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Groundwater monitoring in the context of EU legislation: reality and integration needs†

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A wide range of environmental policies are based on the monitoring of chemical and/or biological parameters which are used to evaluate the environmental status of relevant compartments (*e.g.* water, soil, air) with the ultimate aim of making appropriate management decisions. The soundness of policy decisions is therefore directly related to the reliability of the environmental monitoring programmes. Monitoring reliability in turn is predominantly linked to scientific and technological progress. Hence a correct design, development and implementation process of environmental policies is, at least in part, dependent upon a proper integration of scientific and technological advances (in monitoring, but also for all kinds of permit procedures, remediation strategies *etc.*). This paper examines science-policy integration needs in support of groundwater environmental monitoring, with focus on on-going policy developments. The article aims to summarise key information on groundwater policy and EU scientific developments to raise awareness of the scientific community involved in this issue and to enhance communication among scientists and policy-makers.

Introduction

The development of environmental policies is a complex process, which mixes legal requirements with issues of technical feasibility, scientific knowledge and socio-economic aspects and which requires intensive multi-stakeholder consultations. In this context, the consideration of scientific progress represents one of the key aspects for the design of new policies and the review of existing ones. Within the European Union, this consideration is fully embedded into the Sixth Environmental Action programme which stipulates, namely, that "sound scientific knowledge and economic assessments, reliable and up-to-date environmental data and information, and the use of indicators will underpin the drawing-up, implementation and evaluation of environmental policy".[1] This requires, therefore, that scientific inputs constantly feed the environmental policy process. This integration also involves various players, namely the scientific and policy-making communities but also representatives from industry, agriculture, NGOs *etc.* (Fig. 1).

An example of consultation that has been established to discuss groundwater policy issues is shown in Fig. 2: in this diagram, various topics are under discussion by experts from EU Member States, industry, agriculture, scientists *etc.* with the aim to gather and share knowledge and concern as seen from different perspectives. This approach may be time-consuming but it is the only guarantee that a given policy will be well accepted at various levels. This approach has been developed within the so-called Common Implementation Strategy (CIS) of the Water Framework Directive[2] and has been considered as a very powerful tool for sharing good practices.

Integration in a broad sense, as perceived for the environmental policy sector, goes of course further than science-policy issues. It concerns the need to consider environment as it appears in all relevant policies, interactions of various environmental compartments, socio-economic aspects *etc.* in an overall structure of river basin management (Fig. 3). This paper will focus on integration of scientific and technological progress, taking groundwater policy as an example to illustrate the necessity and complexity of the knowledge-based approach.

2. Needs for protecting groundwater against pollution and related monitoring

Groundwater constitutes the largest reservoir of freshwater in the world, accounting for over 97% of all freshwaters available on earth (excluding glaciers and ice caps). The remaining 3% is composed mainly of surface water (lakes, rivers, wetlands) and soil moisture. Until recently, focus on groundwater mainly concerned its use as drinking water (*e.g.* about 75% of EU inhabitants depend on groundwater for their water supply). Groundwater is also an important resource for industry (*e.g.* cooling waters) and agriculture (irrigation). It has, however, become increasingly obvious that groundwater should not only be viewed as a drinking water reservoir, but also as a critical aquatic ecosystem.[3] In this respect, groundwater represents an important link of the hydrological cycle through the maintenance of wetlands and river flows, acting as a buffer through dry periods. In other words, it provides the base flow (*i.e.* the water which feeds rivers all year round) for surface water systems, many of which are used for water supply and recreation. In many rivers indeed, more than 50% of the annual flow is derived from groundwater. In low-flow periods in summer, more than 90% of the flow in some rivers may come from groundwater. Hence, deterioration of groundwater quality may directly affect other related aquatic and terrestrial ecosystems.

Since groundwater moves slowly through the subsurface, the impact of anthropogenic activities may last for a relatively long time, which means that pollution that occurred some decades ago—whether from agriculture, industry or other human activities—may still be threatening groundwater quality today and, in some cases, will continue to do so for several generations to come. The legacy of the past is clearly visible at large-scale contaminated sites, *e.g.* industrial sites or harbour areas, where it is simply not possible, with state-of-the-art technology and a proportionate use of public and/or private money, to clean up the regional contamination encountered at these locations.[4] In addition, the experience of remediation of the past 20 years has shown that the measures taken have in

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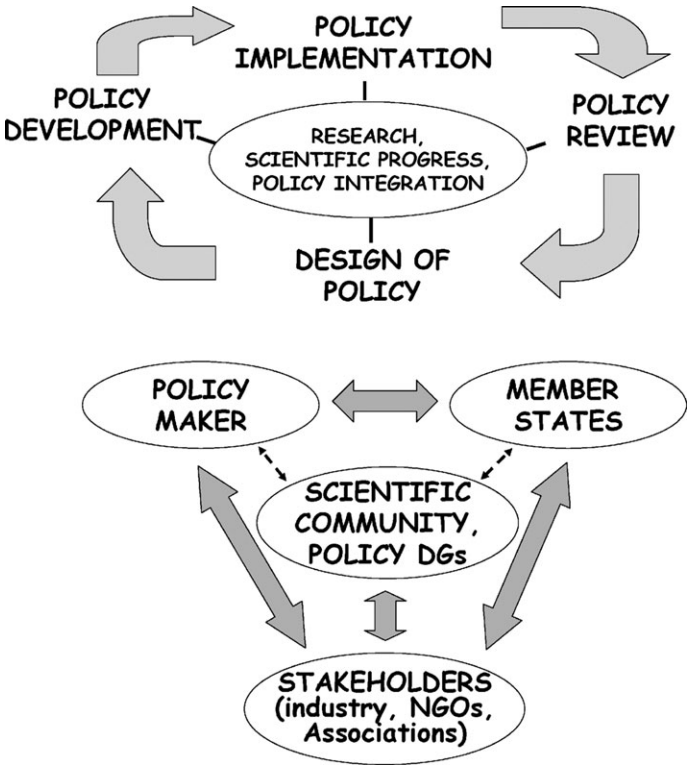

Fig. 1 Integration of scientific progress into the policy-making process.

most cases not been able to completely remove all contaminants and that pollutant sources, even if partially removed, continue to emit for long periods of time (*i.e.* several generations).[5,6] Therefore, an important focus should be on preventing pollution in the first place.

Secondly, since surface water systems receive a continuous discharge of inflowing groundwater, a deteriorated groundwater quality will ultimately be reflected in the quality of surface waters. In other words, the effect of human activity on groundwater quality will eventually also impact on the quality of associated aquatic ecosystems and directly dependent terrestrial ecosystems if so-called natural attenuation reactions such as biodegradation in the subsurface are not sufficient to contain the contaminants.

Finally, groundwater is a "hidden resource" which is quantitatively much more significant than surface water and for which pollution prevention and quality monitoring and restoration are even more difficult than for surface waters mostly due to its inaccessibility. This "hidden" character makes it difficult to adequately locate and quantitatively appreciate pollution impacts, resulting in a lack of awareness and/or evidence regarding the extent of risks and pressures. Recent reports, however, show that pollution from domestic, agricultural and industrial sources is, despite the progress in some fields, still a major concern, either directly through discharges (effluents) or indirectly from the spreading of nitrogen fertilisers and pesticides or through leaching from old landfills or industrial sites (*e.g.* chlorinated hydrocarbons, heavy metals).[7–9] For example, around one third of groundwater bodies in Europe currently exceed the nitrate guideline values.[8] While point sources have caused most of the pollution identified to date, there is evidence that diffuse sources are having an increasing impact on groundwater.

In the above context, a groundwater policy framework has been deemed necessary and developed at the end of the 1970's (Directive 80/68/EEC).[10] This protection regime is now evolving with the requirements of the newly implemented Water Framework Directive (Directive 2000/60/EC),[2] which integrates *inter alia* monitoring as a key decision-making tool for evaluating the quantitative and chemical status of European ground waters. The process of characterisation of groundwater bodies, design of monitoring programme, and later on of a programme of measures, are intimately linked to available scientific knowledge and methodologies. In this respect, a modern legislative framework has to consider the most recent findings arising from research and technological development projects.

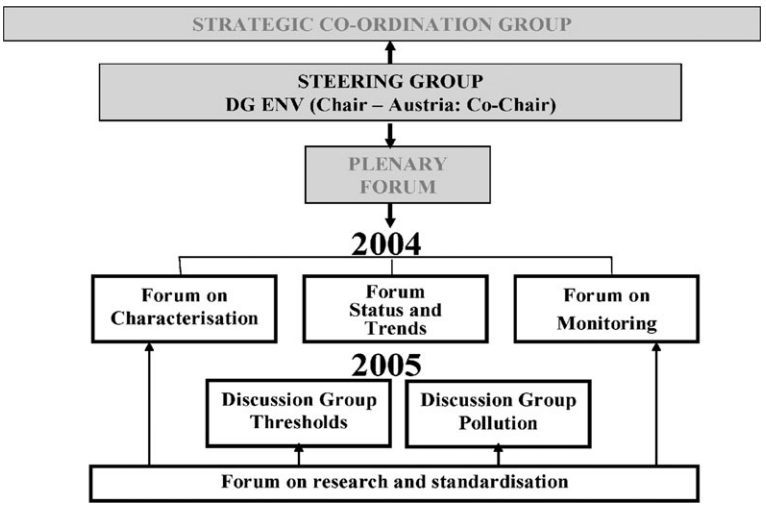

Fig. 2 Example of consultation group: Working Group on Groundwater from the Common Implementation Strategy (CIS) of the Water Framework Directive (WFD).

3. Existing groundwater policy framework

In the context of Directive 80/68/EEC on the protection of groundwater against pollution caused by certain dangerous substances,[10] groundwater is defined as "*all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil*". This directive provides a groundwater protection framework by preventing the (direct or indirect) introduction of high priority pollutants (List I) into groundwater and limiting the introduction into groundwater of other pollutants (List II) so as to avoid pollution of this water by these substances (Table 1). Indirect discharges have to be understood as "*the introduction into groundwater of substances in lists I or II after percolation through the ground or subsoil (Direct discharges correspond to an introduction without percolation)*" whereas pollution is defined as "*The discharge by man, directly or indirectly, of substances or energy into groundwater, the results of which are such as to endanger human*

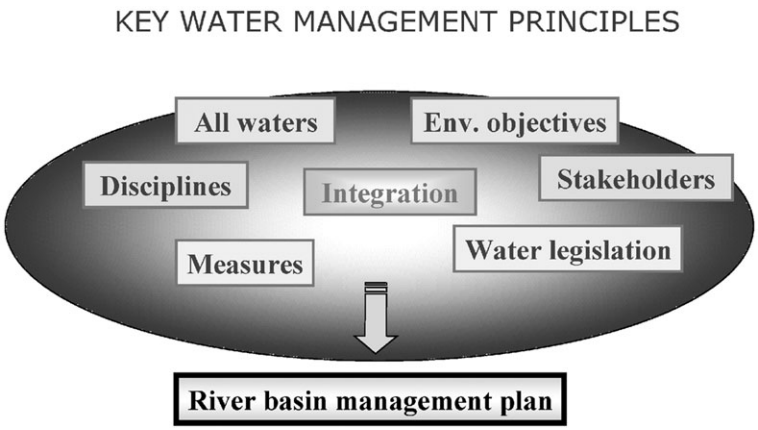

Fig. 3 Integration at the river basin scale.

health or water supplies, harm living resources and the aquatic ecosystems or interfere with other legitimate use of water".

In this framework, consequences of pollution which has already occurred have to be checked or eliminated as far as possible (Article 1). This implies the following:

• With regard to List I substances, direct discharges are prohibited, whereas indirect discharges (due to disposal or tipping for the purpose of disposal) of these substances are prevented, which is linked to an authorisation procedure preceded by a thorough investigation on a case-by-case basis. In this respect, all appropriate measures have to be taken to prevent any indirect discharges due to either disposal or other activities on or in the ground other than disposal.

• With regard to List II substances, direct discharges have to be limited and appropriate measures have to be taken to limit any indirect discharges of these substances due to either disposal or other activities on or in the ground other than disposal. An authorisation procedure preceded by a thorough investigation is required in the case of direct discharge or disposal or tipping for the purpose of disposal of these substances. The authorisation is only granted if all the technical precautions for preventing groundwater pollution by these substances are observed.

It should be noted that this directive does not apply to discharges of domestic effluents from isolated dwellings not connected to a sewerage system and situated outside areas protected for the abstraction of water for human consumption. In addition, it does not apply to discharges of List I and II substances which are found in a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater, nor does it apply to discharges of matter containing radioactive substances.

Another derogation clause concerns the authorisation of discharge of List I substances in groundwater which has been revealed as being permanently unsuitable for other uses (especially domestic or agricultural), providing that their presence does not impede exploitation of ground resources. These authorisations can only be granted if all technical precautions have been taken to ensure that these substances cannot reach other aquatic systems or harm other ecosystems. In addition, authorisation (after prior investigation) may be granted for discharges due to re-injection into the same aquifer of water used for geothermal purposes, water pumped out of mines and quarries or water pumped out for civil engineering works. Finally, artificial recharges for the purpose of groundwater management are subject to a special authorisation on a case-by-case basis, which may only be granted if there is no risk of groundwater pollution. The directive provides specific requirements regarding the authorisation procedures, distinguishing direct discharge and indirect discharge.

In the above context, monitoring is required only for those specific cases of authorisation for the purpose of compliance checking and for assessing the effects of discharges on groundwater. Application of measures relevant to this directive may on no account lead, either directly or indirectly, to pollution of groundwater. Finally, where appropriate, one or more Member States may individually or jointly take more stringent measures than those provided for under this Directive.

From the above description, it can be concluded at first sight that the Directive 80/68/EEC ensures a stringent groundwater protection regime against pollution for all the activities that present a risk of groundwater deterioration through direct or indirect discharges of a wide range of pollutants. The implementation of this Directive is, however, sometimes faced with the difficulties of a lack of groundwater quality data and objectives. In other words, infringement cases may be difficult to judge in some instances in the absence of clear information on background groundwater quality levels in the zone affected by discharges, and of quality objectives on the basis of which deterioration may unambiguously be identified.

This Directive will be repealed in 2013 under the Water Framework Directive (2000/60/EC),[2] after which the protection regime should be continued through the WFD and the future Groundwater Daughter Directive.[11] Let us now examine how the continuity/complementarity will be efficiently ensured.

Table 1 Lists of substances regulated under Directive 80/68/EEC

List I	This list contains eight groups of substances, exception made of substances which are considered inappropriate on the basis of low risk of toxicity, persistence and bioaccumulation: (1) organohalogen compounds and substances which may form such compounds in aquatic environment; (2) organophosphorus compounds; (3) organotin compounds; (4) substances which posses carcinogenic, mutagenic or teratogenic properties in or *via* the aquatic environment (if this is the case for certain substances of List II, they are included under this category); (5) mercury and its compounds; (6) cadmium and its compounds; (7) mineral oils and hydrocarbons and (8) cyanides.
List II	This list contains individual or groups of substances which could have a harmful effect on groundwater, in particular: (1) metalloids and metals and their compounds such as zinc, copper, nickel, chrome, lead, selenium, arsenic, antimony, molybdenum, titanium, tin, barium, beryllium, boron, uranium, vanadium, cobalt, thallium, tellurium, silver; (2) biocides and their derivatives not appearing in List I; (3) substances which have a deleterious effect on the taste and/or odour of groundwater, and compounds liable to cause formation of such substances so as to render water unfit for human consumption; (4) toxic or persistent organic compounds of silicon, and substances which may cause the formation of such compounds in water, excluding those which are biologically harmless or are rapidly converted in water into harmless substances; (5) inorganic compounds of phosphorus and elemental phosphorus; (6) fluorides; and (7) ammonia and nitrites.

Table 2 Definitions of good quantitative and chemical status

Ref. WFD	Good status
Good quantitative status (Annex V.2.1.2)	The level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction. Accordingly, the level of groundwater is not subject to anthropogenic alteration such as would result in: (a) failure to achieve the WFD environmental objectives for associated surface waters, (b) any significant diminution in the status of such waters, and (c) any significant damage to terrestrial ecosystems which depend directly on the groundwater body. Alterations to flow direction resulting from level changes may occur temporarily, or continuously in a spatially limited area, but such reversals do not cause saltwater or other intrusion, and do not indicate a sustained and clearly identified anthropogenically induced trend in flow direction likely to result in such intrusions.
Good chemical status (Annex V.2.3.2)	The chemical composition of the groundwater body is such that the concentration of pollutants do not exhibit the effects of saline or other intrusions (as determined by changes in conductivity) into the groundwater body, do not exceed the quality standards applicable under other relevant Community legislation in accordance with Article 17 of the WFD, and are not such as would result in failure to achieve the WFD environmental objectives for associated surface waters not any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to terrestrial ecosystems which depend directly on the groundwater body.

4. The groundwater policy framework under the WFD

The WFD complements the above directive by stipulating that Member States shall implement the measures necessary to prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the status of all bodies of groundwater. Member States have to protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge, with the aim to achieve good groundwater (chemical and quantitative) status by 2015, following the definitions given in Table 2. These requirements include a range of derogation clauses which are summarised in Table 3.

The Directive also requires the implementation of measures necessary to reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce groundwater pollution. Under this Directive, the framework for groundwater protection imposes on Member States to:

• *Delineate groundwater bodies* within River Basin Districts to be designed and reported to the European Commission by Member States, and characterise them through an analysis of pressures and impacts of human activity on the status of groundwater in order to identify groundwater bodies presenting a risk of not achieving WFD environmental objectives. This *characterisation work* is on-going and should be completed by the *end of 2004*. It should be reported following requirements summarised in Tables 4 and 5a in this paper.

• *Establish registers of protected areas* within each river basin district for those groundwater areas or habitats and species directly depending on water by the *end of 2004*. The registers have to include all bodies of water used for the abstraction of water intended for human consumption[12] and all protected areas covered by the Bathing Water Directive

Table 3 Derogation clauses under the WFD as applied to groundwater

Article (WFD)	Derogation
4.4	Extensions may be granted when improvements of status cannot be reasonably achieved within the timescales for reasons of technical feasibility, disproportionate costs or natural conditions. The extension request has to be explained in the river basin management plan under Article 13, as well as a summary of measures required under Article 11 and the reason for the delay in making these measures operational. Extensions are limited to a maximum of two further updates of the RBPM (2027) except where the natural conditions are such that the objectives cannot be achieved within this period.
4.5	Less stringent environmental objectives may be set out for specific bodies of water when they are so affected by human activity (as determined by the analysis of pressure and impact under Article 5), or their natural condition is such that the achievement of these objectives would be infeasible or disproportionately expensive and that (a) the environmental and socioeconomic needs served by such human activity cannot be achieved by other means; (b) Member States ensure the least possible changes to good groundwater status considering that impacts could not have reasonably been avoided due to the nature of the human activity of pollution; (c) no further deterioration of the affected body of water occurs; (d) the establishment of less stringent objectives and the reasons for it are specified in the RBMP and this is reviewed every six years.
4.6	Derogation also concerns temporary deterioration due to natural cause or *force majeure* which are exceptional or not foreseeable (*e.g.* extreme floods or droughts, accidents), providing that (a) all practicable steps to prevent further deterioration are taken, (b) the circumstances are declared in the RBMP, (c) measures are included in the programme of measures, (d) an annual review is undertaken and all practical restoration measures are taken in order to recover the initial status, and (e) a summary of effects of the circumstances and measures are included in the next update of the RBMP.
4.7	Member States will not be in breach of the Directive when failure to achieve good groundwater status or to prevent deterioration in the status of a body of groundwater is the result of alterations to the level of bodies of groundwater, providing that (a) all practical steps are taken to mitigate the adverse impact on the status of the body of water, (b) the reasons for those alterations are set out and explained in the RBPM, (c) the reasons for those alterations are of overriding public interest and/or the benefits of the alterations outweight those of achieving the WFD environmental objectives, and (d) the beneficial objectives served by these alterations cannot be achieved by other reasons for reasons of technical feasibility or disproportionate costs.
4.8	The application of the above derogation clauses should not exclude or compromise the achievement of the Directive objectives in other bodies of water within the same river basin district, and is consistent with the implementation of other Community environmental legislation.

Table 4 Groundwater characterisation requirements under the WFD

Annex II.2 (WFD)	Characterisation
Initial characterisation (par. 2.1)	The initial characterisation concerns all groundwater bodies, assessing their uses and the degree at which they are at risk to meet WFD environmental objectives. This analysis may use existing hydrological, geological, pedological, land use, discharge, abstraction and other data, identifying: the location and boundaries of the groundwater body or groups of bodies, the pressures to which the groundwater is subject to (diffuse and point sources of pollution, abstraction, artificial recharge), the general character of the overlying strata in the catchment area from which the groundwater body receives its recharge, and those groundwater bodies for which there are directly dependent surface water ecosystems or terrestrial ecosystems.
Further characterisation (par. 2.2)	It concerns the groundwater (or groups of) bodies which have been identified as being at risk, and aims to establish a more precise assessment of the significance of such risks and the identification of any measures top be required under the WFD Article 11. This characterisation has to include relevant information on the impact of human activity and, where relevant, on geological characteristics of the groundwater body (including the extent and type of geological units), hydrogeological characteristics (including hydraulic conductivity, porosity and confinement), characteristics of the superficial deposits and soils in the catchment from which the groundwater body receives its recharge (including the thickness, porosity, hydraulic conductivity, and adsorptive properties of the deposits and soils), stratification characteristics of the groundwater, an inventory of associated surface systems (including terrestrial ecosystems and bodies of surface water, with which the groundwater body is dynamically linked), estimates of the direction and rates of exchange of water between the groundwater body and associated water systems, sufficient data to calculate the long term annual average rate of overall recharge, and characterisation of the chemical composition of the groundwater (including specification of the contribution from human activity—Member States may use typologies for groundwater characterisation when establishing natural background levels for these bodies of groundwater).

76/160/EEC,[13] vulnerable zones under the Nitrates Directive 91/676/EEC[14] and sensitive areas under the Urban Wastewater Directive 91/271/EEC,[15] as well as areas designated for the protection of habitats and species including relevant Natura 2000 sites designated under Directives 92/43/EEC[16] and 79/409/EEC.[17] Registers shall be reviewed under the River Basin Management Plan (RBMP, see below) updates. In this context, vulnerable zones are defined as "*all known areas of land in Member States territories which drain into the waters affected by pollution and waters which could be affected by pollution and which contribute to pollution*". For these vulnerable zones, action programmes are required under the Nitrates Directive to reduce pollution caused or induced by nitrates and prevent further pollution.

• Based on the results of the characterisation phase, establish a *groundwater monitoring* network providing a comprehensive overview of groundwater chemical and quantitative status, and design a monitoring programme that should be *operational* by the *end of 2006*. Monitoring will have to be reported, following requirements summarised in the Section 5 of this paper.

• Set up a *river basin management plan* (RBMP) for each river basin district which will include a summary of

Table 5 Review of impacts on groundwater and authorisations

Annex II.2 (WFD)	Reviews of impacts
Impact of human activity (par. 2.3)	For transboundary groundwater bodies (crossing the borders of two or more Member States) or bodies identified at risk following the initial characterisation, additional information, where relevant, will have to be collected and maintained for each groundwater body: (a) location of points in the groundwater body used for the abstraction of water (with the exception of points providing less than 10 m^3 per day or points for abstraction of water intended for human consumption providing less than 10 m^3 per day or serving less than 50 persons); (b) the annual average rates of abstraction from such points; (c) the chemical composition of water abstracted from the groundwater body; (d) the location of points in the groundwater body into which water is directly discharged; (e) the rates of discharges at such points; (f) the chemical composition of discharges to the groundwater body; and (g) land use in the catchment (or catchments) from which the groundwater body receives its recharge, including pollutant inputs and anthropogenic alterations to the recharge characteristics such as rainwater and run-off diversion through land sealing, artificial recharge, damming or drainage.
Impacts of change in groundwater levels (par. 2.4)	Bodies for which lower objectives are to be specified (see Table 2) have to be identified by Member States, including consideration of the effects of the status of the body on (i) surface water and associated terrestrial ecosystems, (ii) water regulation, flood protection and land drainage, and (iii) human development.
Impact of pollution on groundwater quality (par. 2.5)	Similarly, bodies of groundwater for which lower objectives are to be specified under Article 4.5 of the WFD (see Table 2) have to be identified as a result of the analysis of impact of human activity (Article 5.1).

Article (WFD)	Authorisations
11.3(j)	Authorisations concern: (a) reinjection into the same aquifer of water used for geothermal purposes; (b) injection of water resulting from hydrocarbon extraction or mining activities into geological formations which for natural reasons are permanently unsuitable for other purposes; (c) reinjection of pumped groundwater from mines and quarries or associated with the construction or maintenance of civil engineering works; (d) injection of gas or liquefied petroleum for storage purposes into geological formations which for natural reasons are permanently unsuitable for other purposes, or where there is an overriding need for security of gas supply and where the injection is such as to prevent future deterioration of the receiving groundwater; (e) construction, civil and building works or similar activities on or in the ground which come into contact with groundwater, in accordance with general binding rules developed by the Member States; (f) discharges of small quantities of substances for scientific purposes, providing that such discharges do not compromise the achievement of environmental objectives established for that body of groundwater.

pressures and impact of human activity on the groundwater status, a presentation in map form of monitoring results, a summary of the economic analysis of water use, a summary of the programme(s) of protection, control or remediation measures *etc*. The first RBPM is scheduled at the *end of 2009*. A review is then planned by the end of 2015, and every six years thereafter.

• By 2010, take account of the principle of *recovery of costs for water services*, including environmental and resource costs, having regard to the economic analysis conducted under Article 5 of the WFD, and in accordance with the polluter pays principle.

• Establish a *programme of measures* for achieving WFD environmental objectives (*e.g*. abstraction control, pollution prevention or control measures) by the end of 2009, to be *operational* by the *end of 2012*. Basic measures include, in particular, controls over the abstraction of groundwater, controls (with prior authorisation) of artificial recharge or augmentation of groundwater bodies (providing that it does not compromise the achievement of environmental objectives). Point source discharges and diffuse sources liable to cause pollution are also regulated under the basic measures but they essentially focus on surface water protection. Direct discharges of pollutants into groundwater are prohibited subject to a range of provisions summarised in Table 5b. The programme of measures has to be reviewed and if necessary updated by 2015 and every six years thereafter.

Strategies to prevent and control pollution of groundwater are covered by Article 17 of the WFD, which requires the establishment of criteria for assessing good groundwater chemical status and for the identification of significant and sustained upward trends and for the definition of starting points for trend reversals, considering:

• The characterisation of bodies of groundwater as detailed in Annex II.2 of the WFD (see Table 4);

• Good status definitions as detailed in Table 2, which is based on groundwater level regime (quantitative status) and conductivity and concentrations of pollutants (chemical status);

• Monitoring requirements to respond to the needs of obtaining a comprehensive overview of groundwater status and to detect the presence of long-term anthropogenically induced upward trends in pollutants. In this respect, surveillance monitoring is aimed at supplementing and validating the impact assessment procedure (carried out under Article 5 of the WFD) and provide information for use in the assessment of long term trends both as a result of changes in natural conditions and through anthropogenic activity, while operational monitoring should be undertaken in the periods between surveillance monitoring programmes in order to establish the chemical status of all groundwater bodies or groups of bodies determined as being at risk and to establish the presence of any long term anthropogenically induced upward trend in the concentration of any pollutant. Further details are given in Section 5 of this paper.

• Monitoring results shall be used to identify long term anthropogenically induced upward trends in pollutant concentrations and to set up starting points for reversing these trends.

Article 17 requests the European Commission to present a proposal based on the above requirements. This new groundwater directive proposal has now been issued[11] and is being discussed within the European Parliament and Council environment working parties. This paper will not give details on the proposal at this stage since the proposed provisions might evolve in the framework of the negotiation process. As a matter of fact, the proposal sets up criteria for the evaluation of good groundwater chemical status (based on EU-wide quality standards, groundwater threshold values and WFD criteria), for the identification and reversal of significant and sustained upward trends in pollutant concentrations (taking account of threshold values to be developed by Member States at the national, regional or local level), and provides additional requirements concerning the prevention or limitation of indirect discharges. This new groundwater directive will complement the WFD and ensure a continuity of the protection regime of the 80/68/EEC Directive;[10] it is expected to be adopted before the end of 2005, pending the negotiation process at the European Parliament and Council.

In summary, the WFD[2] (including the new "daughter" groundwater directive[11]) will complement and ensure a continuity of the Directive 80/68/EEC protection regime.[10] This will be achieved through a systematic analysis of pressures and impacts (not done under Directive 80/68/EEC), and requirements related to good chemical status and pollutant trend identification/reversal backed-up by surveillance and monitoring programmes. The programme of measures also sets out provisions that are aimed to replace the existing protection regime. The new groundwater directive aims to provide the necessary common criteria regarding chemical status evaluation, identification and reversal of significant and upward trends in pollutant concentrations, as well as specific clauses regarding indirect discharges to make sure that the existing protection regime will be appropriately strengthened.[11]

5. Environmental integration

Environmental integration means making sure that environmental concerns are fully considered in the decisions and activities of other sectors.[18] This became a priority in the EU's 5th Environmental Action Programme (1993–2002) in response to issues raised at the Earth Summit in Rio de Janeiro in 1992. Since 1997, it has been a requirement under the EC Treaty, which states in its Article 6 that "environmental protection requirements must be integrated into the definition and implementation of the Community policies [...] in particular with a view to promoting sustainable development". The Cardiff Process (named after a European Council meeting held in Cardiff in June 1998) requires putting Article 6 of the Treaty into practice; it has undoubtedly contributed to raising the political profile of integration, which was reaffirmed in the Sixth Environment Action Programme, stipulating that "integration of environmental concern into other policies must be deepened" in order to move towards sustainable development.[1] This concept was also strengthened by the adoption of the EU Sustainable Development Strategy at the Lisbon summit in 2001, requiring a new emphasis on policy coordination and integration. This in turn has led the Commission to introduce a system of extended impact assessment for all major policy proposals, providing concrete information on the tradeoffs between the economic, social and environmental dimensions of sustainable development. By allowing a full appraisal of the potential environmental costs and benefits of all major Commission proposals, in addition to the costs and benefits of specific environmental measures, environmental integration is inherently promoted. This concept should also be viewed under the so-called Lisbon Strategy which is a commitment to bring about economic, social and environmental renewal in the European Union. Identified integration areas are agriculture, development, energy, enterprise, fisheries, internal market, research, structural funds, trade and external relations, transport, and economic and social affairs. In the following sections, we will examine how the groundwater policy framework is

being integrated into other policies and how research and socio-economic aspects are being taken into account.

6. Policy integration and monitoring obligations

6.1. Policy integration

As mentioned in Section 5, one of the key aspects of environmental integration in the light of the EU Sustainable Development Strategy is linked to policy coordination and integration. With regard to the groundwater policy framework, this policy integration appears to be quite complex since it concerns a range of various directives as illustrated in Fig. 4. This section examines how various relevant directives interact with the groundwater policy under the WFD and 80/68/EEC Directive.

The Nitrates Directive[14] aims to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution. It obliges Member States to designate vulnerable zones which correspond to all known areas of land in Member States territories which drain into the waters (including groundwater) affected by pollution and waters which could be affected by pollution and which contribute to pollution. A reference is made to action programmes to reduce pollution caused or induced by nitrates and to prevent further pollution, and to requirements for identifying groundwater vulnerable zones as "those waters which contain more than 50 mg l^{-1} or could contain more than 50 mg l^{-1} nitrates if an action programme is not undertaken". The link with groundwater policy is clear in that respect, *i.e.* nitrate contamination levels should not be over the trigger value set at 50 mg l^{-1} (this argument has been used for proposing this value as an EU-quality standard for groundwater in the above mentioned proposal.[11]).

The Urban Wastewater Directive[15] aims to protect the environment from the adverse effects of discharges of urban waste water and waste water from certain industrial sectors. In this context, the identification of "sensitive areas" relates essentially to freshwaters, estuaries or coastal waters which are found to be eutrophic, lakes and streams reaching lakes/reservoirs/closed bats with poor water exchange, surface freshwaters intended for the abstraction of drinking water which could contain more than 50 mg l^{-1} nitrates. This directive is indirectly relevant to groundwater (protection of receiving groundwaters from possibly contaminated waste waters originating from freshwater sources).

The Plant Protection Products Directive[19] concerns the authorisation, placing on the market, use and control within the Community of plant protection products in commercial form. Regarding groundwater, authorisations are only granted if plant protection products have no harmful effect on human or human health, directly or indirectly, or on groundwater, and they have no unacceptable influence on the environment, particularly contamination of water including drinking water and groundwater. The "uniform principles" set out in the directive specify that no authorisation shall be granted if the concentration of the active substance or of relevant metabolites, degradation or reaction products in groundwater, may be expected to exceed, as a result of use of the plant protection product under the proposed conditions of use, the lower of (i) the maximum permissible concentration laid down by Directive 80/778/EEC,[13] or (ii) the maximum concentration laid down by the Commission when including the substance listed in the directive, on the basis of appropriate data (in particular toxicological data), or where that concentration has not been laid down, the concentration corresponding to one tenth of the ADI (acceptable daily intake) laid down when the active substance was included in the directive.

The Biocides Directive[20] concerns the authorisation and the placing on the market for use of biocidal products. Similarly to Directive 91/414/EEC,[19] authorisation of biocidal products may only be granted if the products have no harmful effect on human or human health, directly or indirectly, or on groundwater, and they have no unacceptable influence on the environment, particularly contamination of water including drinking water and groundwater. Similar principles as the "uniform principles" of Directive 91/414/EEC are set out, which means that the 0.1 μg l^{-1} quality standard of the 80/778/EC[12] plays a role of maximum concentration for all groundwater, but that lower standards may be established following the procedure for including the active substance in Annex I of the Directive.

The Integrated Pollution Prevention and Control (IPPC) Directive[21] lays down measures designed to prevent or reduce emissions in the air, water and land from a range of activities listed in the Annex I of the directive. It establishes provisions for issuing permits for existing and new installations, and makes a specific reference to groundwater, indicating that the permits shall include appropriate requirements ensuring protection of the soil and groundwater on the basis of emission limit values for pollutants which may be supplemented or replaced by equivalent parameters or technical measures based on best available techniques.

The Landfill Directive[22], which concerns the landfill of waste, aims to provide measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, including groundwater. Similarly to the IPPC Directive,[21] the Directive establishes provisions for issuing permits based on a range of conditions including impact assessment studies. Regarding groundwater, site characteristics have to locate groundwater and geological and hydrogeological conditions in the area, prevent groundwater from entering into the landfilled waste, take appropriate measures to collect/treat contaminated water and leachate, and prevent pollution of the soil, groundwater or surface water using appropriate technical precautions (*e.g.* combination of a geological barrier and bottom

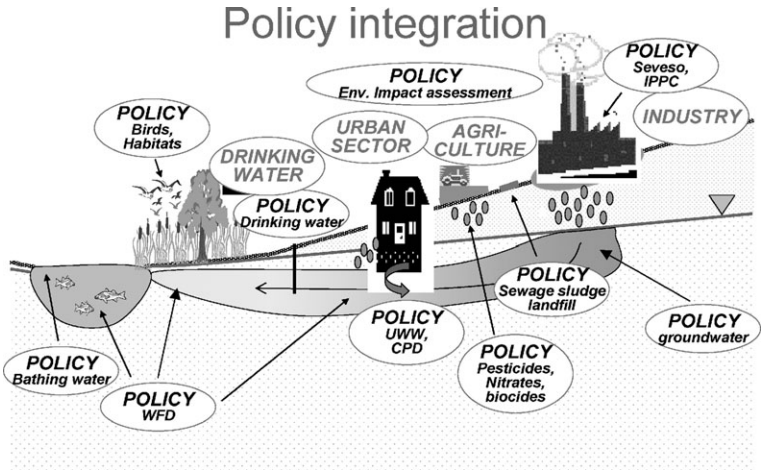

Fig. 4 The overall groundwater policy framework: integration needs.

liner). The Directive establishes criteria for waste testing and acceptance, taking due consideration of the protection of the surrounding environment, including groundwater.

The Sewage Sludge Directive[23] seeks to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man. To this end, it prohibits the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. Treated sludge is defined as having undergone "biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use". The Directive also requires that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired. It sets out requirements for the keeping of detailed records of the quantities of sludge produced, the quantities used in agriculture, the composition and properties of the sludge, the type of treatment and the sites where the sludge is used. Limit values for concentrations of heavy metals in sewage sludge intended for agricultural use and in sludge-treated soils are in given in annexes to the Directive.

Let us note also that Article 4 of the Waste Framework Directive[24] also requires that waste be recovered or disposed of without endangering the environment, which may have an (indirect) effect on protecting groundwater.

Finally, the Construction Product Directive[25] concerns regulatory provisions on construction products. It indirectly concerns groundwater in that construction products for construction works have to be fit for their intended use and respond to requirements regarding hygiene, health and the environment, in particular it should not be a threat to the hygiene or health of occupants or neighbours as a result of pollution or poisoning of the water or soil.

6.2. Groundwater monitoring under the WFD

Fig. 5 summarises groundwater monitoring obligations under the Water Framework Directive,[2] which have been described in detail in a guidance document on monitoring developed under the "Common Implementation Strategy" of the WFD.[26] As shown by the figure, WFD groundwater monitoring obligations concern quantitative and chemical aspects.

Regarding the "quantitative status", the monitoring programme will have to be designed (before the end of 2006) so as to provide a reliable assessment of the quantitative status of all groundwater bodies or groups of bodies including assessment of the available groundwater resource. The network will have to consider the representativeness of monitoring points, taking into account short and long-term variations in recharge, and the frequency that should be sufficient for quantitative assessments (in particular for evaluating the impacts of abstractions and discharges on the groundwater level, and—for transboundary groundwater bodies—estimating the direction and rate of groundwater flow across the Member State boundary).

With regard to the groundwater chemical status, the monitoring network will have to be designed in order to provide a coherent and comprehensive overview of the groundwater chemical status within each river basin and to

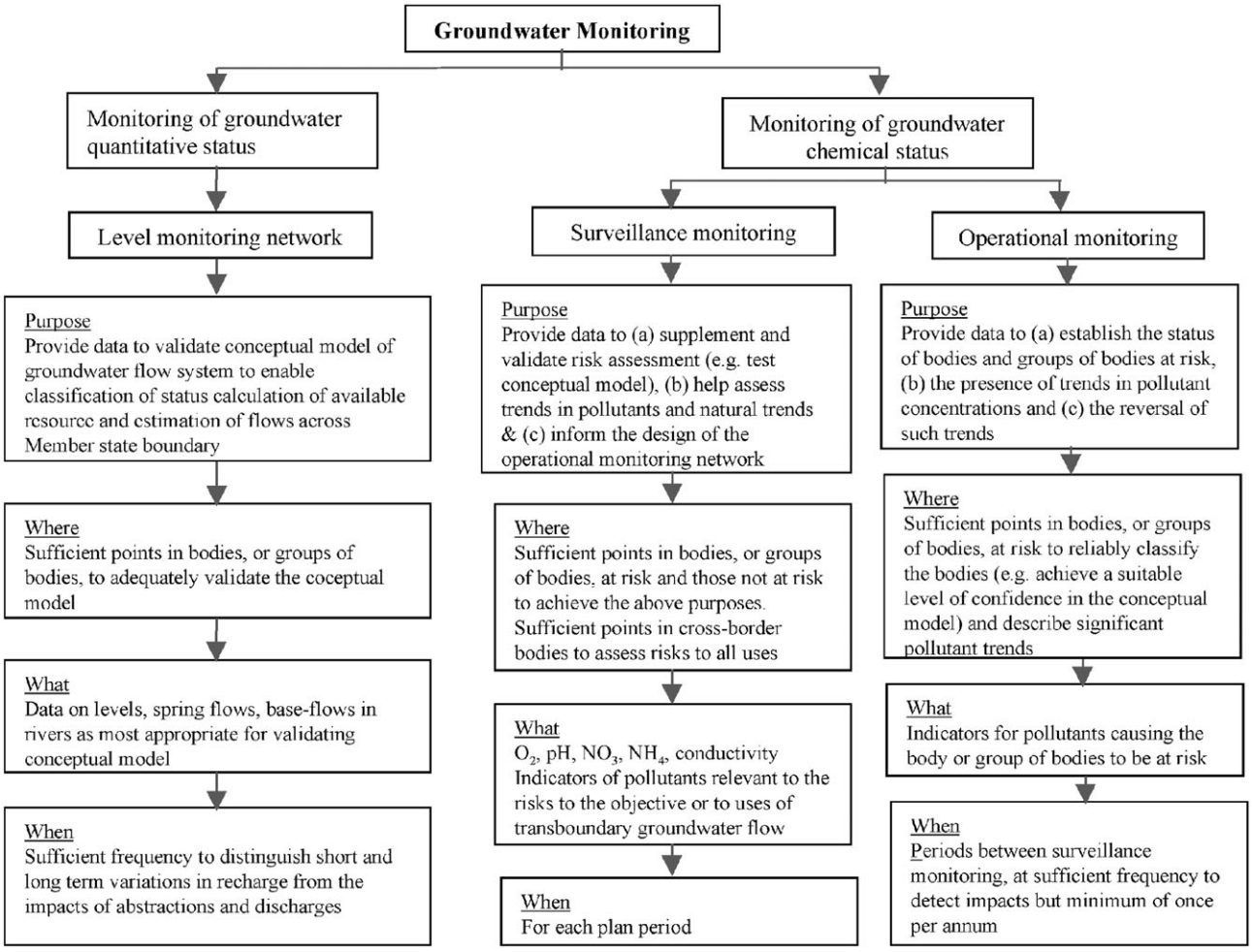

Fig. 5 Summary of groundwater monitoring obligations under the WFD.

detect the presence of long-term anthropogenically induced upward trends in pollutants. Based on the results of the characterisation of groundwater bodies and the impact assessment (to be completed by the end of 2004), Member States will have to establish a surveillance monitoring programme, the results of which being used to establish an operational programme in the framework of each river basin management plan. In other words, the surveillance programme will be used to supplement and validate the impact assessment procedure, and provide information to be used in the assessment of long term trends both as a result of changes in natural conditions and through anthropogenic activity. Similarly to the quantitative monitoring, aspects of representativeness and frequency will have to be carefully considered. Minimum monitoring parameters concern oxygen content, pH value, conductivity, nitrate and ammonium (for all groundwater bodies). Groundwater bodies which were found to be at risk (following the 2004 impact assessment) will also have to be monitored for those substances which are indicative of the impact of these pressures. In this respect, operational monitoring will have to be undertaken in the periods between surveillance monitoring programmes in order to establish the chemical status of all groundwater bodies determined as being at risk and the presence of any long term anthropogenically induced upward trend in the concentration of any pollutant. The frequency of surveillance monitoring is not strictly defined in the WFD, but operational monitoring will have to be performed at a minimum once per year. Regarding the identification of trends in pollutant concentrations, the monitoring programmes will have to be adapted to local situations and the trends will have to be demonstrated statistically, stating the level of confidence associated with the identification.

6.3. Groundwater monitoring under other existing EU legislation

Monitoring obligations also concern other existing EU legislation (see Section 6.1) with direct or indirect links to groundwater policy. They are summarised below:

• The Nitrates Directive[14] requires the implementation of suitable monitoring programmes to assess the effectiveness of action programmes at selected measuring points, making it possible to establish the extent of nitrate pollution in the waters from agricultural sources. The designation and monitoring of vulnerable zones is to be carried out at regular intervals at sampling stations which are representative of groundwater aquifers, taking into account the provisions of the Drinking Water Directive.[12] The monitoring has to be repeated at least every four years, except for those sampling stations where the nitrate concentration in all previous samples has been below 25 mg l^{-1} and no new factor likely to increase the nitrate content has appeared (in which case the monitoring programme needs to be repeated only every eight years). The directive also stipulates that reference methods of measurement have to be used. This however concerns freshwaters, coastal waters and marine waters (*i.e.* no specific mention is made of groundwater).

• The Urban Wastewater Directive[15] monitoring obligations are directly related to verifications of appropriate treatment, prior regulations and/or specific authorisations of discharges from urban waste treatment plants to freshwaters and estuaries. In the framework of this directive, monitoring will have to focus on discharges from urban waste water treatment plants to verify compliance with requirements set out in the directive (corresponding to criteria concerning different types of discharges) and following control procedures laid down in the annex (reference monitoring methods and evaluation of results). These requirements focus on flow-proportional or time-based 24 h sample collection at well-defined points in the waste water treatment plant outlet and if necessary in the inlet in order to monitor compliance with the directive's requirements for discharged waste water. They include an obligation to apply good international laboratory practices in order to minimise the degradation of samples between collection and analysis. Let us note that these monitoring obligations do not concern groundwater.

• The Plant Protection Products Directive[19] monitoring obligations concern the authorisation regime imposed by the Member States according to the Directive's provisions. Decision-making provisions are included in the annex to the directive. The granting of authorisations has to take account of the agricultural, plant health or environmental (including climatic) conditions in the areas of envisaged use (this implicitly concerns groundwater, even if this is not specifically mentioned). These considerations may result in specific conditions and restrictions of use and, where necessary, in authorisation being granted for some but not other areas within the Member State. The control measures are obviously linked to the current analytical knowledge (and authorisation may be limited to a limited period if limitations in analytical science and technology are recognised), with requirements regarding method's reproducibility. As mentioned in Section 6.1, the directive makes a direct reference to groundwater contamination (with drinking water standards not allowed to be exceeded), which therefore needs to be monitored. There are no specific monitoring criteria in this respect other that the mention that analytical methods must reflect the state of the art, and analytical criteria on method performance as set out in the annex.

• The decision-making provisions of the annex to the Biocides Directive[20] follow the same lines as the one described above (related to the Plant Protection Products Directive) with respect to groundwater. Monitoring obligations are closely linked to the authorisation regime which requests a prior risk assessment for which criteria are defined in the evaluation provisions of the same annex. This risk assessment has to take into account any adverse effects arising in any of the three environmental compartments—air, soil and water (including sediment)—and of the biota. The analytical work has, therefore, to focus on the properties and potential adverse effects of the active substances present in the biocidal product for its classification. In case this classification is not possible, information on *e.g.* bioaccumulation potential, persistence characteristics, information from toxicity studies *etc.* have to be taken into account. If appropriate, adequately measured exposure data, likely pathways to environmental compartments and potential for adsoption/desorption and degration *etc.* have to be evaluated. This obviously includes effects on groundwater. Specific monitoring requirements are, however, not included, except the mention that testing should be carried out according to Community guidelines if these are available and applicable. Where appropriate, other methods can be used (*e.g.* ISO, CEN or other international standard method, national standard method or other methods accepted by the Member State) and if relevant field data exist, these can also be used.

• The permit procedure under the Integrated Pollution Prevention and Control (IPPC) Directive[21] includes a provision for suitable release monitoring, specifying measurement methodology and frequency, evaluation procedure and obligation to supply data required for checking compliance with

the permit. The Directive includes a provision for installations that may have significant negative effects on the environment of another Member State. Monitoring is focused on the releases, the results of which have to be regularly submitted by the operator to the Competent authority (and without delay in case of any incident or accident significantly affecting the environment). There are no specific monitoring requirements for groundwater, but the directive's provisions obviously imply that risks to groundwater be appropriately monitored.

• The Landfill Directive[22] imposes control and monitoring procedures with a frequency which is to be defined by the competent authority (and in any event at least once a year) and on the basis of aggregated data, in order to demonstrate compliance with permit conditions. The corresponding article notifies that the quality control of the analytical operations of the control and monitoring procedures are carried out by competent laboratories. Further requirements are provided in the annex. They include reporting obligation for meteorological data (volume of precipitation, temperature, wind, evaporation, atmospheric humidity) to check whether leachate is building up in the landfill body or whether the site is leaking. Samples of leachate and surface water are also required to be collected at representative points (for surface water, no less than two points, *i.e*. one upstream from the landfill and one downstream). A separate section on the protection of groundwater is included, which requests that information on groundwater likely to be affected by the discharging of waste is provided, with at least one measuring point in the groundwater inflow region and two in the outflow region (this number can be increased on the basis of a specific hydrogeological survey and the need for early identification of accidental leachate release in the groundwater). Sampling has to be carried out in at least three locations before the filling operations in order to establish reference values for future sampling (following the requirement of the ISO 5667 standard 'Sampling Groundwaters', Part 11, 1993). The parameters to be analysed in the samples taken must be derived from the expected composition of the leachate and the groundwater quality in the area, with account of mobility in the groundwater zone and a frequency adapted to the local conditions. Adverse effects are considered to have occurred when an analysis of the groundwater sample shows a significant change in water quality as defined by a trigger level which should be determined by the competent authority (taking account of the specific hydrogeological formations in the location of the landfill and groundwater quality) and laid down in the permit whenever possible.

• In the framework of the Sewage Sludge Directive,[23] monitoring requirements are focused on specifies rules for the sampling and analysis of sludges and soils, *i.e*. there are no specific requirements concerning groundwater.

• Finally, the Construction Product Directive[25] focuses on conformity aspects of construction products, taking into account possible risk to water environments (in particular release of dangerous substances to water). As such, the directive does not provide for specific groundwater monitoring other than the requirement for a verification that the construction work is designed and built in such a way that it will not generate pollution of the water or soil. Conformity testing of construction products is generally carried out at the factory or on site from a batch which is ready for delivery. The surveillance concerns the factory production and product testing rather than monitoring possible effects on the environment.

7. Research and technologial development (RTD) integration needs

7.1. Introduction

It is now well recognised that the better understanding of environmental problems requires an improved awareness of multidisciplinary scientific developments. Awareness by itself, however, is not sufficient, and a better integration of research results is required at the various stages of policy developments (design, development, implementation and review). Ideally, the relevant research for any environmental policy should be feeding the policy-making process directly in a "tailor-made fashion" so that results may be used in the right way and at the right time (in relation to the policy agenda). In many instances, however, this is far from actually being the case. This paragraph lists some research and technological development (RTD) projects directly or indirectly related to EU groundwater policy and examines how they contributed to policy implementation (Directive 80/68/EEC and/or Water Framework Directive) or development (proposal for a new Groundwater Directive).

7.2. Examples of research projects and networks supporting groundwater policy

A range of EU-funded projects of direct interest to groundwater policy are currently on-going or in their starting phase. A brief overview of selected projects is given below, along with the address of the co-ordinator (this list is not exhaustive). All projects presented in Sections 7.2.1 to 7.2.4 correspond to projects funded under the EC 5th RTD Framework Programme (1998–2002) through the "Water Key Action". The AQUATERRA project (Section 7.2.5) corresponds to one of the "new instruments" of the 6th Framework Programme (2002–2006), referred to as "integrated project", which is funded by the Priority 6 "Global Changes and Ecosystems" of the EC DG Research. Section 7.2.6 presents two projects, also funded under the 6th FWP, which correspond to another Priority of the EC DG Research, namely the "Scientific Support to Policies" Priority, publishing research topics responding to needs expressed by EC policy General Directorates. Finally, Section 7.2.7 describes relevant networks which also support directly or indirectly groundwater policy development through the gathering of expertise and consultations. Further information on the various research funding mechanisms implemented by the European Commission is available on the *Europa* site of the DG Research (http://www.europa.eu.int/comm/research/).

7.2.1. Risk assessment.

• TRACE-Fracture (toward an improved risk assessment of contaminant spreading in fractured underground reservoirs). The project studied two fractured sites contaminated by organic pollutants (granite rock contaminated by waste oils located in Spain; and clay till contaminated by leaking storage banks of an abandoned tar and creosote factory located in Denmark), which led to a conceptual geological model and a database with field measurements of spatial and temporal distribution of organic pollutants (PAH, phenols, BTEX) in groundwater, with recommendations on risk assessment and various remediation schemes. As such the project is directly supporting the analysis of pressures and impacts under Article 5 of the WFD, as well as the future programme of measures. Contact: Christos Tsakiroglou, Foundation for Research and Technology Hellos (ctsakir@iceht.forth.gr).

• GRACOS (Groundwater Risk Assessment at Contaminated Sites). The

project aimed to study strategies for an improved groundwater risk assessment at contaminated sites and issued guidelines which will be soon made available. This research therefore also supports the characterisation of groundwater bodies as required under Article 5 and Annex II of the WFD. Contact: Hans van der Slot, Netherlands Energy Foundation ECN (vandersloot@ecn.nl).

• ABACUS (Evaluation of availability to biota for organic compounds ubiquitous in soils and sediments). The project deals with a protocol for measurement of concentrations of bioavailable contaminants and a chemical modelling software. The conclusions are of indirect relevance to groundwater policy but could be of interest to the Soil Thematic Strategy. Contac: John Parsons, Free University of Amsterdam (jparsons@science.uva.nl).

7.2.2. Groundwater remediation.

• INCORE (Integrated Concepts for Groundwater Remediation). The project provides publicly available guidelines for assessing human health risks from groundwater contamination, a literature study on natural attenuation of organic pollutants in groundwater and an integrated concept for groundwater remediation. This guidance will be of direct use to Member States in support of the WFD programme of measures. Contact: Thomas Ertel, Umweltwirtschaft GmbH (Thomas.ertel@uw-d.de).

Other examples of remediation projects which are of direct or indirect relevance for groundwater policy in the light of the WFD programme of measures (in particular concerning links to contaminated soils) are: ORGONATE (On-site remediation of groundwater contaminated by polar organic compounds using a new adsorption technology)—Contact: Karsten Levesen, levsen@item.fraunhofer.de); PIRAMID (Passive *in situ* remediation of acid mine/industrial drainage)—Contact: Paul Younger, http://www.piramid.org; PURE (Protection of groundwater at industrially contaminated sites)—Contact: Anja Sinke, sinke@mep.tno.nl.

7.2.3. Diffuse pollution.

• PEGASE (Pesticides in European Groundwaters: actual status and scenarios of possible evolution). The project studies representative aquifers to elucidate transport processes of pesticides and the development of tools (mathematical model, socio-economic instrument) supporting the management of pesticides usage with regard to groundwater quality. Alternative scenarios for pesticide management strategies implemented within a software tool (PEG@SE) have been evaluated through interactive demonstrations. The project is of direct interest to the WFD programme of measures as well as to the Plant Protection Products Directive[14]—Contact: Christophe Mouvet, BRGM (c.mouvet@brgm.fr).

• AgriBMPwater (System approach to environmentally acceptable farming). A comparison between different management plans is carried out through a cost/effectiveness assessment, along with a study of their acceptability by farmers (focusing on nitrate loads). This project is more focused on the Nitrates Directive[8] but it has an indirect relevance to groundwater policy—Contact: Ramon Laplana, CEMAGREF (ramon.laplana@cemagref.fr).

• SOWA (Integrated soil and water protection from diffuse pollution). Interdisciplinary expert forum focusing on integrated protection of soil and water resources, in particular the diffuse pollution aspects (disposal of non-regulated wastes, agricultural activities, atmospheric deposition of pollutants *etc*.). This project is of interest for gathering knowledge on soil–groundwater interactions, which will be relevant to the on-going discussions on the new Groundwater Directive[6]—Contact: Peter Grathwohl, Univ. Tübingen (grathwohl@uni-tuebingen.de).

7.2.4. Management issues and information tools.

• EUGRIS (European Sustainable Land and Groundwater Management). The project is developing an online portal in the form of a web-based information platform for soil, groundwater, and contaminated land, which will be accessible by the end of 2005. It is obvious that this information tool will be of direct support/interest to groundwater policy implementation—Contact: Jörg Fraueinstein (joerg.fraueinstein@woa.de).

• WELCOME (Water, Environment and Landscape Development of Contaminated Megasites). The project aims to develop an integrated management system (IMS) for the prevention and reduction of contamination at large-scale contaminated sites (megasites). This tool will enable environmental megasite managers to establish an appropriate management system for their respective sites on the basis of a risk-based management (RBM) approach, in line with the so-called DPSIR (Driving Force, Pressure, State, Impact, Response) principle. This project is of particular relevance for management issues related to large point sources of pollution to groundwater such as regional industrial agglomerations and harbour areas—Contact: Huub Rijnaarts (H.H.M.Rijnaarts@mep.tno.nl).

• WATCH (Water Catchment Areas – Tools for management and control of hazardous compounds) is developing a model on how to deal with risk management zones and to implement groundwater regulation (WFD and Groundwater legislation). The project focuses on analytical methods and instrumentation for on-site/*in situ* monitoring of hydrocarbons (*e.g.* MTBE, BTEX) in groundwater and sediment, an integrated early warning and management tool on a catchment scale (sensors, *in situ* testing, immonuassay kits, protocol for sample handling *etc*.). The project responded to one option that had been examined during the drafting process of the new Groundwater Directive[11]—Contact: Thomas Track (track@dechema.de).

7.2.5. The AQUATERRA Integrated Project. The newly started AQUATERRA project (Integrated Modelling of the River–Sediment–Soil–Groundwater System—Contact: Elisabeth Frank (efrank@uni-tuebingen.de) aims to provide the scientific basis for improved river basin management through a better understanding of the river–sediment–soil–groundwater system as a whole, at different temporal and spatial scales. In particular, the project will include the development of modelling, monitoring and management tools. This very large project (integrated project) is composed of nine sub-projects which could have a significant impact on the WFD implementation, providing that appropriate communication flows are ensured with the policy-makers.

7.2.6. Other relevant projects.

• SWIFT-WFD (Screening Methods for Water Data Information in support of the implementation of the Water Framework Directive) started in January 2004. It focuses on an inventory of existing screening methods for measuring WFD-relevant chemical and biological substances, the production of quality control tools for validation purposes of selected screening methods, and their comparison through laboratory-based (tank experiments) and/or field interlaboratory studies and with classical laboratory-based analyses to validate their results and demonstrate

their equivalence. These activities will be complemented by guidance on method validation/quality assurance and tailor-made training programmes. In parallel, the project will consider the development of new "low-cost", innovative, screening techniques (both for chemical and biological parameters) and their validation using the same approach (interlaboratory testing and comparison with laboratory-based methods). Finally, an assessment of the economic impact of low-cost screening and monitoring techniques will be carried out, and links will be established with policy implementers to make sure that results will be properly disseminated. The project is 'tailor-made' to research needs in support of the WFD monitoring programme and it will hence evolve along with its design. Contact: Catherine Gonzalez (Catherine.Gonzalez@ema.fr).

• BRIDGE (Background Criteria for the identification of groundwater thresholds) aims to study and gather scientific outputs which could be used to set out a common methodology for establishing groundwater threshold values (maximum concentrations of pollutants) at appropriate levels (national, regional or local) in relation to criteria linked to the good groundwater chemical status definition given in the WFD Annex V. The research will be undertaken in close consultation with policy decision-makers, and examine the key criteria to be considered for establishing groundwater thresholds (*e.g.* interactions with surface waters and/or dependent terrestrial ecosystems, hydrogeological characteristics, pollutant mass flows, groundwater uses *etc.*). This project is being launched at the request of the EC DG Environment and will hence be closely liaised with the negotiation process of the new Groundwater Directive.[6] It is expected to start in January 2005. Contact: Anne-Marie Fouillac (am.fouillac@brgm.fr).

7.2.7. Relevant networks.

• ANCORE (Academic network on contaminated land management in Europe) provides a platform for the exchange of innovative know-how in the field of applied research for contaminated land and groundwater issues in the framework of an academic network. It aims to promote an active co-operation between the academic network partners and the owners of contaminated land (industry) and to identify research needs in order to provide an input to the EU-administration, industry, as well as researchers and students, in the field of contaminated land and groundwater.

• CLARINET (Contaminated Land Rehabilitation Network for Environmental Technologies in Europe) primarily aims to develop technical recommendations for sound decision-making on the rehabilitation of contaminated sites in Europe. The network is active in various policy consultations, organising scientific seminars and publishing technical reports (website: http://www.clarinet.at).

• IMAGE-TRAIN (Innovative Management of Groundwater Resources in Europe – Training and RTD co-ordination project) is an accompanying measure funded under the 5th Framework Programme, aiming to support related research activities by establishing topical links between thematically related research projects and to propose, on this basis, innovative and economic solutions for specific groundwater pollution problems. This goal is achieved through the organisation of meetings and events to gather researchers of related topics, communicate current research activities and train researchers and students through advanced study courses (website: http://www.image-train.net).

• NICOLE (Network for industrially contaminated land in Europe) is a leading forum on contaminated land management in Europe, which started its activities more than 10 years ago. The network promotes co-operation between industry, academia and service providers on the development of sustainable technologies. The overall objectives are to provide a European forum for the dissemination and exchange of good practices, practical and scientific knowledge and ideas to manage contaminated land in a sustainable way. Furthermore, the network aims to stimulate coordinated interdisciplinary projects on collaborative research and knowledge transfer to address identified needs, in addition to strengthening and developing relationships with other networks (website: http://www.nicole.org).

• SENSPOL (Sensors for monitoring water pollution from contaminated land, landfills and sediments) aims to enhance the development of sensors for practical applications in the abatement of water pollution by guiding technological development of sensors for environmental pollutants. The network aims to accelerate the development of chemical sensors, biosensors and biomimetic systems to provide sensitive and robust devices for water monitoring, contaminated soils and sediments (website: http://www.cranfield.ac.uk/biotech/senspol/).

• SNOWMAN (Sustainable management of soil and groundwater under the pressure of soil pollution and soil contamination) is focusing on coordination aspects of research programmes through the so-called ERA-NET scheme. The network aims to produce an overview of current research programmes in the specific field concerned and to develop a Vision Paper which will define the goal of European research activities in this specific field of environmental research. The ultimate goal is to implement and conduct a research programme on a bi-/multilateral level throughout Europe. Contact: Stefan Vetter (Stefan.Vetter@lebensministerium.at).

7.3. Standardization

The European Committee for Standardization (CEN) is developing activities that are directly or indirectly relevant to groundwater policies. Examples are the Technical Committees 230 for water, 292 for waste and 345 for soil. In this context, regular contacts among the standardization, scientific and policy-making communities are taking place, even thought coordination among the activities in the different sectors is not always operational. An example of successful information exchange concerns the way a 'release' of pollutants from *e.g.* contaminated soils, wastes, sewage sludges and construction products may affect groundwater. The need to reach a common understanding on the harmonisation of test methods for risk assessment arising from direct or indirect discharges of regulated substances into water has indeed been recently discussed in the framework of various discussion groups. A development in this direction will have an impact on the implementation of a series of EC Directives, namely the sewage sludge, waste, landfill and future soil (monitoring) directives, as well as on the future groundwater directive (and of course of the Water Framework Directive). It is indeed clear that protection measures and related investigations/authorisations, as well as measurements of pollution effects (related to quality standards) will be directly dependent upon the available methods which are generally operationally-defined (based on leaching properties). In other words, the achievement of data comparability will only be possible if common methods are used. Without harmonisation efforts for horizontal standardization, there will be no common decision-making tools to judge the extent of risks due to *e.g.* indirect discharges and the validity of authorisations given by Member States and to monitor them. In this respect, on-

going activities such as *e.g.* the HORIZONTAL project or the proposed CEN mandate on construction products, will open the door for harmonisation in other sectors, which should enable to avoid a multiplication of "vertical" standards. Besides these needs, harmonisation work needs to be supported by a scientific foundation and research needs have also been expressed by various stakeholders. This is a typical example where a strong coordination among CEN, Policy General Directorates (in this case DG Environment and DG Enterprise), DG Research and the scientific community is required to make sure that the outputs of the different activities will be naturally integrated and made operational.

8. Socio-economic integration

Integration may also be viewed from a socio-economic perspective, including public awareness, to ensure that scientific and policy developments are responding to social and economic needs.

8.1. Impact assessment

As mentioned in Section 5 of this paper, EU regulatory proposals have now to be prepared on the basis of an effective analysis of whether it is appropriate to intervene at EU level and whether regulatory intervention is needed. This analysis should also assess the potential economic, social and environmental impact of the proposal, as well as the costs and benefits of the chosen approach. In this context, a new integrated impact assessment method has been developed by the Commission.[26] The aim of impact assessment is to help structure the policy-making process, identifying and assessing the problem and the objectives pursued. It identifies the main alternative options for achieving the objective and analyses their likely impacts. It outlines the advantages and disadvantages of each option and the synergies and trade-offs. So it should be considered as an aid to political decision-making, not a substitute for it. Such an extended impact assessment has been carried out within the development stage of the Groundwater Directive proposal; it examined a strict normative option *versus* a more flexible approach and their potential economic, social and environmental impacts,[27] and strengthened the orientations chosen for the proposal.[11] The extended impact assessment is available on the European Commission's website (http://europa.eu.int/comm/environment/water/) in three languages (DE, FR and EN).

8.2. Public participation

The Århus Convention[28] establishes a number of rights of the public (citizens and their associations) with regard to the environment. Public authorities (at national, regional or local level) are to contribute to allowing these rights to become effective. In the light of this convention, the WFD includes a specific article on public information and consultation (Article 14) on the basis of which Member States have to encourage the active involvement of all interested parties (including users) in its implementation, in particular in the production, review and updating of the river basin management plans. This enables the general public to have access, on request, to background documents and information used for the development of the draft river basin management plan. This new citizen right is an important step towards integration of socio-economic awareness into the policy-making (development, implementation and review) process.

8.3. Other needs

Linked to the above, integration may also concern education needs at various levels. In this respect, water policies in general and groundwater policy in particular represent a good example of a field in which multidisciplinary expertise is required, with appropriate training at all levels (basic scientific disciplines, economics, research and technology, policy *etc.*). Within the WFD framework, training activities are currently being undertaken, focusing on specific areas such as *e.g.* quality assurance (within the SWIFT project, see Section 7.2.6) and economics. An emerging training need concerns aspects of 'translation' (transfer) of knowledge of scientific or technological developments into solutions that are directly applicable to appropriate levels of policy development (design, development, implementation or review). This latter need goes hand in hand with current efforts to improve a proper integration of scientific outputs into the WFD implementation process.

9. Conclusions—need for an overall science-policy integration framework

This paper highlights the need for integration at various levels for a proper understanding and implementation of water policies, with a focus on science-policy integration and groundwater policy. Difficulties experienced to date stem from the fact that there is insufficient streamlining of information from *e.g.* the scientific community to policy decision-makers. In this respect, efforts are on-going in the framework of various initiatives to examine how an efficient and operational 'science-policy interface' could be developed in support of the implementation of the Water Framework Directive (hence of direct interest to groundwater policy). This development is being undertaken in the framework of the Common Implementation Strategy of the WFD[29] in close co-operation with an EU-funded concerted action (Harmoni-CA).[30] The aim is to develop such an interface in a way that it could meet the demand of different levels of users (*e.g.* policy-makers, industry *etc.*) and stakeholders (*e.g.* the scientific community, academia *etc.*), ensuring an efficient dissemination and use of research results. This development has been recently discussed in the framework of a workshop (held in Ghent on 4–5 October 2004) gathering representatives of the Member States environment ministries and agencies, coordinators of research, development and demonstration projects, European Commission officials, of which the main conclusions will be published in the open literature.[31]

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References

1 European Commission, 6th Environment Action Plan, European Commission, Brussels, 2000.
2 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, *Off. J. Eur. Communities* L 327, 22.12.2000, p. 1.
3 J. Gibert, in *Groundwater Ecology – A tool for management of water resources*, ed. C. Griebler, D. L. Danielopol, J. Gibert, H. P. Nachtnebel and J. Notenboom, European Commission, EUR 19887, rue de la Loi 200, B-1049 Brussels, 2001, p. 413.
4 S. Heidrich, M. Schirmer, H. Weiss, P. Wycisk, J. Grossmann and A. Kaschl, *Toxicology*, in press.
5 P. Grathwohl, in *Diffusion in natural porous media, contaminant transport, sorption/desorption and dissolution*

kinetics, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1998.
6 G. Teusch, H. Ruegner, D. Zamfirescu, M. Finkel and M. Bittens, *Land Contam. Reclam.*, 2001, **9**, 1.
7 EEA, Europe's environment: the third assessment, 2003.
8 EEA, *Groundwater quality and quantity in Europe*, Environmental Assessment Report No. 3, Copenhagen, 2000.
9 EEA, *EEA signals 2004*, Copenhagen, 2004.
10 Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution, *Off. J. Eur. Communities* L 20, 26.1.1980, p. 43.
11 Proposal for a Directive of the European Parliament and of the Council on the protection of groundwater against pollution, COM(2003)550 final.
12 Council Directive 80/778/EEC of 15 July 1980 relating to the quality of water intended for human consumption, *Off. J. Eur. Communities* L 229, 5.12.1998, p. 32.
13 Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water, *Off. J. Eur. Communities* L 31, 5.2.1976, p. 1.
14 Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, *Off. J. Eur. Communities* L 375, 31.12.1991, p. 1.
15 Council Directive 91/271/EEC of 21 May 1991 concerning urban waste treatment, *Off. J. Eur. Communities* L 135, 30.5.1991, p. 40.
16 Habitats Directive 92/43/EEC, *Off. J. Eur. Communities* L 206, 22.7.1992, p. 7.
17 Birds Directive 79/409/EEC, *Off. J. Eur. Communities* L 103, 25.4.1979, p. 1.
18 European Commission, Integrating environmental considerations into other policy areas – a stocktaking of the Cardiff process, Press release IP/04/700, June 2004.
19 Council Directive of 15 July 1991 concerning the placing of plant protection products on the market, *Off. J. Eur. Communities* L 230, 19.8.1991, p. 1.
20 Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market, *Off. J. Eur. Communities* L 123, 24.4.1998, p. 1.
21 Council Directive of 24 September 1996 concerning integrated pollution prevention and control, *Off. J. Eur. Communities* L 257, 10.10.1996, p. 26.
22 Council Directive 99/31/EC of 26 April 1999 on the landfill of waste, *Off. J. Eur. Communities* L 182, 16.7.1999, p. 1.
23 Sewage sludge Directive 86/278/EEC, *Off. J. Eur. Communities* L 181, 8.7.1986, p. 6.
24 Waste framework directive 75/442/EEC amended by Directive 91/156/EEC.
25 Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products, *Off. J. Eur. Communities* L 040, 11.12.1989, p. 12.
26 Communication on Impact Assessment, COM 2002/276 final, European Commission, 2002.
27 Extended Impact Assessment – Proposal for a Groundwater Directive (2003), http://europa.eu.int/comm/environment/water/water-framework/index_en.html.
28 UN Economic Commission for Europe, Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, 25 June 1998.
29 Common Implementation Strategy for the Water Framework Directive, European Communities, ISBN 92-894-2040-5, 2003. Final CIS document available under: http://europa.eu.int/comm/environment/water/water-framework/implementation.html.
30 Harmonised Modelling Tools for Integrated River Basin Management, Harmoni-CA, EU funded concerted action, Contract EVKI-2001-00192, http://www.Harmoni-CA.info.
31 Proceedings of the workshop on Research and Technology Integration in support of the Water Framework Directive, *Environ. Sci. Policy*, in preparation.