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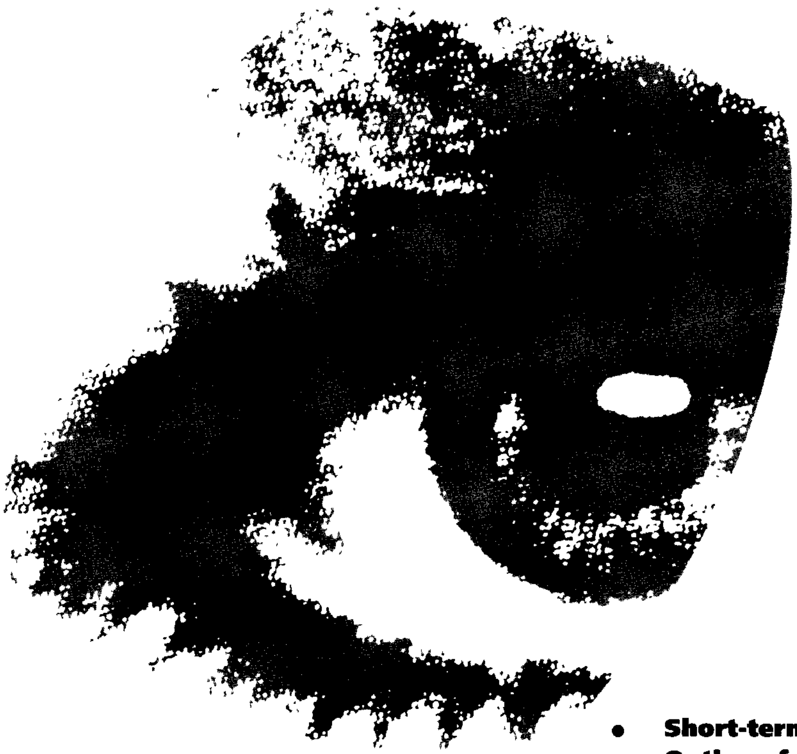

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EUROPEAN COMMISSION
Joint Research Centre

This Report is addressed to the decision-makers involved in 'managing change', seeking distilled, selective presentation of technoeconomic intelligence and prospective alert on under-discussed facets of a topic, rather than a deluge of data and encyclopaedic reviews.

This Report stands as the most visible indication of the commitment of the IPTS to Technology Watch, its main priority and mandate. In this context, the Report aims to focus on issues of projected pertinence for decision-makers, exploring *prospectively* the socio-economic impact of scientific and technological developments. On the one hand, such exploration implies signalling on issues which are not yet clearly on the policy-makers' agenda, but can be projected to draw attention sooner or later. On the other hand it implies alerting actors about underexplored aspects of an issue on the agenda, aspects which, though under-appreciated today may have substantial consequences tomorrow.

The Report benefits from a validation process, underwritten by networks of renowned experts and Commission services, making this Report a product of not only the IPTS but also of its collaborating networks inside and outside of the Commission. The process of interactive consultation used guarantees the validity of the points highlighted, the relevance of the topics chosen, and the timeliness of their examination.

There are many publications excelling within their discipline. The Report takes the extra step, prospectively exploring interdisciplinary repercussions, often drawing surprising connections. Moreover, sharing the Commission's priorities, the Report is still the product of a research institute, and can be a neutral platform for dialogue on issues of relevance and a nexus for facilitating debate.

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CORRIGENDUM

We would like to apologise for the following errors in the 05 Issue:-

- Towards Greener Refrigeration Technologies: p16, para. 5, 'Ammonia is flammable at relatively high concentrations and toxic at low concentrations'
- Climate Change Research - Facts, uncertainties and responses:, p21, para.3, 'A better understanding of the so-called **"missing carbon sink mechanisms"** may also provide corrections to the exptected average temperature increase in the future.; p 21 para.7, 'Oceanic **circulation** and, especially the so-called "North-Atlantic thermohaline circulation" constitutes an internal climatic forcing factor.'

This issue marks the end of the pilot series of the IPTS Report. The warm reception accorded to the Report encourages us to continue providing techno-economic intelligence on topics of anticipated relevance, through the pages of this review. With this issue we also launch a new phase for the IPTS Report, in the sense that the Report will from now on be available at the beginning of the month instead of in the middle, as has been the case so far.

The first article in this issue discusses the rising nitrate concentrations in European ground and surface waters, the drinking water standards with respect to nitrates. It takes into account agricultural policy issues, and suggests that short term technical solutions are called for, as well as longer term, serious reflection towards a strategy addressing health, environmental and agricultural policy concerns in an integrated fashion.

The second and third articles deal with information technologies. The first of the two argues in favour of the importance of parallel computers as the paragons of high performance computing. It is argued that parallel computing, and strong investments therein, are important not only for research reasons but also for applications and industrial competitiveness in Europe, which has not yet fallen behind although other countries have been investing heavily in this field. The next article argues that the repercussions of the information revolution will change conventional ideas of national sovereignty and international relations. The complexity of interactions and the possibilities afforded by the information revolution make decentralisation forces very strong and annul many of the 'constants' people and organisations use to understand, manage, and adapt to the world.

The fourth article explores the promising developments of biosensor technology based on miniaturisation and increased reliability and specificity. The none-intrusive character of such sensors makes them highly useful in certain situations (eg. in medical or police work), but their overzealous use or abuse could open a Pandora's box of privacy violations.

Finally, the last article examines the future of coal technology in Europe. It suggests the EU market itself is not forecast to be strong enough to support technological innovation in the coal industry. China, which is expected to be a very large coal user, may provide the necessary demand which Europe could exploit, especially since environmental pressures may drive China to seek more advanced technologies in which Europe has a lead. On the other hand if the price of such technologies is high, China may develop its own technology, may buy from other sellers, or may simply forego reducing the environmental impact altogether.

The European Confidence Pact for Employment

The European Confidence Pact for Employment, proposed by President Santer to the Heads of State and Prime Ministers meeting in the European Council of Florence (21-22 June 1996), is a continuation of the strategy against unemployment contained in the 1994 Commission White Paper on Growth, Competitiveness and Employment and developed in the "Five Points" singled out for action by the 1995 European Council of Essen[1].

The Pact does not seek a new transfer of powers and/or resources to the European level. The idea of the Pact is rather that of helping the public authorities and the social partners at European, national and local level to work better together in combating unemployment. It does so by proposing a number of directions and steps to be taken by the public authorities and the social partners in four interrelated areas: the macroeconomic environment; the enterprise environment; the labour markets; the European structural policies.

The Pact reaffirms that a macroeconomic environment of stable prices and sound public finances is the most conducive to long-term growth and employment, and that the realisation of EMU in the respects of the convergence criteria in inflation and public finance is therefore "the best friend of future generations". Government and social partners must continue to engage in public finance consolidation and wage moderation but special attention should be given to preserving the levels of investment in infrastructure, innovation and human resources and to restoring the balance between the taxation of labour and other factors of production.

A number of simple steps are suggested by the Pact to improve the competitive environment in which European enterprises operate with particular regard to the completion of the Single Market and the conditions of SMEs: Member States should put an end to the situation in which Single Market directives are not translated into national legislation in such important areas as public procurement, insurance and securities investment; they should reach an agreement on how to achieve the Single Market in electricity and how to cover the gap in the financing of the Trans-European networks; "one-stop-shop help desks" should be initiated at national and local level to deal with all the bureaucratic formalities linked to setting up a business, and the Community legislation for the Single Market should be scrutinised by the Commission for opportunities for simplification (SLIM initiative - Simpler Legislation for the Internal Market).

On labour markets the Pact proposes essentially an acceleration of the reforms of the employment systems which are taking place in different countries. Among the measures that are considered most promising are: the transformation of unemployment benefits in employment subsidies for the enterprises willing to take on long-term unemployed; the promotion of job-creation initiatives in the service sector sheltered from international competition through service-vouchers and local credits; the reorganisation of working time (part-time, "annualisation" of working time, flexible retirement) also through accords reached at European level between the social partners; the certification of professional competencies by means other than traditional school diplomas.

The European structural policies offer, according to the Pact, significant room for manoeuvre for a re-orientation in favour of employment-creating initiatives: areas targeted include SMEs, the sheltered service sector, unemployment-preventing initiatives through the anticipation of industrial change (ADAPT programme). Existing regulations for the structural funds already allows for an informal association of local social partners for projects in the field of employment. This could form the basis for local pacts associating local authorities and social partners at the level of the region or the city. Besides providing direct support, the Community initiatives could facilitate the exchange of good practices between the various cities and regions undertaking the local pact experiment.

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[1] The "Five Points" concern the following policy areas/problems: vocational training, employment-growth intensity, non-wage labour costs, active labour market measures, groups particularly hit by unemployment.

Personal interviews conducted for the article 'Olive Oil on the Increase, Oil Blends on the Attack: Technology and market displacement' which appeared in Issue 04 are as follows:-

International Olive Oil Council

- Mr Fausto Luchetti, Executive President
- Mr Hedi Guerbaa, Adjoint Director
- Mr Aurelio Segovia, Promotion Director

FEDIOL, EC Seed Crushers' and Oil Processors' Federation

- Mr P.Cogels, General Director FEDIOL

SEVITEL, Athens, Greece

- Mrs Rhea Spyridou
- UNAPROL, Rome, Italy
- Dr P.Nigro

Agricultural Research Organization, Volcani Center, Bet-Dagan, Israel

- Prof. Shimon Lavee Instituto de la Grasa, Sevilla
- Prof. J.Alba Mendoza, Experimental Station Director

Instituto de Agricultura Sostenible, Cordoba

- Prof.Paco Orgaz
- Prof.Miguel Pastor
- Dr.Juan Castro

Istituto Sperimentale di Elaiotecnia - Pescara, Italia

- Prof L.Di Giovacchino

Vandemoortele Foods, Belgium

- Mr P.Somers, General Manager
- Junta de Andalucía
- Prof Marino Uceda Ojeda
- Oleicola El Tejar
- Mr.M.Manaute, Coordinador social

  Pieralisi, Spain
- Mr.A.L.Gonzalez Vera, Director Gerente

Short-term and Long-term Options for Achieving Nitrates Standards for Drinking-Water in Europe

L. Bontoux, N. Bournis, D. Papameletiou

Issue: Due to potential adverse public health effects, standards for a maximum acceptable concentration of nitrates in drinking water have already been established in many parts of the world. However, nitrate levels in many drinking water supplies are on a rising trend. In this context, a 1991 European Directive concerning the "protection of waters against pollution caused by nitrates from agricultural sources" set ambitious goals aimed at preventing pollution by nitrates with expected benefits both for nitrate levels in drinking water sources, including groundwater, and eutrophication, etc.

Relevance: The current trend of rising nitrate concentrations in European ground and surface waters, and the numerous cases where the drinking water standards are being breached, has meant that a pan-European reflection in terms of public health, prevention policy and engineering response is now appropriate. Such action should be viewed within a general strategy integrating environmental and agricultural policy issues.

By the end of the 1980's, rising nitrate levels in groundwater made clear that setting drinking water standards (Directive 80/778/EEC) was insufficient and that proactive policies should create the conditions for compliance. Besides nitrogen oxides (NOx) deposition from the atmosphere and other municipal and industrial sources, evidence of the significant contribution of agriculture to rising nitrate levels in groundwater (through the use of nitrogen fertilisers and intensive animal farming), led the EU to adopt the Nitrates Directive (91/676/EEC). This directive seeks to reduce pollution and to prevent the contamination of water by farming practices. However, this will only bear fruit in the long term. Even if all nitrate inputs from agricultural activities were to cease overnight, nitrate concentrations in groundwater would, reportedly in many cases, continue to increase for some years because of the previous accumulation of nitrates in the soil column, where as nitrate concentrations in surface waters would begin to fall quickly.

The benefits of the Nitrates Directive will only be seen in the long term

In order to meet the drinking water standard for nitrate at 50 mg/l, remediation measures are needed. Several different types are already practiced throughout the EU. A normally applied, practical, low cost measure is to lower the nitrate concentration through blending with water low in nitrates. However, blending is already widely practiced and is reaching its limits in some areas. Strict enforcement of the standard will therefore increase the demand for denitrification technology in the short-term. While the use of denitrification techniques such as ion exchange, biological denitrification, solvent extraction, chemical reduction, reverse osmosis, electrodialysis and other membrane treatments, is generally considered as a last resort after blending or development of alternative water supplies, sometimes it cannot be avoided.

The size of the problem

The first report by the European Environment Agency (EEA) on Europe's environment states that there is a pronounced general lack of published monitoring data for nitrates in groundwater. Therefore, the EEA used model calculations to predict the leaching of nitrates from the root zone in agricultural land and estimate the related risk of polluting aquifers. These calculations indicate that for more than 85% of the agricultural lands in Europe, the groundwater one metre below the soil surface is expected to show nitrate concentrations in excess of the guide level (25 mg/l). The same model also shows that the maximum acceptable nitrate concentration (50 mg/l) is exceeded in 20% of the cases.

While the relevance of the one metre depth to groundwater use throughout Europe can be questioned, these calculations clearly show the potential size of the nitrates problem in Europe. It should also be noted that the very different local conditions, such as soil permeability and composition, natural denitrification capacity, groundwater depth, nitrogen inputs, etc. can strongly influence the fate of nitrates.

Data from France clearly illustrate the potential scale of the nitrates problem

Very little recent data on the amount of ground and surface water that exceeds the 50 mg/l standard, and that is used to produce drinking water, has been published. Reportedly, about 11% of the groundwater in Germany contains at least 50 mg/l nitrates. However, the nitrates levels in drinking water supplies have stabilised and are even decreasing in some areas, thanks to a prevention policy applied over the last 5 to 10 years.

Recent reports from France estimate that more than 0.5 million people - in particular in the intensive pig-farming area of Brittany and in the eastern regions bordering Germany - currently receive drinking water with nitrate concentrations that chronically exceed the 50 mg/l standard. Approximately 3.4 million people receive water that occasionally exceeds the standard. Additionally, the Loire-Bretagne water agency estimates that some 60% of the water resources within its catchment area are at risk of becoming unusable within the next 10 years. These data show the degree of urgency required in treating the nitrates problem.

Current policy issues

The EC has already introduced a Maximum Admissible Concentration (MAC) of 50 mg/l and a recommended Guide Level (GL) of 25 mg/l in the Drinking Water Directive (80/778/EEC). The determination of these values was strongly influenced by the work of the World Health Organisation which recommends a guideline concentration (average) of 50 mg/l nitrates in drinking water (1993). The US EPA Federal standard for nitrates in drinking water is 10 mg/l nitrate-nitrogen (i.e. 44.3 mg/l nitrate).

These standards and guide values should be viewed in their context and will not be discussed here. It should be noted that in the proposal for the revision of the Drinking Water Directive, adopted by the Commission in January 1995, the parametric value for nitrate has been retained at 50 mg/l. However, this revision opens the possibility, previously absent, of short-term derogations to the 50 mg/l standard. In any case, although the human health impacts of nitrates no longer appear to be acute, at least in the Western world (see box below), this new flexibility does not question the validity of the existing standard. Because of the possibility of transformation of nitrates into nitrites, the proposed revised Drinking Water Directive also considers a linked nitrite/nitrate standard.

The Nitrates Directive intends to reduce and prevent water pollution from agricultural sources. It requires the Member States to designate Nitrate Vulnerable Zones (NVZ), i.e. areas where, because

Box 1: Effects of Nitrates on Human Health

There are two main public health concerns regarding the presence of nitrates in drinking water: methemoglobinemia and carcinogenicity. Methemoglobinemia occurs when the nitrites present in blood oxidise the ferrous iron (Fe++) of haemoglobin to its trivalent form (Fe+++) which is unable to carry oxygen. This decreases the oxygen carrying capacity of the blood, leading to death in extreme cases. The carcinogenicity concern arises from the possible connection between the presence of nitrates in the body and the formation of potentially carcinogenic N-nitroso compounds.

Although there is strong evidence showing that there is no direct correlation between the amount of nitrates ingested (most of them coming from eating vegetables) and methemoglobinemia, the discussion is still open. Nitrates can be an important factor causing methemoglobinemia in combination with other factors. The toxic effects of nitrates are closely associated to its conversion to nitrite by bacteria in the alimentary tract. There are even cases of methemoglobinemia without any exogenous source of nitrates or nitrites thanks to the endogenous formation of nitrites. Therefore, methemoglobinemia is mostly linked to particular pathologies (infections, gastric disturbances,...) or to bacterial contamination with nitrate reducing bacteria. In this respect, infants are the most sensitive population because of the condition of their gastro-intestinal tract, which is less able to minimise the conversion to nitrite than that of adults. A low nitrate intake is therefore desirable against methemoglobinemia. However, it must be noted that methemoglobinemia is virtually absent from Western Europe.

For the carcinogenicity aspects, it is true that N-nitroso compounds have been found to be carcinogenic in animals, that nitrates can be reduced to nitrites in the human body and that these may react with N-nitroso precursors to form N-nitroso compounds. However, the quantities produced by the human body are far smaller than the doses proven to cause cancer in animals. Additionally, the concentration of nitrates in the human body is not necessarily related to the intake of exogenous nitrates since there is also an endogenous formation of nitrates. There are also many inhibitors of nitrosation (e.g vitamin C), making any link between the presence of nitrates, N-nitroso precursors and N-nitroso compounds difficult. The numerous epidemiological studies published on the topic remain inconclusive, showing positive, negative and absent correlations between exposure to nitrates and cancer rates.

As a conclusion, nitrates do not appear to be a major public health hazard but some concerns remain relative to methemoglobinemia. The evidence on N-nitroso-related carcinogenicity is less strong but it would still be prudent to maintain precaution on the matter.

of agricultural inputs, surface waters contain an excessive concentration of nitrates, where groundwater nitrate levels are likely to, or already exceed 50 mg/l, or where waters are eutrophic. Farming practices within the NVZ must then be controlled to reduce nitrate leaching and run-off. By implementing "Codes of Good Agricultural Practice" and "Action Programmes", Member States are required to make sure that the amount of manure applied during and after the fourth year of the first Action Programme does not exceed 210 kg N/ha per year by 1999. During and after the fourth year of the second Action Programme, in 2003, this value will be reduced to 170 kg N/ha per year.

The EC intends to promote a more harmonised interpretation of the NVZ designations between Member States

Some farmers are resisting the measures proposed by the Nitrates Directive

Since, in the Nitrates Directive, the designation of Nitrate Vulnerable Zones (NVZ) is left to Member States, differences in the interpretation of the term 'vulnerable' are already apparent and affect the extent of the territory designated. This creates differences in the overall influence of the directive in each Member State.

In the UK, this flexibility enabled the Government to designate a much smaller area as NVZ than originally expected: only one third of the area with surface and groundwater exceeding the 50 mg/l limit (650,000 hectares in 70 NVZ out of 2 million hectares). This is because the Government's proposals only apply to groundwater used for the public water supply. Ireland does not intend to designate any NVZ. On the other hand, the Netherlands and Denmark have designated the whole country as nitrate sensitive. These variations reflect both the different philosophies and different local realities in the Member States. However, the Commission intends to promote a common understanding and more harmonised interpretation of the Directive.

Prevention through good agricultural practices

According to the Nitrates Directive, minimum measures that must be included in the Action Programmes refer to restrictions on the timing and quantity of manure applications. Farmers will be required to have sufficient properly designed manure storage capacity to be able to avoid spreading during periods of prohibition. Record keeping of all fertiliser and manure applications is also foreseen. Spreading of manure in areas outside the NVZ and reduction of livestock numbers are also considered as last options.

The implementation of such measures could have significant consequences for the local farming economy, raising serious socio-economic issues, and generating resistance against compliance with the Directive. Many experts believe that the target of 170 kg N/ha per year set for the end of the second Action Programme, will not be attainable in regions of intensive animal farming without a significant reduction in livestock numbers.

Improvements could be achieved through better management of animal feed. Research in livestock nutrition has shown that nitrogen excretion by livestock can be reduced by 20% to 30% simply by modifying animal feed. However, according to the European fertiliser industry, only a 15% reduction can be achieved in practice and this only when the animals are kept in stables.

Aside from the Nitrates Directive there are other measures which also help to prevent nitrate pollution by agricultural practices. In general, the Common Agricultural Policy is increasingly adopting a strategy aimed at reducing the use of nitrates (extensification) and their impact on the environment (land use management). The regulation 2078/92 (Agri-environmental measures to accompany the Common Agricultural Policy) is a good example of this trend, as it provides an incentive to reduce inputs and to protect water resources.

Good agricultural practices cannot be set uniformly throughout the EU. Accordingly, sustainable N-fertilisation practices should be adapted to local conditions (climate, soil, water balance, denitrification capacities in soil and groundwater, hydrogeological flows, etc.). However, in all cases better coordination is needed between agriculture and environmental management. In particular, the polluter-pays-principle should be promoted, a policy which has not yet penetrated the conscience of most of the farming population, as is apparent in the following example.

Recently, the National Farmers' Union (NFU) in the UK, in its attempt to critically review the Government's plans to establish Nitrate Vulnerable Zones (NVZs), claimed that even exposure to 100 mg/l of nitrate would not present "any perceptible risk to human health". Farmers, now being forced by the Nitrates Directive to pay for manure disposal or the reduction of their livestock numbers, perceive the nitrates problem as being "largely hypothetical" and a result of an unrealistically stringent standard for drinking water.

Farmers and landowners in the UK have been objecting to many of the proposed NVZ designations, claiming that they will restrict agricultural activities, reduce farm incomes and depress land values. Moreover, they doubt whether the controls on farming practices specified by the EC Directive will have much effect on nitrate levels in areas where non-agricultural sources, such as sewage discharges, cess pits and nitrate deposition from the air contribute to nitrate concentrations in ground or surface water. This is the case for around half of the land within the proposed NVZ in the UK.

Denitrification technology

Following the establishment of nitrate standards for drinking water in the early 1980's, many actors foresaw a growing demand for denitrification. Significant effort was therefore devoted to adapting known denitrification concepts to the concentration ranges necessary in the drinking water supply industry. The main driver for technological development has been the reduction of cost. However, despite the early expectations of the technology developers, groundwater contamination by nitrate has mostly been solved by tapping deeper wells or by increasing the use of surface water. Denitrification technology has only been applied as a last resort, either for tackling temporary nitrates peaks in the water supplies, or for permanent treatment.

Recent reviews of the commercially available technologies show that most development work has been carried out in Germany, in Italy and in France. Most of the existing commercial plants have been built since 1983 and have treatment capacities between 25 and 2000 m^3 water per hour. The largest plant in Europe is reported to be in the UK. The most popular processes are based on heterotrophic and autotrophic biological treatment (denitrification), ion exchange (denitratation), reverse osmosis, and electrodialysis. Catalytic denitrification is also possible.

Reverse osmosis and electrodialysis remove dissolved solids but do not selectively target nitrate. The indiscriminate removal of dissolved solids and its associated energy costs, together with the need for brine treatment and high disposal costs make these processes uneconomical. Although ion exchange technology remains more nitrate selective than electrodialysis or reverse osmosis, it also extracts other constituents such as sulphate ions from water. The increased chloride ions transfer to the treated water produced by some resins is also undesirable but can be avoided by using CO_2 for the regeneration of resins.

The different biological processes available to remove nitrate from drinking water (fixed bed, fluidised bed, combined membrane bioreactors) do not disturb the ion composition of the water. However, the cost of biological processes is also high, mainly due to the complex post-treatment steps needed to remove denitrification by-products, such as bacterial cells, turbidity and pesticides, which may be present in nitrate-polluted water or which may originate from the direct contact of the water with the denitrifying biomass.

Denitrification technology will only be used as a last resort due to its high cost

Defining good agricultural practices requires a detailed knowledge of the nitrogen cycle

R&D priorities

The fundamental point of the nitrates problem is their presence in an unknown but large quantity in the soil column. Their leaching behaviour is complex and poorly understood. It can be accompanied by natural transformation processes. Most notably, nitrates may be, under certain conditions, eliminated by various natural denitrification processes such as the microbiological reduction of nitrate in the presence of ferrous sulphide, other ferrous ions, methane, or organic matter in the absence of oxygen. These processes can transform considerable amounts of nitrates either into nitrogen gas or into nitrous oxide (N_2O), a potent greenhouse gas and destructor of the ozone layer. They also increase the risk of groundwater acidification by sulphates and ferrous ions. Our understanding of the various sources of nitrogen, its fate in the soil and its transfer to groundwater is still insufficient to allow a determination of the nitrogen load tolerable for a given site. These are clearly important research avenues for the future, as such knowl-

Adopting a preventive policy will be less costly in the long term than relying on the curative approach

However, preventive policies need to be sensitive to their short term problems

edge would be invaluable for the definition of the best agricultural practices.

Better knowledge of nitrogen transfer from the soil to the unsaturated zone and from there to the groundwater would allow a significant improvement of the existing fate models. In particular, it would extend our ability to predict the fate of nitrogen and help in managing nitrogen inputs. Monitoring should be developed in parallel, in particular where data are missing. The improved calibration and validation of the models and the systematic detailed mapping of soil nitrogen is a clear priority across the EU.

Denitrification technologies are already available and used at industrial scale but are expensive. Experts expect an expansion of their market, at least in the short to medium term, leading to a reduction in cost simply through economies of scale. However, in the long term, as stated above, prevention policies should start to bear fruit and limit this expansion. In these conditions, it is unclear whether it is worth investing significant effort into R&D on denitrification processes.

Other areas of interest for future research are the uptake of nitrates by crops, the use of natural or constructed wetlands to reduce the nitrate load to soil and groundwater, the optimisation of the soil denitrification capacity, and livestock nutrition as a factor to reduce nitrates in manure.

The European Commission is currently supporting research on nitrogen saturation in forested ecosystems, the effect of tillage on soil and water quality, and risk analysis of the impact of agrochemicals on soil and water. Nitrate leaching and biological transformation are being investigated in a project aimed at quantifying the effects of various agricultural practices on groundwater pollution by nitrates. Certified reference materials for the quality control of nitrate determination in freshwater are also being investigated.

Conclusions

In order to comply with drinking water standards, water suppliers already use denitrification technology in cases where the raw water supply exceeds 50 mg/l nitrates. This creates additional costs, borne both by them and by the consumers. Since most of the nitrates emissions come from agriculture, and as the polluter-pays-principle is at the base of European policy, farmers should also participate in the costs. This raises short-term implementation issues. However, while curative policies (e.g. denitrification) have a single use perspective and perennial costs, preventive policies (e.g. good agricultural practices) have multi-use perspectives and ensure the long term maintenance of resources. Long term costs are therefore more likely to be lower for a preventive policy even if their short-term costs appear to be high.

The implementation of the European Nitrates Directive was too recent to show any noticeable improvement in nitrate pollution. This is in part because many of the Action Programmes foreseen by the Directive are not yet finalised. It is also because the pollution prevention options taken (e.g. improved agricultural practices) cannot show results in the short-term, and because the nitrates already present in soil will take years to eliminate. Whether the goals of the Nitrates Directive can be met in a timely fashion and at an acceptable cost, and whether the compliance with the drinking water standards for nitrates (80/778/EEC) can also be achieved at a reasonable cost remains to be seen. Already, some early experiences have generated criticism, claiming that the Nitrates Directive is unfair towards agricultural interests. In any case, the continuously increasing nitrate concentrations in European aquifers dictate the need for practical solutions that integrate options for both the short-term and the long-term.

In spite of the prevention measures taken at European level, nitrate concentrations in water supplies (at least in the best characterised water supplies, the overall monitoring being still incomplete), and consequently in drinking water, are generally on the increase. This trend suggests that the number of cases where the nitrate drinking water standard is breached will be increasing. It is now clear that the prevention measures are proving difficult to implement, and will in any case only bear fruit in the long-term. This leaves us with two immediate problems: how to establish harmonised prevention measures for the long term? and how to manage the cases where nitrate concentrations in the water supply exceed 50 mg/l?

Preventing the release of excess nitrates into the environment should be achieved via the integration of environmental and agricultural policies, and the joint consideration of the key issues of eutrophication, acidification and global climate change.

Keywords:

Nitrates Directive, drinking water standards, agricultural practices, denitrification technology

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High Performance Computing: European efforts

Agostino Mathis

Issue: High performance computing (HPC) is a strategic issue with increasingly important applications not only in science and technology but also in industry. Computer simulation, for instance, is becoming a powerful means of understanding the structure and behaviour of very complex systems, both in fundamental sciences, and an increasing number of fields related to applied sciences and engineering.

Relevance: Funding activity in the US and Japan highlights a belief that success in this arena will be helped by cutting-edge R&D on massively parallel computing platforms. The competitiveness of European research, and consequently of Europe's industry, may be helped by the early availability of such systems. In terms of computational applications, Europe is already witnessing the spontaneous constitution of "networks of users" of supercomputing platforms identified as being particularly effective in a specific area.

The new R&D policy environment

The emerging focus in R&D policy, in Europe and worldwide, is on funding "strategic research" - research which has an explicit potential to benefit the nation's economy, health, environment, education, or other important goals. This new focus replaces the goal of simply advancing science, and also the priorities related to military requirements, which have prevailed over the last 40 to 50 years.

A shift in R&D policy towards more strategic research is forcing computer scientists to give more attention to research applications

Similarly, in computer science during the 1980s the challenges were to advance the frontiers of science, or to face military threats. In the 90's, in the new policy context, it is easy to show that computer science and computer technologies are essential tools for the aforementioned strategic areas of research.

In the past, the computer science community has sometimes been described as inward-looking, due to the fact that many of its members have avoided applications entirely. The new perspective should force computer scientists to become more outward-looking.

Exploiting the potential of high performance computing for scientific and economic gain is a challenge that the US, in particular, has attacked with vigour. Some years ago Europe seemed ready to do likewise - but hasn't. There are still, however, windows of opportunity, and Europe may still refocus its attention on this particular grand challenge.

Technological trends

Growth in computing power continues to be astounding and shows no signs of abating: over the next two decades growth will exceed a factor of 1000, and this coming after five decades of already explosive growth. We can expect with confidence that 10 megaflops of computing power with 10 megabytes of memory will cost $5 in 2015, and for practically every computer we are using now, we can expect that by 2015 there will be, for the same cost, 999 other machines working in parallel with it to provide a better service.

On the other hand, we appear to have reached a plateau in terms of the maximum computing power that can be obtained with a single processor based on current silicon technology. Nowadays, therefore, high-performance computing is often synonymous with parallel computing.

Parallel architectures follow a diversity of approaches depending on how the processors are connected and how the calculations are syncronized. From a design point of view, a parallel computer can be considered as an "application-specific hardware/software system", not unlike the computing devices widely used in engineering processes or embedded in commercial products. The development of a unified know-how for the design and the manufacturing of such systems - an approach known as "hardware/software co-design" - is clearly of interest not only for computational applications, but more generally for every kind of intensive data processing required by automatic control, monitoring and multimedia applications.

The increasing performance and availability of personal computers and workstations, easily interconnected by standard hardware and software, is encouraging the spread of distributed computing and is providing an alternative to customized parallel computing platforms. In this case, however, experience shows that communication and coordination between parallel processes, when performed by messages that are explicitly sent and received by processors, leads to a rapid fall in efficiency as the number of processors grows. Moreover, general-purpose off-the-shelf processors, though a natural choice when extending an existing workstation network, are not necessarily the best choice for massively parallel platforms in which hundreds (and possibly thousands) of processors may have to perform a few specific operations very efficiently. Such a general-purpose processor would require considerable space and power, but would only use a very limited fraction of its silicon: application-specific integrated circuits offer a much better solution.

The need for massive parallelism has emerged in computer simulation as a powerful means of understanding the structure and behaviour of very complex systems (commonly called "grand challenges"). A particularly powerful form of computer simulation involves the ***ab initio*** solution of the fundamental equations of a system, to perform self-consistent "computer experiments" to be compared and eventually substituted for "physical experiments".

The powerfulness of such a computational environment is currently exploited not only for the traditional challenges of fundamental sciences, but in an increasing number of fields related to applied sciences and engineering. Some typical examples of these new "grand challenges" are: climate and weather forecasting; air and water pollution management; molecular design for new materials and new drugs; bioengineering; numerical wind tunnels for aerodynamics optimisation of cars and planes; electromagnetic design for telecommunications and control systems; optimal design (with respect to energy saving and pollution control) of engines, both for power stations and vehicles, etc.

The international context

In 1991 the US Congress passed the High Performance Computing and Communications (HPCC) Act, which established a significant increase in federal funding for the principal agencies engaged in supercomputing research (ARPA, DOE, NASA and NSF). For 1995 the budget was about $1150 million. Many universities and national laboratories established complementary programmes and other agencies joined the main four.

While using off-the-shelf processors may be the obvious choice for extending a workstation network....

....a switch to customised parallel platforms can offer enormous improvements in efficiency where only a few specific operations are needed

In 1995, the US Federal government dedicated approximately $1150 to research in supercomputing

Computing power developed under the US ASCI project will help to deal with the most challenging of problems (eg. drug design)

The Department of Energy (DOE) plays a unique role in HPCC. It has been involved in supercomputing for longer than any other federal agency. DOE laboratories are capable of contributing effectively to large innovative projects, which require complex interdisciplinary cooperation and the focusing of resources on a limited number of problems with a higher probability of success.

In 1995 the US Congress defined new guidelines for R&D expenditures, and in particular invited the National Science Foundation (NSF) to increase concentration and qualification in its supercomputing centres, which were used mainly by academic scientists. At the same time, however, President Clinton declared an end to all nuclear testing, and offered the DOE's three weapons laboratories (Livermore, Los Alamos, Sandia) a $3 billion package of scientific projects to replace testing.

Among these projects, the Accelerated Strategic Computing Initiative (ASCI) has been launched, with a request of $910 million by 2002 in pursuit of computers that will surpass today's systems by a factor of many decades in processing speed and in storage capacity. ASCI kicked off on 7 September 1995, when DOE announced a one year, $45 million collaboration with Intel Corp. to build a supercomputer 10 times faster than any in existence. A full quarter of the ASCI funds will be dedicated to the Superlab program, an effort to build a computer network with data transfer rates a million times higher than those of the fastest existing networks.

The ASCI project has evidently been set up to also spur on technological development, by shaping cutting-edge computer technologies in collaboration with universities as well as industry. Non-defence users will also have the possibility of exploiting the computing power, developed under ASCI, for their most challenging problems, like the prediction of forest fires or the modelling of AIDS or influenza to design adequate drugs.

At this point it is clear that the US is ready for another leap in computing technologies and computational methodologies, with respect to both Europe and Japan. However, Japan's industry is well established as a supplier of more traditional supercomputing platforms: a relevant example is the contract that Fujitsu has recently secured to supply the European Centre for Medium-range Weather Forecasting (ECMWF) with a new vector parallel supercomputing system, replacing the existing US made supercomputers, and to provide software and maintenance over a period of almost five years. In such an international perspective, therefore, Europe's position may be the weakest one.

The need for a European policy

A few years ago there were several proposals for initiatives to boost Europe's presence in the high performance computing market, such as the European Teraflops Initiative (ETI), which was largely driven by scientists, and the European Industries and Institutions Initiative (Ei3), which had a strong focus on industrial applications.

An eminent example of an approach initiated by EU policymakers was a study by a committee chaired by Nobel-prize-winning particle physicist Carlo Rubbia. The final report of the Rubbia committee, completed in October 1992, recognized High Performance Computing and Networking (HPCN) as a high priority technology, essential for scientific and industrial competitiveness. The Rubbia committee proposed a 10-year industry-oriented programme driven by user needs, but placed much less emphasis on identifying computational grand challenges and on promoting related, innovative development of high performance computing technologies.

Over the last few years in Europe large R&D efforts in parallel computing have been oriented towards application software, and specifically to the transfer of industrial codes onto parallel architectures. This approach has forced software companies towards "architecture-independent" solutions, i.e. practically to the "message passing" model of parallel computing outlined earlier - where in most cases the messages are passed between microprocessors which are mass-produced elsewhere.

This emphasis may not have been conducive to strengthening the position of Europe's computer makers, or to the development of an effective European activity in the grand challenges (which, as we have seen, are also increasingly frequent in the areas of health, environment and engineering). Success in this arena may be helped by cutting-edge R&D on massively parallel platforms, including mastering silicon design and manufacturing (owing to the fact that in modern computer technology an increasing fraction of high level functions is transferred from software to hardware).

The analysis above suggests the importance of exploiting and developing capabilities to design and build top-rate supercomputing platforms, and of getting these large systems used in the field. The competitiveness of European research, and potentially of European industry, will benefit from the availability of such systems.

Since parallel systems are still something of a novelty for both manufacturers and users, they present a window of opportunity for Europe (though maybe not for long), especially since European competence is not negligible. On the side of computational applications, for instance, it is interesting to note the spontaneous constitution of "networks of users" of supercomputing platforms being particularly effective in their specific area. By means of such networks, it is easy to foster the collaborative development of "computational engines", i.e. integrated hardware/software platforms for the optimal cost/ performance solution of the most challenging scientific and industrial problems. Examples of this kind are already established in the field of computational physics and chemistry, among German, Italian and British scientists, by using the Italian Quadrics parallel supercomputer. Similar networks could soon be promoted in the fields of environment (meteorology, climatology, etc.) and of engineering (fluiddynamics, electromagnetism, etc.).

Europe could further exploit and develop its capabilities to design, build and use top-rate supercomputing platforms

Keywords:

Supercomputing, parallel computing, information technology, computer science networks, complex systems

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The Impact of the Information Revolution on International Relations

SJD Schwartzstein

Issue: The 'information revolution' is bringing about a great number of significant changes around the world. These changes are taking place not only within our societies and within nation-states, but between nations and globally. Just assessing the scope of the changes may be an impossible task, let alone understanding their secondary and tertiary implications. We are entering an era of international relations which might well be called one of 'searching for coherence'.

Relevance: Most existing structures and, indeed, ways of looking at the world were not only developed in the industrial age, but many are rooted in practices and needs of pre-industrial societies. The existing formal system of international relations, fundamentally reflecting 19th century thinking, is rapidly being eroded by significant changes brought about by the so called 'information revolution'.

Many view the changes arising from the spread of information and communication technologies as equal in magnitude to those of the industrial revolution

The term "information revolution" in this paper refers to the significant changes being brought about by the development and widespread (and growing) use of powerful computers, software, computer networks and advanced, high-speed communications, all of which are themselves bringing about change, but which in their totality are having a transforming effect in a number of areas - including, but not limited to, international relations. While there may be a current debate over whether the changes that we are seeing - both the technological developments and their impacts - constitute enough of a discontinuity with the past to warrant the term "revolution", what is clear to most observers is that the changes are, at the very least, significant and far-reaching. Many of us, including this writer, are of the view that what we are witnessing is change of the order of the industrial revolution.

However, the change that we are seeing is still ongoing and one suspects, is still in its early stage - a stage marked by continued rapid technological change (in some areas at exponential rates) and little agreement the most appropriate analytical frameworks or analogues. What is also happening is that technological change continues to outpace the ability of most individuals, governments and, indeed, businesses to adapt, with time lags found in many areas. (It might well be said that an increasing number of technology cycles can fit into any one "policy" cycle.) At the same time, the kinds of issues necessary for public policy decision-making are changing and growing in complexity: questions relating to ecosystems, global climate change and biodiversity are increasingly recognized as vital (quite literally) and are necessarily highly complex; intellectual property issues, already becoming economically and politically significant, will continue to grow in importance as commerce is based more on digitized information than on goods and services.

However, within developed countries the impacts of the information revolution on business and industry, organizations, institutions, governments, media, education and entertainment - virtually every aspect of life - have been significant and are continuing to be felt, not only directly but in second and third order effects. The impacts are beginning to be seen in less developed countries, though typically to a lesser degree. Nonetheless, the changes are not only internal to societies and nation states, but are global and are having real impacts on relations between countries around the world. More broadly, how individuals see themselves, organize themselves, and interact on a global basis, is also changing. But perhaps most significant are the following four aspects:-

- the development of "cyberspace", not simply as a means of communication, but as a place of interaction;
- that we are not only creating complex adaptive systems, but learning from them, imitating them and becoming aware of their dynamics;
- new kinds of intelligence -"artificial intelligence" - which can act independently of human intervention will have increasingly greater impacts;
- the changes which will be engendered by those broad developments will shift much of our thinking and create wide-ranging changes in human interactions.

It should be noted here that while the term "information revolution" subsumes some of the shifts and changes that have taken place as a result of faster communications and uses of electronic media (i.e. radio, television and improved telephone links), these are not responsible for the almost seismic shifts now taking place, although certainly they are not insignificant. These changes, which in many respects have had a good deal of impact throughout the 20th century, have been evolutionary, rather than revolutionary: they have increased the availability of information and increased the pace of everyday life; they have been important in the evolution of industrial-age activities, including warfare, and changed the course of history, but they have their origins in the printing press and the telegraph which should be seen as part of earlier revolutions. Rather, the revolutionary change we are seeing is due to the development and use of computers and, particularly, computer networks. The development, growth, exploration, exploitation and, in some important respects, settlement of "cyberspace" is what is truly revolutionary. The "electronic frontier" is emerging in a number of dimensions: as geography, memory, society, school, forum, market, as reality, "hyperreality" and as a wonderland as fantastic as that of Lewis Carroll. Time, space, distance and identity are challenged. Perhaps what is most extraordinary is that in the space of just a few years - the last decade of the 20th century - the kinds of visions that very recently were considered only science fiction and the imaginative excesses of a few writers, are indeed becoming part of everyday life.

In order to deal effectively with the changes that are taking place, it may be useful to consider the following characteristics of the "information revolution" which may be most relevant to discussion of changes in international relations:

1. There is (and will be) significantly greater availability of ubiquitous information - the result of better, more rapid communications, greater storage capacity, a multiplicity of systems for information retrieval and applications permitting faster and easier processing and use of information.

2. Information is available in a wider range of forms, with varying characteristics, allowing for greater ability to manipulate, replicate, hide and provide for secrecy, deception and disturbance, destruction and disruption.

However, the information revolution is only just beginning...

...its direct impacts, as well as its second and third order impacts will continue to be felt for some time to come

The traditional dominance of the nation state in international relations is slowly giving way to a less coherent, less orderly and less easily understood system

3. More, faster and more precisely-attuned, functionally-integrated feedback loops have been developed.
4. At all levels, the number, importance and effectiveness of individuals and small groups has increased due to their enhanced ability to communicate and manipulate information through computers and computer networks. This results in fragmentation, or the ability to act effectively without central authority.
5. There is greater integration at all levels: greater centralization, integration of functions and interoperability through systems management.
6. Systems have been developed with behaviours little influenced directly by human actions and decision-making.

These characteristics will have considerable impact on the kind of world that is emerging as a result of the information revolution. However, in considering the broad topic of international relations we can differentiate between its impacts on the "formal" or symbolic relations - those conducted through state-to-state relations (diplomacy and officials) - and on "actual" or structurally-based relations.

State-to-state relations, conducted through diplomacy and official exchanges, have changed considerably over the last decade and themselves deserve attention. But the larger, more important changes that we will see relate mainly to the kinds of shifts and changes in many societies - initially, of course, those of the more-developed countries - and many countries. With respect to international relations, there are four general trends which should be given primary consideration:-

1. Coherence

The still-existing (and relatively stable) system of international relations, conducted primarily and almost exclusively by nation states is, if slowly, giving way to a less coherent, less orderly and less easily understood system - one that is likely to reflect a multiplicity of systems and players. Many of the older structures and ways of doing things will have become out of date, obsolete and of relatively little relevance. Many of the old demarcations and boundaries, delineating responsibility, national sovereignty, etc. will lose much of their meaning or will have become complex to the point of requiring entirely new structures. It may be useful to consider the following:

a) ***Structures***: Nation-state governments usually consist of both legislative bodies and bureaucratic structures necessary for the administration of government functions, including the administration of law and the carrying out of policies and plans relevant to relations with other states and international organisations. Key to both legislative functions and government bureaucracies is information and controls of information. But with the "information revolution" there are a number of significant changes with respect to information dynamics:-

- larger amounts of information are available at all levels;
- the capacity for information storage has increased significantly and continues to increase at high rates (20-40% annually);
- the speed with which information is transmitted and is available has increased;
- information flows have become geographically insensitive;
- controls on flows of information have become more difficult to maintain, at all levels - national, intramurally and by hierarchies;
- effective use of information is changing, and is now less a function of possession than of management;
- networks are changing many aspects of how information is handled e.g. information security has become a significant concern to network users.

Within many bureaucracies (governmental and non-governmental) the changed (and changing) information dynamics are having effects on the bureaucracies themselves: largely a "flattening" of hierarchies, an increased number of players and changes in the skills required. What we are beginning to see are parallel "informal" structures co-existing with the older, long-established "formal" bureaucratic structures. Some of the changes taking place within the U.S. Department of State and embassies abroad may be illustrative: communications between the State Department and embassies, traditionally in the form of messages conveyed either through diplomatic couriers or encrypted telegrams, have been subject to the controls of the bureaucratic hierarchy, with authority to send messages restricted. But with the increased use of telephone, the development of faxes and the advent of e-mail, a good deal of communication is now done informally and is not subject to the controls which are still maintained for traditional means of communication. State Department statistics (which may apply equally to other foreign ministries of most Western countries) are telling: from 1985 to 1995, despite an increase in the number of posts (embassies and consulates), the number of telegrams (the formal means of communication) decreased by nearly 20%. E-mail has replaced the older system for many essential communications, particularly those for which timing is critical - and e-mail is not subject to the same hierarchical control, of course.

b) *Boundaries*: The geographically-insensitive nature of network communications has given rise to what is often termed "cyberspace", distinguishable by the absence of geography in any traditional sense or by, what might be termed, an entirely new kind of geography. Flows of large amounts of information of all kinds through networked communications are now commonplace and the ability of networked systems to accommodate greater flows is continuing. Sourcing and production by industry is increasingly crossing borders through use of networks, and the transferal of funds across borders and other financial transactions are now, for the most part, carried out in digital form.

c) *National sovereignty*: The ability to transfer large amounts of information and funds and to transfer technology and conduct business through networked communications not subject to the control of individual governments, necessarily weakens national sovereignty. The ability of most central banks to regulate national currencies has been lost, and networked communications and computer-based trading of stocks have placed important economic activity beyond the control of national governments. Governments' attempts to control information in order to maintain overall control or influence elections are increasingly likely to meet with failure, just as attempts to eliminate flows of obscene or kinds of offensive material have, for the most part, failed.

Likewise, as more and more business is conducted through networked communications, questions of taxation and regulation become more difficult and national approaches are not likely to work. That attempts are being made by various governments to both regulate and tax transactions is itself not an indication that they will either succeed or that, even with a measure of success, they do not raise serious questions. Prime among these will be the degree to which government entities, formed on the basis of industrial or even agrarian societies, should continue to exercise authority in a much-transformed world.

2. Fragmentation and Multipolarity

The ability to organise globally through computer networks, the increased access to information and the speed with which individuals can coalesce has given rise to both an increased number of groups and a greater ability of those groups to mobilise effectively. Even though computer networking is still at a relatively early stage in development, we have already seen the effectiveness with which individuals and groups have been able to organise and generate political action through the sharing of information (as in using Web sites) and network communications (both laterally and through messages to important parties, such as legislators). Combined with still important older forms of communication - such as the news media - we have been seeing activist groups (e.g. Greenpeace) and corporations (e.g. Shell) play important roles in determining public policy. At the same time, insurgent

The advent of e-mail allows more informal communication, which is not subject to the same controls as traditional telegrams or letters

Government authority is becoming increasingly difficult to enforce

Geographical boundaries become irrelevant in an information society

Use of the computer network is increasing the number of different interest groups and enabling them to mobilise more effectively

In an increasingly complex world there are fewer agreed-upon rules and fewer central controls

groups, like the Zapatista group in Mexico are able to wield considerably greater power in resisting central authority. Similarly, opposition groups like the Bahrain Freedom Movement based in London, are able to communicate and provide information to large numbers quickly, comprehensively and in ways that the Bahraini government cannot control. The "cassette revolution" of Khomeini, first superseded by the use of faxes (as by the Chinese students at the time of the Tiananmen demonstrations) has now been superseded by the use of computers and computer network communications. With this, the power of the state may well be circumscribed or, at least, must change in how it is exercised.

3. Complexity

The world is becoming considerably more complex (and being recognised as such) with larger numbers of significant players at a variety of levels, fewer agreed-upon rules (other than protocols, as with internet protocols) and fewer central controls. Key to the development of this more complex world is networked computing: large numbers of systems can organise in various ways, without central control, various groups can coalesce, and vast amounts of information can be transferred, stored or utilized. A larger number of players, able to interact with each other in a variety of ways, certainly makes for a less-tidy, less organised world, but the often far-flung, less-bureaucratic and decentralised nature that many organisations are showing now, and which will be increasingly commonplace in the future, will make organisational behaviours more difficult to predict as well. In addition, it might be considered that the systems themselves, as with complex adaptive systems, may behave in ways that are either not entirely predictable or which pose difficulties for decision-making.

4. Ambiguity

Greater complexity, a greater number of players and a large number of difficult-to -resolve issues (e.g. those with respect to jurisdictions) will undoubtedly result in a number of policies and positions that are open to a variety of interpretations - that is, which are ambiguous. The large amounts of available information will necessarily add to this ambiguity by giving rise to significant differences in analysis and interpretation. The lack of clear-cut authority - which is likely to become increasingly common in a world of "flattened" hierarchies and bureaucracies - will enable these different interpretations to become more widely available, as information flows are not subject to the same degree of central control as has previously existed.

In closing, the statements above should not be taken as contending that nation-states will disappear in the foreseeable future due to the impact of new technologies. They are likely to remain in existence, in many (perhaps even most) respects in much the same form as at present, but they will be forced to evolve in ways that reflect the impacts of new technologies, the creation of "cyberspace" and significantly changed attitudes. As with many older institutions through history whose authority and power has risen and fallen over time, - like that of the Church, the Holy Roman Empire, local nobility, the communist party and other institutions and organizations, nation-states will be forced to change, for the most part ceding power or finding that authority simply cannot be exercised with the same degree of certainty.

Keywords:

Information society; international relations; national sovereignty

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Where Sensing can make Sense: The example of biosensors

Mario Demicheli

Issue: Sensor technology has recently entered a phase which stresses practicality, miniaturisation and reliability. One of the key advantages of using biological components in sensors is their specificity for particular substances.

Relevance: The use of biosensors would be an invaluable tool in preventive medicine, alleviating health expenditure burden. Moreover, the introduction of the novel multisensor approach in the food industry, environmental monitoring or the detection of clandestine drugs might call for a redefinition of current standards. On the other hand, the use of such technology could raise ethical problems, since biosensors may compromise privacy. Thus, both the positive as well as the potentially problematic aspects of biosensors call for a general thematic debate on how to best deal with this technology.

Single sensor vs. analytical system

From a general perspective there is competition between a single sensor approach and the analytical system approach, originating in their economics. Attaching suitably hard laboratory-type analytical instruments to industrial processes has always been expensive. Hence the need for on-line sensors that are simpler and therefore more economic. However, with the development of manufacturing techniques within the electronics, optics and photonics industries, it is now possible to miniaturise analytical instruments to such an extent that they may become competitive with single sensor approaches. Thus, the competitive advantages of each approach are being reduced by technological change. At minimum a sensor needs to have signal conditioning and a display and so, in fact, will always be a system. Furthermore, today's sensors are making use of the same miniaturisation trends seen in analytical instruments, and we now have sensors with integrated signal conditioning and sophisticated functions (smart sensors). So, while the question still exists as to whether simple single function sensors or more powerful and flexible analytical systems should be used, in reality these two extremes are moving closer together.

The capabilities and cost of single function sensors and powerful analytical systems are now beginning to merge

Recent technological developments

Gas sensors

Array microsystems of conductivity sensors can now include several dozen metal oxide detectors in an area of less than 10x10 sq. mm. The sensing material is integrated with advanced processing techniques for pattern recognition and data evaluation, such as chemometrics or neural networks [1]. This enables the analysis of more than one component simultaneously. Research is now being oriented towards customising the selectivity and improving the stability of the sensing material [2].

While glucose sensors are already commercialised, there is potential for biosensors to contribute much more widely to preventive medicine

Biosensors in medicine

Biosensors are devices combining a biological recognition system and a transducer - which translates the result of the biological interaction proportionally into an electric signal. This enables the detection of traces of substances in complex media with high sensitivity.

One type of biosensor, known as the "amperometric" biosensor, now allows the sensing of almost all biochemicals [3]. Biosensors of this type incorporate progress in the areas of the sensing of bioaffinity reactions (e.g. between antigens and antibodies), the sensing of DNA hybridisation and the sensing of glucose *in vivo*. Single-use glucose sensors for home glucose assay by diabetic patients have recently been commercialised [4].

Cardiac infarction diagnosis should become faster thanks to a biosensor which detects the tissue where, within two to three hours, a stroke will occur. The 'heart' of the instrument is a graphite electrode, on the surface of which an antibody molecule reacts selectively in response to a fixed, abnormal tissue content in blood plasma [5].

In the USA a microphysiometer has been constructed which allows the characterisation of isolated cells and examination of medication effects. German researchers have developed an interface between neurones and silicon chips. Such a joint-element can transmit nerve signals onto an electronic module. With the additional help of biosensors, the function of specific nerve centres can be studied [6]. The impetus for development of neurosensors lay in the continuing search for sensors that are non-invasive. Unlike microelectrodes, which can damage the neural membranes when suction is applied, the recently developed biomagnetic neurosensors are not in contact with the nerve tissue [7].

Biosensors for environmental control and monitoring

A novel methodology for direct monitoring of hazardous gases in air uses biological probes enclosed in polymer electrolyte gels 'wired' to electrochemical transducers. The resulting "gas micro-biosensors", can tackle chemical sensors' inherent problem of poor resolution in complex mixtures.

Non-fouling, hydrogen peroxide sensors have been developed for multiple or continuous use in flow systems. These sensors are more stable in biological fluids than those employing platinum surfaces [8]. At RCAST (University of Tokyo), researchers are considering microbial sensors (MBs) for on-line control of biochemical processes. In particular, the rapid detection of organic pollution in the presence of interferences is possible with these sensors. MBs also offer an alternative to generally expensive enzyme sensors, and their future applications rely on progress in genetic engineering, i.e. improved microorganisms for conferring the sensor on higher selectivity [9].

Of particular interest is the use of cultured mouse neurones to detect organophosphate nerve agents in the soil. The approach involves the exposure of nerve cells to contaminated soil samples and the subsequent use of biochemical assays to determine the concentration of specific molecules that corresponds to exposure levels in the soil [7].

However, when evaluating a contaminated environment, sensing alone is rarely sufficient. A vast amount of complementary work is often needed to trace pollutant transformations, and to understand and model global environmental impacts.

Biosensors for drug detection and analysis

There is a pressing need for a universal, sensitive, hand-held monitor for the rapid detection of traces of commonly trafficked drugs. This is particularly important for non-intrusive searching of travellers for possession or trafficking of illegal drugs. Ion mobility spectrometry technology has been proving very efficient in the detection of drugs and explosives in America and abroad. Its main drawbacks, however, could be its lack of functionality, and limited sensitivity compared to potential biosensor applications.

At the moment distinct biological-sensing agents can be used in biosensor development for drug or toxin detection, such as receptor proteins, enzymes that act as receptors for drugs, or antibodies. A research group at the Karlsruhe Research Centre is currently working on the development of biosensors for drugs to be used in clinical emergency diagnosis (overdose) and drug monitoring (including self-measurement by the patient). These two fields require fast, reliable, pocket-sized instruments that can be used outside the laboratory with no special training. Biosensors can fulfil these requirements. On this basis a biosensor for salicylate and theophylline has already been developed, and this scope is currently extending to paracetamol, barbiturates, tranquilisers and alcohol [10]. A recent paper describes a novel liquid chromatographic assay for the selective quantification of D9-tetrahydrocannabinol, the major indicator of cannabis intoxication in saliva [11].

Current biological techniques for detecting cocaine employ immunochemical assays, animal olfaction, electrochemical biosensors and acoustic wave biosensors. Although highly specific and sensitive, these methods require physical contact with some amount of the substance - even if traces - left in clothes, skin or luggage for detection and analysis. A special case of drug trafficking control is non-intrusive inspection of luggage and containers in customs. In this respect, technology developed by the US Navy is being secretly tested by British airport security officials in a bid to stop the smuggling of drugs and explosives. Unlike previous detector machines it needs no surface trace of substances, therefore leading to fewer false alarms. The detector uses a technique called quadruple resonance (QR) in which the response to pulsed, low intensity radio waves sent onto the luggage is analysed, then compared with "fingerprints" of drugs and explosives stored in the detector's memory. This technology is to be integrated with existing baggage screening systems [12].

Biosensor Trends

Currently, glucose sensing for the control of diabetes is the only high-volume market for biosensors. Yet a variety of lower-volume niches are available for exploitation in medical diagnosis and the pharmaceutical and other industries. The area of intensive care is promising, especially for enzyme- and antibody-based biosensor developments. Real and potential advantages of biosensors over the more traditional methods of analysis include lack of sample preparation, fast response and portability (e.g. immunoassays in the field). Nevertheless, the many areas deserving biosensor applications are also open to non-biosensor methods. These include small clinical laboratory analysers, portable gas and liquid chromatographic systems, and simple colour-change dipstick tests which create serious competition to biosensor development [13].

Over the next 50 years, the structural engineering of silicon may give rise to revolutionary applications. The procedure of making and combining miniaturised mechanical and electronic components is known as micro-electromechanical systems, or MEMS. Micromechanical devices will allow electronic systems to sense and control motion, light, sound, heat and even chemical properties [14].

Biosensors with associated microelectronic components in minute, autonomous detection systems will even be able to be implanted in the human body. Measurements of the content of sugar or fats in blood as well as uric acid will become available. Presumably, they will also make possible the determination of hormones and the so-called marker-proteins; these are substances which can signal a diseased state in an organism.

Biosensors have the advantage of being both quick and easy to use, and of providing an immediate response

Developments in the structural engineering of silicon will enable the eventual combining of biosensors with microelectronic components...

. the resulting minute detection systems could have far reaching benefits, not least for medical diagnosis and monitoring

The use of biosensors raises important questions about personal freedom and confidentiality

In about 20 years, biosensors will allow the continuous monitoring of the functioning of implanted organs, e.g. artificial pancreas. More generally, these instruments will make health care provision easier and help to lower medical diagnosis costs. In environmental analysis, impurities in air and water will be detected earlier than has been the case to date [6].

Immunoassay technology is rapidly taking on a biosensor format, especially in "point-of-care" circumstances. BIA, a biosensor technology for monitoring biomolecular interactions in real time, is having a significant impact on analyses in the field.

Atomic force microscopy (AFM) can be used to monitor the force of interaction between individual pairs of biological systems. Molecular nano-biotechnology is a rapidly advancing branch of this technology and creates the capacity to hold, position and manipulate individual molecules at surfaces. Such techniques will be required in the next century to make nano-machines, sensors, micro-robots and imaging systems [3].

Useful applications but problematic implications

Multiple gas sensors would be useful for detection and quantification of gaseous air contaminants at low cost. Control of simple processes with gaseous emissions such as food production and ageing, or the control of combustion processes are also good candidates for these systems.

In medical diagnosis, biosensors can already announce heart strokes and could help to identify, *a priori,* a tendency to cancer through regular analysis of exposed organs (lungs, liver). This broadens the scope immensely for preventive medicine.

In the field of bioremediation, highly innovative multi-sensors will help face two major challenges: first, the development of an automatic, continuous monitoring system which can be assembled in a specific site (soil, surface/ ground water) and transmit data to a central station; second, the development of a disposable screen probe and a simple pocket instrument for measuring directly in the field. Targeted pollutants range from pesticides, hydrocarbons, heavy metal ions and bacteria, to toxins such as polychlorinated biphenyls (PCB). Furthermore, organophosphates are found not only in pesticides but also in chemical warfare agents, and neurosensor screening could help monitor the use and abuse of these potentially deadly compounds.

The flip side of the coin is that a highly efficient laboratory may become available to the public. People could be monitored and/or examined in many different contexts, with or without their consent. Biosensors will make it possible to identify a driver who has been abusing cannabis, or other drugs, thanks to a little sample of saliva; but they will also show whether an office employee or a customer entering a shop has been drinking - and even how much, or whether he has dietary habits which employers may not approve of. Biosensors will enable the continual surveillance of people who have critical health problems, or who are overstressed; but this capability could easily be extended for purposes other than for medical surveillance, for example, for recruitment purposes. Clearly, these issues raise ethical questions about violating privacy. Furthermore, this multi-availability of tests could be abused by insurance companies. Individuals must therefore be assured the right to limit outsiders' access to private and confidential information.

In summary, in the coming decades a growing market for low-cost systems combining minute mechanical, electronic and biological components may have a profound impact on society by providing improved security and health care services. In environmental monitoring (control of impurities in air, water and soil), the food industry (quality control, elimination of frauds) as well as in other, not yet contemplated, detection arenas new standards might be necessary to keep up with the development of ever more sophisticated sensors. However, these advances come with a warning about the negative effects that the abuse of such techniques may have in the hands of the wrong people, or even authorised users if utilised overzealously, without attention to privacy concerns.

Keywords:

biosensor, health care, food industry, environment, drug abuse, ethics

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The Future of Coal Technology in Europe

P.Russ

Issue: Environmental concerns such as the acid rain and climate change have put pressure on coal as a fuel for electricity generation. While the future of coal technology in Europe is uncertain, China is currently building up considerable coal-fired capacity and is projected to do so over the next twenty years. Hence, a substantial market for coal technology exists.

Relevance: Europe currently enjoys a lead in coal technologies. China's inclination to use coal as an important energy source, with the associated environmental repercussions, will enhance demand for clean coal technologies. The provision of such technologies by European firms may have beneficial effects, both for the environment and for the firms themselves which, in the current market, face an uncertain future.

Coal is still one of the main pillars of European electricity supply. In 1992, 36.5% of the total electricity generated and 65.3% of the fossil fuel electricity generated in the EU was produced by coal-fired power plants.

However, the prospects for new coal capacities in the EU are not optimistic. Environmental concerns, such as the acid rain debate and especially the climate change issue, have put pressure on coal as a fuel for electricity generation. With diminishing demand within the domestic market, the future of European coal technology may be uncertain.

European coal technology suppliers face a declining domestic market.

The situation within the EU

Within the European Union, environmental considerations have a significant impact on decisions regarding which type of new power plants will be built in the future. In order to comply with environmental regulations aimed at the reduction of acid depositions, additional investments are necessary especially for coal-fired power plants. The debate on global warming has led to a perceived need to reduce carbon dioxide emissions. This again puts pressure on coal, being the fossil fuel with the highest specific CO_2 emissions. Combustion of natural gas, nowadays the main challenger, produces less carbon dioxide per energy input. Additionally, the use of natural gas allows combined cycle systems to be developed easily and cheaply, with efficiencies of 55% and more. When compared to the 45% efficiency of advanced coal systems, the impact on CO_2 emissions is clear. The coal-fired plant will release about 0.8kg CO_2 per kWh of electricity generated, and the gas-fired combined cycle system will release about 0.4kg CO_2 per kWh. Besides advantages in terms of emissions, natural-gas-fired power plants offer shorter construction times, and lower investment costs. Even if leakage from gas piping may offset the potential advantages with respect to CO_2 emissions, cost-advantages still favour gas-fired plants. Against this background the prospects for coal, at least in the medium-term, are not optimistic. Coal-fired power plants have been closed to be replaced, increasingly, by gas-fired combined-cycle systems.

Despite natural gas' clear economic and environmental advantages ......

In the long-run, the situation could change in favour of coal. The increasing demand for gas may have a significant impact on the availability and price of natural gas, which in turn may improve coal's competitive position. Also, in the long term, availability and security of supply considerations may plead for the use of coal. Coal reserves are larger and more evenly distributed, hence reducing the risk of becoming overly dependent on one or few suppliers. Another factor relevant to the coal versus gas debate is the hydrogen content of natural gas. While combustion of coal is depleting the world's carbon resources, burning of gas is depleting the much more limited free hydrogen resources. It is therefore possible to develop an argument on sustainability grounds in favour of coal use.

However, a possible revival of coal power plants in Europe in twenty or thirty years may not be enough to justify efforts to maintain the leadership in coal technology over this extended period. Only if, in the foreseeable future, considerable markets for European coal technology exist can the industry survive in a competitive market.

Searching for markets

Since the market for coal technology within the EU is uncertain, other potential markets outside of the European Union have to be found. Indeed there are a number of markets like China, India and Eastern European countries, where coal will maintain its position as the main fuel for electricity generation. Attention is necessarily drawn to China, where most of the world's new coal-fired power plants will be built.

The market for coal technologies in China is indeed impressive: more than 200GW of new coal-fired capacity is projected up to the year 2010, equivalent to adding between ten and twenty 1000-MW power stations per year. The necessary capital for this capacity extension is estimated to amount to approximately US$134 billion. Naturally such a huge market is well known within Europe, and the potential in China is often mentioned as an argument in favour of maintaining European leadership in coal technology. If this market could be successfully penetrated the future of the European power plant industry, and hence its jobs, would be secured. The total potential mentioned, however, does not reflect actual export possibilities. The enormous investment necessary to build up Chinese power plant capacities should be weighed against a shortage of capital within China. A recent analysis of costs carried out by Chinese institutions indicates that the cost of building equipment in China is one-half or less than the cost of importing it from industrialised countries. The share of imports in power systems equipment has already been confined to around 20%. Also, in the future China will try to limit its imports as much as possible, hence reducing the potential of European suppliers to export technology.

A further constraint for European coal technology exports is the fact that China prefers to buy standard applications rather than advanced coal-fired systems. Lower skills are required to operate the standard plants and less risk is associated with well-established, proven technologies (see recommendations of the World Bank). Furthermore, buyers' contributions to the power plants can be higher, and the total capital necessary lower.

The competitors

The Chinese market may be huge, but the share of European technology in the market is uncertain. All efforts to maintain European leadership in coal technology do not necessarily help in successfully penetrating the market in China or elsewhere, because currently advanced technologies are not in demand. On the other hand, development carried out in the US, a main competitor, serves a two-fold purpose. Since the future of coal in the US is not in question, the technology will be applied in the domestic market and, additionally, the technology can be exported. In the long-term, therefore, the US power plant industry has the advantage of lower risk because of a stable domestic market.

.... coal's long-term prospects are favourable.

The market for coal technology outside of Europe is substantial, especially in China

European manufacturers face competition from the US...

...and the Chinese themselves

China, too, has to be seen as a serious competitor. Co-operation contracts and joint-ventures with foreign companies, together with the learning effect gained from huge plant investments, will necessarily lead to some domestic expertise. Unlike small economies, China's huge domestic economy allows factories to achieve sufficient economies of scale to produce most types of equipment. Sooner or later, at least standard coal technology will be sourced almost entirely domestically, hence leaving only a relatively small share to foreign competitors.

Creating markets: power plants for nature swaps

Within the EU, as well as on a global scale, the market situation does not seem to be conducive to efforts to maintain Europe as the stronghold of coal technology. Nevertheless, the European concern for the environment; Europe's existing position in coal technology; and the fact that on a global scale coal capacities will increase, all point to a basis for the future of European coal technology.

The EU should look to joint implementation of advanced coal technology with developing countries

On-going negotiations dealing with the threat of global climate change are showing that the EU and its Member States are willing to take the lead in actions to tackle the problem. Joint implementation schemes are being discussed seriously (see IPCC). The underlying idea is that CO_2 emissions should be reduced where it is cheapest. "Joint implementation" schemes would allow industrialised countries to comply with their commitments within international agreements by financing CO_2 reduction measures in other countries, thus nevertheless reducing global emissions. The joint implementation projects currently in place focus mainly on renewable energies and re-forestation. However, coal technology also presents a means to reduce CO_2. Advanced coal technology can reduce CO_2 emissions by approximately 20% in comparison with standard technology. If 200GW of additional coal-fired power plants were built in China with advanced technology, over the plants' lifetime the CO_2 emissions saved would amount to 9Gt. (assuming 45% instead of 37% conversion efficiency, 40 years lifetime, utilization 75%). This is three times the CO_2 emissions of the EU in 1992

With regard to this CO_2 reduction potential, the EU and other countries may be willing to provide advanced environmentally-friendly coal technology to China and other countries under a joint implementation scheme at subsidised below-cost prices. Such a deal should be mutually beneficial since the receiving country would enjoy the advantages of the advanced technologies namely higher electricity output and lower local pollution as compared to standard technology, and the foreign investor would achieve the lower global CO_2 emissions. Additionally, such a "power plant for nature swap" would create a market for advanced European coal technologies and hence serve as a basis for the future of the European coal equipment industry.

Keywords:

electricity generation, coal technology, China, competitiveness, technology transfer, environmental protection

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Workshop on Institutional and Methodological Issues in Long-Term Management of Water Resources

The Directorate General for Research (DG XII) and the Forward Studies Unit of the Commission organized a workshop in Brussels on 13 May 1996 aimed at fostering an exchange of information on research, in progress or recently completed, on institutional, socio-economic and methodological aspects of long-term, sustainable water management.

The meeting examined driving factors behind trends in water supply and demand, and the likely implications of these trends. The experts noted that variability between Member States in methodologies for data collection and reporting makes comparisons and integration of data difficult. Furthermore, the system of supply and demand is, in fact, a "complex" system and models need to include feedback variables such as the impact of increased supply on demand levels, and socio-cultural factors.

Nevertheless, it is apparent that in many parts of Europe water demand is increasing, largely due to socio-economic and demographic factors. Land reforms in some Central and Eastern European countries have temporarily reduced agricultural demand, but this trend is expected to be reversed in the near future as land ownership issues are clarified. One of the possible consequences of an increased demand for water may be the increasing emergence of transboundary water resources management issues which cannot be managed within the national planning context.

The experts emphasized that water management planning cannot be based on averages which conceal regional and inter-annual differences. Many countries may experience severe regional water problems even if national averages of quantity and quality appear satisfactory. Similarly, it is the non-average years in which droughts and floods occur.

It was noted that although price increases may have some impact on urban demand levels, the public's impression of the severity of water shortages may have a larger impact on domestic water usage.

Considering both the probable changes in water demand, as well as the possible impact of climate change on the hydrological regime, it is important to ensure that one of the design criteria for water supply systems is a "robustness to an uncertain future".

The countries of Europe demonstrate a wide variety of water management systems, including different mixes of private vs. public management responsibility, different levels of centralised control, and varying philosophies about the relative role of technological, economic, political and social instruments for balancing supply and demand. The system in each country largely reflects its historical and cultural context, rather than any natural characteristics of the landscape or climate.

It was noted that the national innovation system needs to be evaluated to understand the technical choices that are made within a country. However, most present-day water resource problems exist not because of a lack of appropriate technological solutions but because of social and institutional problems blocking the decision-making process. Examples of such problems include: fragmentation of water management decision-making (both by sectors and geographic level), and the mismatch between the structure of existing institutions and new water management goals (including the EU directives).

Engineering and economics are the traditional water management tools for making supply meet demand. However, in order to promote sustainable development, socio-economic and environmental goals also need to be included in the planning process, as well as consideration of the cultural and political climate. As a result, what appears to be the "best" technical solution is often not the best overall solution for society. The experts concluded that the changing context makes it difficult to continue using the 'old' logic of infrastructure management (to continually build supply to meet demand) and that demand side management must be emphasized in the future. Furthermore, the "hidden" subsidies to water users should become an explicit variable in the decision-making process.

In general the EU water directives were felt to have played an important role in raising consciousness and improving the quality of European surface waters. There was some concern, however, that in certain situations the directives encourage a mentality among national planners that the goal is strictly compliance, rather than optimization of water management. It was noted that the directives have been implemented very differently between countries. The decision on how to implement is often influenced by what is socially and politically feasible in each national situation. However, in all cases, implementors and lower-level actors (users) should be more involved in policy development.

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My suggestion for a name for the IPTS Report is:

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The Institute's main activities, defined in close cooperation with decision-makers, are:

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