacts of alternative strategies of channel management, which should examine both the short and long-term consequences and the implications for sustainability of channel management policies; research on the range and continuum of behaviour from perennial to ephemeral streams; and, work directed towards the implications of change from sub-humid to semi-arid climates. The particular problems posed by the juxtaposition of mountain areas to drier lowlands in the Mediterranean should also be considered.

Aquatic and wetland ecosystems

The well-functioning of aquatic and wetland ecosystems is increasingly endangered in Europe and world-wide by global or regional environmental changes due to discharges or depositions of excess nutrients and /or harmful substances, and due to reclamation of wetlands for agriculture, forestry, urbanisation, industrialisation, engineering of water flows, etc. This has resulted in increasing conflicts over the use of natural waters and is threatening the integrity of valuable ecosystems. Within the framework of the EC supported projects, major advances have been made in understanding the fundamental processes and biogeochemical cycles which sustain the structure and functioning of those ecosystems.

In these projects, emphasis was given to field and laboratory studies to develop an operational methodology for the analysis and prediction of wetland functioning, considering a broad spectrum of climatic, hydrological and ecological situations and various anthropogenic stresses. Modelling of spatial patterns and the dynamic process were carried out using the results of hydrological, ecological and bogeochemical process studies. Hydrological investigations clearly demonstrated the importance of understanding the effects of human activity on the hydrological regimes of wetlands, in particular the construction of ditches for agricultural improvements, river regulation, and excessive groundwater abstraction. The biogeochemical studies highlighted a number of factors, such as fluctuating water tables, productive vegetation types to take up nutrients, and land management practices that permanently remove biomass that could be used to predict the performance of nutrient and export functions. Studies have shown that variations in soil type and specific landscape features such as zones of groundwater seepage or ditches can be used to predict areas where nitrogen removal by denitrification may be optimal when nitrate is supplied via surface or sub-surface waters. Studies of ecological process have been used to establish predictors for ecosystem maintenance and food web support, both important ecological functions performed by wetlands. On the basis of field studies and modelling activities a system for evaluating wetland functioning was developed. By integrating valuation techniques into the functional analysis procedure a methodology was established that enabled researchers to describe a direct comparison in economic terms between wetlands used for conservation and the returns from alternative activities. Such a system provides an important management tool, since management decisions can then be founded upon a process-based assessment of functioning.

Waste water treatment and reuse

Within the EC funded projects priority is also being placed on the integrated abatement of industrial emissions. Developed were integrated approaches to water recycling and emission abatement (e.g. textile, pulp and paper industry), membrane separation technologies and electrochemical rectors for waste water treatment, and the coupling of biological and physicochemical treatments of industrial wastewater. The aim is to bring the technologies as close as possible to the process of abating industrial emissions, or even to integrate them into the process. In the field of wastewater monitoring, significant progress was made toward developing advanced measuring techniques with new improved analytical tools, state-of-the-art hyphenated techniques, and biosensors. Significant progress has also been achieved in the measurement of polycyclic aromatic hydrocarbons, nitroaromatics, phenolic compounds, detergents etc. and in the measurement of new parameters such as toxicity, genotoxicity, and endocrine-disrupting effects using biosensing techniques.

Water reuse becomes an important element in water planning, particularly in water deficient regions where it may have an important economic impact on the region's sustainable development. Although plans have been developed and applied in several EU countries, the environmental and water management implications of water reuse in integrated water management schemes have not been studied. Recent projects supported in the framework of EC RTD environmental programmes are evaluating the potential of water reuse as an alternative resource. Emphasis is given in field studies and modelling activities aiming to develop socio-technical-economic methodologies for water reclamation schemes that ensure public health and environmental protection. Public acceptance and socio-economic impacts involved with water reuse are also being investigated, with a view of providing the basis for common principals and criteria for integrated management practices regarding water reuse.

Over-exploitation of groundwater resources

The over-exploitation of groundwater resources due to the increasing water demand for agriculture, industry and public supply has emerged as a pan-European problem. For example, in the semi-arid Mediterranean regions of Europe, the absence of high rainfall and perennial rivers place have increased pressure on groundwater resources, resources which are commonly over-exploitated due to abstraction for irrigation. In Northern Europe, on the other hand, over-exploitation occurs principally because groundwater resources have historically provided a low-cost source of high quality water for public water supply. However, the historical growth in the exploitation of groundwater resources is, in many cases, unsustainable. And in a large number of catchments, this has already brought on severe economic, environmental and social consequences, which, in turn, have already given rise to severe economic, social and political pressures to resolve the conflicting demands for groundwater. Further environmental change and increased water demands will certainly exacerbate the problem.

European research projects have studied the interaction between the various natural and socio-economic process in representative catchments to provide methods and indices for identifying over-exploitation, and to develop appropriate modelling approaches and guidelines for developing and assessing alternative water resource management plans. Various conceptual and physically based groundwater models have been calibrated and applied in various catchments to illustrate the likely results of selected management scenarios. The assessment of the historical development of the catchment's water resources highlighted the negative consequences of intensive use of water for agricultural development, which has been a critical factor affecting water use in many Mediterranean catchments. The intensive use of the water in the Upper Giadiana Basin in Central Spain, especially during long periods of low rainfall has led to a dramatic and dangerous decline in groundwater level, which has resulted in the disappearance of important wetlands and a decline in water quality. A dramatic drop in the groundwater level and the drying up of springs which used to sustain havens for flowers, insects, birds and small animals in the surrounding hills and wetlands have been also observed in the western Messara valley in Crete, Greece.

In the Argolid, in the Southern Peloponnese, recent water mismanagement is responsible for the spectre of rapid and total degradation in the very near future. The inclusion of the region in the European market has caused major changes in land use. As a result of the increase in irrigated-citrus cultivation, recent years have seen a very rapid fall of the underground water table to some 130 m. below surface. The consequent reduction of underground freshwater pressure has allowed seawater to penetrate the aquifers, while evapotranspiration of the irrigation water has led to an increased salinisation of the soil. Here, research effort is also devoted to developing a dynamical model that combines hydrology, present-day farmers' perceptions, and decision-making with respect to water management. As a model which can help policy implementation, it uses data from both the natural and the social aspects of the socio-natural interaction. These include the relationship between the size of landholding, the proportion of other activities, demographic and social variables, and individuals' perceptions of the problems regarding cultivation. The model enables experts to carry out, on the one hand, simulations employing different policies (water taxes, cheap water free market, subsidies on either oranges or olives), and on the other, the assessment of their impact on agriculture economic output, salt deposition, and on the ways most suitable for policy implementation.

This work highlighted the need for integrated management of hydrological, ecological and socio-economic issues at the river basin scale. Although better planning can offset the very high levels of uncertainty along several different time scales, such planning must integrate relationships pertaining to ecology, landscape, land degradation and urban development. Indeed, integrated water management concepts need to be better defined and their cost effectiveness as a tool more clearly demonstrated, especially in relation to the existing planning systems. Before such approaches can be adopted though, there is a need for a much better understanding of social factors involved; for instance, the hierarchies of actors and power, the roles of incentives, and the farmers' response to authorities at different levels - regional, national and European.

Research is also being devoted to techniques aiming to increase the natural replenishment of groundwater, which could constitute alternative ways to mitigate the over-exploitation of ground water. Experimental investigations in laboratory and at various field sites across Europe are being carried out to provide a deeper insight into the physical and geochemical processes that occur during the artificial recharges of groundwater, including clogging, degradation of organic compounds, geochemical reactions and survival of pathogenic microorganisms. Numerical models of different complexity are being developed, which range from simple spreadsheet models over models for specific processes to integrated models comprising flow, transport, and inorganic and organic chemical reactions. The major geochemical processes have been simulated with acceptable accuracy, which suggests that a reactive model is a valuable tool for the design and operation of an artificial recharge facility. These results provide a basis for establishing guidelines for the design and operation of artificial recharge facilities to prevent pathogen problems.

Groundwater contamination by diffuse sources of pollution

Pollution by diffuse sources, especially from agricultural activities, is one of the greatest water resource concerns in terms of water quality and drinking water production. As a result, several existing European policy measures are devoted to minimising agricultural pollution. Past and ongoing EC funded projects have investigated the validity of the application of various predictive models, in particular the effects of changes of the scale of resolution of input parameters and the development of upscaling approaches, which include Geographical Information Systems (GIS) techniques that use the large number of digital spatial data which already exist within the European Union.

The use of Spatial Decision Support Systems (SDSS) to assess the risk of contamination from diffuse sources of pollution can be limited by uncertainty. Environmental models and Geographic Information Systems (GIS), the main building blocks of these systems, carry with them uncertainties which, as they accumulate, will be propagated and reflected in outputs. Quantification of the cumulative uncertainty, due to model and data errors, is essential to enable decision-makers to make justified and reliable decisions when using SDSS. Within the framework of a European research project, two models, MIKE SHE/DAISY and SMART2, have been used to predict the risk of contamination of groundwater through nitrates and aluminium linked to agricultural activities and/or atmospheric deposition. Readily available data from standard

European databases have been used as the basis for modelling. Models have since been adapted to a larger scale than usual due to both the need for providing large scale model outputs to assist policy making at the European scale, and the shift from experimental data to geo-referenced databases as model inputs. The statistical aggregation/upscaling procedure of MIKE SHE/DAISY appears to be generally valid. Remarkably good simulation results on water balance and nitrogen concentrations in groundwater were obtained. However, important limitations with regard to hydrograph shape have been highlighted due to the failure to account for scale in relation to stream aquifer interaction. Large uncertainties have been detected in flux concentrations where the root zone remains at grid level, whereas uncertainties in simulated concentrations at aquifer level on catchment scale were much smaller. With regard to the consequences of atmospheric deposition of acidifying substances on concentration of aluminium in groundwater, large prediction intervals were noted because of uncertainty in input data. However, despite this large uncertainty, the procedure was able to predict a notable decrease in aluminium concentratio when testing a reducing deposition scenario on a large scale over a long time period. Results also emerged showing that the width of the prediction interval is highly dependent on whether block median concentrations or block areal exceedances are considered.

Turning to the determination of the different sources of error, continuous soil parameters contribute more to uncertainty in aluminium concentration, whereas soil and vegetation maps are the main contributors to uncertainty in nitrate concentration caused by atmospheric deposition of acidifying substances.

From the groundwater management perspective, economic risk analyses have demonstrated that the uncertainties surrounding the outputs of hydrological models that run on a European scale may result in large prediction intervals in regards the economic value to society. Scenarios for contamination reduction tested in the framework of the project has resulted in prediction intervals that vary between 6 and 63 percent of the expected economical outcome of the scenarios. It should be stressed that the economic value assigned to the groundwater resource plays a major role in the uncertainty of the prediction intervals.

As regards the strategic implications of the project's technical and economic findings, emphasis has been placed on data quality and the availability of European geo-referenced databases; on the development of relevant geo-referenced databases related to soil characteristics; on the use of subjective probability as a source of data when expert knowledge is requested; and, finally, on the need to take cumulative uncertainty into account when performing risk analysis.

CURRENT RESEARCH LIMITATIONS IN THE FIELD OF WATER

While it is evident that Community research programmes have addressed a wide range of different water related research priorities and provided significant insights to many water problems, the following section highlights and discusses some of the limitations of current research efforts.

Although various efforts have been made in the EU Member States, and significant progress been achieved in developing elements for the integrated management of water resources, very limited progress has been made to reach the level of required integration. So far, the approaches taken are highly individualistic or fragmented. Major lines of fracture remain not only between large groups of disciplines, notably between natural, life and social sciences, but also between the research focused on explanation and understanding and the research aimed at their better application. Any major way forward will have to mediate between the many conflicting sectorial interests operating in virtually all of the European territory. To answer the many questions involved, in turn, requires the collaboration of a large number of disciplines on a basis of equality; consequently, important efforts are needed to develop a truly integrated, transdisciplinary framework for co-operation and collaboration.

Surface waters and groundwaters have traditionally been considered as isolated bodies. As such, most water management approaches have been directed either to the surface or ground water. However, from the perspective of climate change and expected future growth of water demands, the two water resources cannot be viewed as isolated bodies. What is needed is the development of scientific, methodological and managerial tools and approaches to support a better understanding of surface and groundwater interactions in an integrated way, i.e., in terms of quality and quantity; in terms of influences by other natural resources, in particular soil and land resources; in terms of economic development; and, in terms of short, medium and long-term planning.

Although the mechanisms of riverine processes have largely been identified, their quantification for given large-scale river systems of European importance still requires much effort. Coupled hydrochemical and ecological models at the scale of whole catchments need to be improved or developed and appropriately validated to accomplish the following: to quantify the non-point loads of nutrients and persistent organic and toxic pollutants from the terrestrial compartments of the catchment to the surface waters; to assess their impacts on the biota of aquatic ecosystems; and, to develop criteria, methodologies and approaches for the integrated management and restoration of impacted aquatic ecosystems.

Regarding riparian wetland ecosystems, many unresolved questions remain for analysis. For example, the effect of longitudinal connectivity and fragmentation on the retention capacity for water, excess of nutrients and pollutants, the dynamics of organisms and the effect of woody debris on food webs; the influence of sediment fluxes on the organisation of plant communities; the spatio-temporal scales; the effects of natural and anthropogenic disturbances on the regeneration and succession of riparian woodlands and the time lags and legacies from past events. A further question is to what extent can predictive models accurately simulate river sections where water storage predominates over water flow in riparian wetlands. Also of interest would be to better understand the factors that "trigger" resistance and resilience of various types of riparian wetlands in view of their sustainable use and their relationships to quantity and quality of the water resource. Finally, the integrated management of riparian wetlands is an issue whose treatment has to combine the ecology with their socio-economic utilisation.

Supply and demand for water have changed dramatically in recent years. Changes in water demands and needs, brought on by various economic activities and the failure of regulatory mechanisms to reduce the water demand, are threatening the availability, distribution, and quality of freshwater resources and, consequently, the quality of human life and the ecosystem. The changes due to demography, particularly in Southern Europe, are likely to prove more critical in determining the sensitivity of water management systems in the coming decades. Better demographic models are therefore required to meet this problem. High costs and limited opportunities for increasing water supplies with dams, reservoirs, and other infrastructure have curbed the traditional supply-side approach to water resource planning in recent years. However, current planning tools are not able to predict in an integrated way how these changes will affect the supply and demand for water at the river basin and sub-catchment scales. It is therefore essential to improve short, medium and long-term prediction of the evolution of water resources, and to assess trends and needs in freshwater demand and use. This, in turn, should help to establish regional forecasts regarding water availability, with the possibilty of predicting abnormal drought periods and the possible miscalculations of anticipated levels of water abstraction. In addition, such planning would also help to develop an understanding of the major cause/effect relationships in regard of water resource deterioration.

Barriers to the sustainable management and use of water are often non-technical, and arise from the social, economic and institutional context. For instance, institutional arrangements are poorly adapted to sustainable use/management goals; water operators, the general public and policy makers are poorly informed of one another priorities; depletion, degradation or pollution of water resources are very minimumly incorporated in accounting schemes and policy options. Socio-economic research must provide a better understanding of the complex system of interactions between the different parties (consumers, water operators, decision-makers, political leaders) and help in the framing of appropriate policy options and societal perceptions, as well as in the contribution to the design of policy instruments. Special consideration should be given to policy formulation and policy implementation, taking into account the interplay between the various local and regional conditions and the policies set at national, European and international levels.

A whole range of chemical and biological pollutants arises from anthropogenic activities and impairs the quality of inland surface waters and groundwaters. The shear number of chemical compounds released directly into the aquatic environment or found in the aquatic environment during their passage from the source to their final sink obstructs their complete analysis. In consideration of this, only key hazardous pollutants shall be selected by analyists to perform risk assessments of the aquatic environment, i.e. to identify, characterise and quantify their sources, pathways, and impacts to underpin the development of a scientifically sound legal, economic, technological and management response to water pollution of EU-wide significance. In addition, strategies and techniques for the monitoring of pollutants in surface and groundwater bodies need to be developed and/or harmonised.

At present, major limitations for current research activities exist in regards the following: the behaviour of agrochemicals during their passage to groundwater and inland surface waters; the different impacts of diffuse pollution by nitrogen and phosphorus and agricultural pesticides at a regional scale; the poor accessibility of available research results and their incorporation into policies; and, the insufficient availability of science-based guidelines for sound agricultural practices (especially regarding irrigation techniques), bearing in mind that improved agricultural practices require a societal, sectorial and legal response at EU level. Apropos of the final point, environmental policies have been slower to confront non-point source pollution from agricultural land-use than industrial-point source problems, due to the complexity of the problem, and the lack of appropriate decision support tools. Yet, combating diffuse (non-point source) pollution from agricultural sources represents an eminent environmental problem which urgently needs to be addressed. Improving, validating and consolidating methodologies and techniques to minimise the impacts of nutrients, pesticides on surface and ground waters and to develop scientifically sound guidelines for agricultural practices are needed in order to improve the policy process and help to alleviate the overall pollution problem.

Integrated water management is not possible without reliable data upon which to base decisions. Most EC water legislation includes obligations to monitor the quantity and quality of both wastewater streams and the receiving ground and surface waters bodies. Until now, quality monitoring activities have essentially been directed towards recording the state and evolution of pollution by single substances, and have rarely taken predictive and management purposes into account. But, despite the existence of regional, national and international agencies in charge of monitoring the quality of the aquatic environment and data collection, this information has been, in the past, of rather poor quality (due to unharmonised approaches) and virtually inaccessible. As such, this has made it difficult to validate the management models. Therefore, it is necessary to improve the scientific basis of monitoring systems to advance the technological monitoring and surveillance devices and approaches for specific purposes (presented below), and to develop monitoring systems which are able to react on different time and space scales, including early warning systems with direct feedback to pollution sources.

Nowadays, regional water stress is a major issue in many parts of Europe, and it will become an even more acute issue in the future if current and future water demands are not balanced. Water demand has increased tremendously over the past few decades and there is an upward pressure for public supplies and increased irrigation. In Southern European countries, consumption of water supplies often exceeds the annual replenishment of water resources by rainfall and water transfer. Water shortages are also associated with increased pollution problems, groundwater over-exploitation, impacts on river flows and wetland ecology, and the increasing costs (of questionable efficiency) for large hydraulic works, interbasin transfers and water treatment facilities. As a consequence, water conflicts have increased between different groups (farmers, environmentalists, energy utilities and others, which have created serious social problems.

Current research activities centre upon the development of several water conservation technologies in agriculture and industry, on aspects of alternative supply techniques (artificial recharge, desalinisation, etc.), and on the understanding of the role of various economic instruments to control demand. However, their effectiveness and operational possibilities are constrained because of at least three factors: the lack of an overall approach in the application of technologies, which do not consider environmental and socio-economic aspects; the use of technologies and techniques, which are poorly adapted to specific applications; and, most importantly, the lack of both user involvement in the research activities and awareness by key end-users of the potential for water conservation.

FUTURE RESEARCH PERSPECTIVES WITHIN THE 5TH FRAMEWORK PROGRAMME

The 5th Framework Programme of the European Community for research, technological development and demonstration activities (1998-2002) provides an opportunity to follow a new approach to policy with regards research conducted at Community level. This approach is designed to address contemporary issues and meet the aspirations of Europe's citizens.

It is organised in four thematic and three horizontal programmes. The thematic programmes are organised in such a way as to reconcile the desire to focus efforts on a limited number of objectives with the need to maintain and strengthen the European Union's science and technology base. Research priorities, as defined, are based on three basic principles: scientific and technological excellence; relevance to the main EU policies and European added-value; and, that not only scientific and technological factors are to be considered, but also the EU's economic and social needs and its overall competitiveness. To this end. each of the thematic programmes includes limited number of key actions plans, generic activities and support for research infrastructures.

Within the 5th Framework Programme, research on water issues will mainly be implemented under the specific programme "Energy, environment and sustainable development". The strategic goal of this programme is to contribute to sustainable development by focusing on key activities crucial for social well-being and economic competitiveness in Europe. To address complex societal-driven issues, this programme proposes an innovative approach based upon two main elements: integrated multidisciplinary and multisectoral activities involving, wherever possible, the principal stakeholders - private-public sector partnerships, and end-users from the business, industrial and policy-making sectors; and, concentrated efforts to find solutions to strategic problems, supporting only those proposals which are of substantive regional, European and global significance.

The sustainable management and quality of water has been identified as one of the six key action plans of the specific programme mentioned above. The main challenge to this action comes from trying to protect and provide high quality of water in sufficient quantity at affordable costs, while maintaining the various functional roles of ecosystems and bettering match water demands with the availability of the resource. The following action lines constitute the essential elements for an integrated sustainable management approach for water resources.

Integrated management and sustainable use of water resources at catchment scale

The objectives are to develop the knowledge and the technologies needed for the rational management of water resources; to match water supply with demand and achieve cost-efficiency and sustainability; to improve the science base, methodologies and management tools to provide a better understanding of the functioning of aquatic and wetland ecosystems with the aim of creating an integrated management and sustainable use of water and wetlands at catchment or river-basin scale, within the constraints of availability, environmental quality, and the socio-economic costs and benefits. This management should take into consideration the various functions of water systems, the relationships between water use, water availability, and spatial planning — in particular, land use changes, rural/urban interactions, and socio-economic development.

Treatment and purification technologies

The objectives are to develop technologies to prevent and treat pollution of water; to purify water and to use and/or re-use water rationally, including closed-loop approaches; to ensure the reliability of collection and distribution networks; to enhance efficient water supply and treatment of waste water; and, to minimise environmental impacts from waste water treatment and prevent potential effects on health.

Pollution prevention

The objectives are to develop comprehensive approaches to prevent pollution of water bodies; to assess and minimise pollution originating from contaminated sites, waste disposal sites and sediments; and, to prevent or reduce diffuse pollution originating from land use practices.

Surveillance, early warning and communication systems

The objective is to develop and validate various systems able to react on different time and space scales, including early-warning systems, with direct feedback to pollution sources; also, for the control of treatment plants, or such control in support of flood and drought management.

Regulation of stocks and technologies for arid and semi-arid regions and water-deficient regions in general

The objective is to improve and protect water resources and aquatic ecosystems; to optimise water management systems in arid regions; and, to better manage water crises.

CONCLUSION

The European Commission has an important role to play as catalyst in the provision and dissemination of information regarding the current state of water research. Water is of Europe-wide interest and it will affect various EU policies (e.g. Environment, Agriculture and Regional Policy, etc.)

The forthcoming Fifth Framework Programme of RTD represents a turning point in the history of European Union research. Explicitly conceived at the service of the European citizens, and in support of the Union's policy objectives, it is characterised by an orientation of the research activities towards the large social and economic issues that Europe is facing: not only the improvement of European industrial competitiveness and the employment situation, but also improvement of the quality of life of European citizens in its different dimensions, notably health, environment and security.

Research on water shall be supported under the key action plan "Sustainable management and quality of water", which constitutes an important component of the specific programme "Energy, environment and sustainable development". Key actions reflect the new philosophy in FP5, the body which has to identify the challenges or problems to be addressed through a multidisciplinary approach. Effective implementation and success in obtaining the anticipated benefits of the key action plan on water will call for the appropriate support for development, demonstration and dissemination activities and a closer involvement of the scientific community, industry, users and national organisations. Finally, it should be noted that beyond this research, other EU policies (i.e. the Environmental policy) offer different contexts wherein some concrete actions on water may be dealt with: the EU framework provides other opportunities to enhance co-operation and synergies between the various actors and policies involved in water resource management.

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