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FOREWORD

At its meeting in November 2003, the Working Party on Global and Structural Policies (WPGSP) agreed to undertake work on the linkages between selected Multilateral Environmental Agreements (MEAs) and private investment activities. This work has so far generated the following outputs:

- an analytical background report [ENV/EPOC/GSP(2004)4/FINAL]; and
- an experts workshop which took place in Helsinki on 16-17 June 2005, involving representatives from governments, MEA Secretariats and implementing agencies, business, civil society organisations, academia and other stakeholders.

The overall objective of this work is to draw conclusions for improved coherence between MEA and investment policy goals, including ways of maximising the contribution of the private sector towards the achievement of global environmental goals by supporting the implementation of MEAs.

The above-noted Workshop was organised in co-operation with the Finnish Ministry for the Environment. The Workshop could not have been organised without the financial support received from the Governments of Finland and The Netherlands. This support is gratefully acknowledged.

This paper summarises the presentations, discussions and key messages that emerged from the Workshop. It has been written by Simone Gigli and Cristina Tébar Less (OECD, Environment Directorate).

The report does not necessarily represent the views of either the OECD or its Member countries. It is published under the responsibility of the Secretary General.

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LIST OF ACRONYMS

CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CEITs	Countries with Economies in Transition
CERs	Certified Emission Reductions
CFC	Chlorofluorocarbon
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO_2	Carbon Dioxide
COP	Conference of the Parties
CSR	Corporate Social Responsibility
CUTS	Consumer Unity & Trust Society
EBRD	European Bank for Reconstruction and Development
ECA	Export Credit Agency
EU	European Union
GEF	Global Environment Facility
GHG	Greenhouse Gas
GM	Global Mechanism (of the UNCCD)
HC	Hydrocarbon
HFC	Hydrofluorocarbon
IFC	International Finance Corporation
IIED	International Institute for Environment and Development
IISD	International Institute for Sustainable Development
ISO	International Organization for Standardization
MDB	Multilateral Development Bank
MEA	Multilateral Environmental Agreement
MES	Markets for ecosystem services
MOP	Meeting of the Parties
MW	Megawatt
NBSAP	National Biodiversity Strategy and Action Plan
NEFCO	Nordic Environment Finance Corporation
NGO	Non-Governmental Organisation
NO_x	Nitrogen Oxide
PPP	Public-private partnership
SBSTTA	Subsidiary Body in Scientific, Technical and Technological Advice
SEC	US Securities and Exchange Commission
SO_x	Sulfur Oxide
UN	United Nations
UNCCD	UN Convention to Combat Desertification
UNEP	United Nations Environment Program
UNFCCC	UN Framework Convention on Climate Change
WRI	World Resources Institute
WWF	World Wildlife Fund

PART I

EXECUTIVE SUMMARY: KEY MESSAGES

Governments have the main role to play in MEA implementation, but private investment is also crucial for attaining MEA objectives.

- *Implementation of MEAs needs the involvement of all actors.* MEAs deal with global environmental problems, and the way in which they are addressed is decided by the Parties. Governments have an important role to play in facilitating private investment and supporting of other actors towards achieving the goals of MEAs.
- *MEAs provide both challenges and opportunities for private investors*. Business is both part of the problems and part of the solutions addressed by MEAs, and therefore needs to be involved directly in MEA implementation. Governments and business should work together to explore opportunities for business to further contribute to MEA implementation.
- *Governments can promote private sector engagement, inter alia*, by supporting public-private partnerships, promoting capacity building, contributing to the development of markets and trade opportunities (*e.g.*, carbon financing opportunities and markets for renewable energies).
- *Partnerships between different stakeholders*, including public-private partnerships, can be helpful in establishing more effective policies and legal frameworks for business involvement in achieving MEA commitments and goals. They can also help overcome budgetary restrictions by providing new sources of funding, and harness the efficiency of the private sector.

Other stakeholders can also make an important contribution to MEA implementation.

- *International governmental organisations and MEA Secretariats* can disseminate information about MEA objectives, provide technical support and assistance to technology transfer, develop guidance for business involvement, and (in the case of financial institutions) provide financial support to projects that help achieve MEA objectives.
- *Civil society organisations* can contribute by supporting environmentally-friendly projects; raising public and consumer awareness; exerting pressure on governments and the private sector, and by providing technical assistance and training.
- *Financial institutions* can contribute to MEA goals, by requiring that supported projects comply with environmental standards, and by providing instruments to mitigate the risks associated with innovative investments.

There are many ways for private investors to get involved in achieving MEA goals.

- *Enterprises can contribute to the implementation of MEAs, while, simultaneously achieving good business outcomes.* They can do so by, *inter alia*, enhancing their overall environmental management, engaging in innovative investments, developing and transferring environmentally sound technologies, entering into partnerships with other stakeholders, and creating funds to support specific MEA goals.

- *First steps for enterprises to support MEAs* can include linking MEA objectives to the company's core business and corporate social responsibility approaches, and developing business plans and feasibility studies around concrete business opportunities and sustainable development benefits.
- *Private sector involvement in MEA implementation can bring many advantages, but some caution is also needed.* For example, the environmental impacts of investments need to be carefully assessed to ensure that global and local environmental problems are adequately addressed.

Trust, stability and a solid regulatory framework are keys to involving business in MEA implementation.

- *Investors require stability to engage in long-term operations.* Predictability is important: before engaging in risky and innovative investments in support of MEAs, investors need to know what is expected from them, and by when.
- *Governments can build trust* by putting in place and maintaining solid and predictable regulatory systems and effective enforcement mechanisms; long-term strategies for MEA implementation and private sector involvement in such strategies (including long-term incentives); transparency and effective involvement of all stakeholders in the development of macro-economic policies and assessments of "what has worked and what has not".

For business to get involved, MEA objectives and targets have to be clear.

- *Clear and concrete objectives and targets under MEAs* create a framework within which the business sector can both align its practices with MEA goals and seize new business opportunities. Some MEAs include clear objectives, *e.g.*, those established under the Montreal and the Kyoto Protocols. Most MEAs, however, have general objectives, which cannot always be easily translated into concrete action by the private sector, and further efforts may therefore be needed to improve clarity, as a step toward enhanced business involvement.
- *Governments can contribute to bridging the gap* between general objectives and concrete contributions by the business sector and other stakeholders. They can do so by: (i) translating general MEA objectives into clear and specific requirements, targets and standards; (ii) involving stakeholders more efficiently in MEA negotiations and in the development of national implementation policies; (iii) putting in place adequate incentives to meet national targets; and (iv) developing economic instruments and markets that support MEA goals to promote effective business engagement.

The right tools and incentives have to be in place and unnecessary barriers need to be removed.

- *Develop tools that allow for the internalisation of environmental costs* (*i.e.* for taking account of the cost of externalities). Adequate tools, standards, economic instruments and regulation would help internalise such costs thus linking MEA objectives to decision-making processes within businesses.
- *Provide appropriate incentives to business.* Some MEAs provide only indirect incentives to business. Working with MEA processes therefore often proves difficult for enterprises. Governments can develop more appropriate incentives, for example, by better tailoring implementation policies to business activity, and by developing economic instruments which encourage business to actively support MEA goals.

- *Level the playing field and remove perverse incentives.* Governments need to remove incentives and subsidies that prevent the effective implementation of MEAs, or that support activities which run counter to the targets and objectives of MEAs.
- *Remove unnecessary barriers*. Government inertia to implement environmental measures, lack of institutional capacity, and unwillingness to change unsustainable policies deter business engagement. Removing excessive bureaucratic requirements (*e.g.*, to access funding) would also enhance business involvement in MEA goals.

Governments and financial institutions need to ensure that they support the right investments.

- *Environmental guidelines should be geared towards MEA objectives.* Most governments, and both private and public financial institutions, have mechanisms and guidelines in place to ensure that the projects they finance comply with certain environmental standards. To ensure a level playing field, it is desirable that the whole financial community effectively apply such mechanisms and guidelines. Efforts should be made to disseminate "best practices" for the assessment of environmental risk as an element of credit risk. Existing guidelines, such as the World Bank and International Finance Corporation (IFC) safeguard policies and guidelines, could be enhanced to be better geared towards achievement of MEA objectives.
- *Financial support should go to the right projects.* The public is more and more vigilant about the private sector receiving subsidies and other support to achieve environmental and social goals. Some guidance could be useful to help identify how public sector agencies and the private sector can collaborate most effectively.
- *Develop risk management strategies to "crowd in" private sector finance.* Developing new technologies or engaging otherwise in innovative investments involves risks. Product and market risks constrain technological change. These risks may crowd out finance by private institutions. In these situations, adequate risk-sharing strategies can stimulate a "crowding-in" effect. Examples include mechanisms that help share the financial and market risks of introducing new technologies and related products, and procurement policies that provide opportunities for innovative companies to enter new markets.
- *Influence large-size capital flows.* Institutional investors, such as pension funds and insurance companies, manage large funds. However, they often do not take the environmental impacts of their investments into account. It is therefore important that institutional investors also apply guidelines for the assessment of environmental impacts.
- *Governments can serve as leaders to leverage good practice* by others, by making sure that their own investment flows are in line with MEA goals. This can be achieved by "green" procurement policies, modernisation of central heating and cooling plants to reduce emissions, constructing of future buildings in compliance with environmental standards, "greening" the fleet of official vehicles, etc.

Innovation, development and transfer of technologies are key to MEA implementation, and can be supported through the right incentives.

- *Channel investments toward new technologies.* Investments will go into technologies anyway, so the key will be to provide incentives for fostering the innovation and development of technologies that contribute to the goals of MEAs, *e.g.*, by offering instruments to mitigate risks. It is important that such incentives be elements of governments' long-term strategies to achieve MEA objectives.

- *Enhance conditions for the transfer of appropriate technologies to developing countries.* This requires an enabling environment, community choice and appropriation, stakeholder involvement, adequate information and networking, and flexible frameworks. Transfer and sharing of knowledge between developing countries can also be an efficient approach in some circumstances.

Communication and language barriers have to be overcome.

- *Improved communication about the objectives, targets, and means of implementation* is needed, in order to get business interested and involved in MEA implementation. Links between business goals and benefits to MEAs need to be made evident: not only environmental benefits, but also business opportunities, have to be identified. When communicating with businesses, not only environmental departments and advisors, but also departments linked to the core business including core managers (CEOs), should be targeted.
- *Improving communication concerns all stakeholders*. Governments can explain to businesses what each MEA means, how it will be implemented at national level, and how business can contribute. They can also improve the integration of MEA goals in economic policies by, *inter alia*, enhancing communication of such goals throughout government, including at regional and local levels. MEA Secretariats can continue providing useful information on specific aspects of MEAs, along with lessons learned, constraints and success stories, *e.g.* through their websites and databases. Business associations can provide to their members information on MEAs and ways for enterprises to contribute to their implementation. Civil society organisations can relay the views of the general public, exert pressure, and provide an educational support role.
- *The right signals have to be given in order to involve all.* For example, there is often a perception that only large multinational enterprises have a role to play in incorporating better environmental management practices and preserving the global environment. However, small and medium enterprises can also make an important contribution, and governments and others need to make special efforts to give these firms opportunities for involvement, and to provide adequate incentives.

All MEAs are different, and approaches to private sector contribution to their implementation need to take these differences into account.

- *No "one-size-fits-all approach".* Although most MEAs address global environmental problems which are often inter-linked, “umbrella” approaches to enhance private sector involvement do not seem to offer particularly promising avenues for progress. Rather, the specific goals and objectives, *modus operandi*, and requirements of each MEA should be considered when designing approaches to promote private sector involvement.
- *Synergies exist and should be further explored.* Lessons learned from experience with private sector involvement under one MEA could be useful for effective implementation of other MEAs. Improving communication, exchange of information, and sharing of experience among MEA Secretariats, as well as among National Contact Points of the different MEAs, would be useful steps. Further reflection is needed on how experience gained under mechanisms that have been set up under one MEA to involve business (such as the Clean Development Mechanism), could serve in the implementation of other MEAs.

Where to go from here?

- *Continue the dialogue*. The workshop was not designed to develop any concrete guidelines or recommendations on how to enhance private sector involvement in MEA implementation. Its purpose was to facilitate a dialogue between actors in MEA implementation, and to share relevant experiences. This dialogue should continue in other *fora* and involve other relevant stakeholders.
- *Reflect on further improvements and share experiences*. All actors – governments, MEA Secretariats, international organisations, financial institutions, enterprises, civil society organisations – have a different role to play, within their respective capacities and mandates, and should continue to reflect on how to further improve their own approaches to MEA implementation, as well as co-operation with others active in the field.
- *Concrete action can include* increasing private sector involvement in relevant meetings related to MEAs and their implementation; organising side events at Conferences of Parties to further raise awareness and sensitise government officials; exploiting synergies between the MEAs aimed at strengthening the case for private sector involvement; encouraging multi-stakeholder discussions around concrete experiences and lessons learned; improving collaboration among stakeholders, including bilateral and multilateral agencies, the business sector, civil society organisations and research institutes, to develop or enhance proposals and feasibility studies for further private sector involvement in MEA implementation,
- *The role of the OECD*. The OECD should continue to reflect whether and how best it can contribute to enhancing private sector involvement in MEA implementation. Useful related recent experience includes the revision of the OECD Guidelines for Multinational Enterprises and work on the implementation of the Environment Chapter of these Guidelines, as well as the Recommendation on Common Approaches on Environment and Officially Supported Export Credits.

PART II

SUMMARY OF PRESENTATIONS AND DISCUSSIONS AT THE WORKSHOP

Introduction

The OECD Workshop on Multilateral Environmental Agreements and Private Investment, organised in co-operation with the Finnish Ministry for the Environment, took place in Helsinki on 16-17 June 2005. It provided an opportunity to bring relevant stakeholders together to exchange views and discuss recent experiences regarding private investment that contributes to the solution of global environmental problems.

The workshop focused in particular on the three Rio Conventions – the UN Framework Convention on Climate Change, the Convention on Biological Diversity and the UN Convention to Combat Desertification – as well as the Montreal Protocol on Substances that Deplete the Ozone Layer, but was also open for discussion related to other environmental Conventions. The Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Ramsar Convention on Wetlands were also represented at the workshop.

The main objectives of the workshop were to:

- improve understanding on how to promote private investment that contributes to the implementation of MEAs and thus also to the broader objective of sustainable development;
- explore business opportunities under MEAs and new ways to engage business in MEA implementation; and
- share experiences and disseminate information that can encourage and help businesses take further action to contribute to addressing global environmental problems, thereby making the implementation of MEAs more effective.

The first day focused on experience with initiatives that have contributed to promoting private investment in support of MEA implementation. The second day looked at two issues related to successful implementation of MEAs that are particularly relevant to the role of private investment and business engagement: (i) the financial aspects of MEA implementation; and (ii) innovation, development and transfer of environmentally friendly technologies.

This report has two parts: the key messages emerging from the workshop (Part I) and a summary of the presentations and discussions (Part II). It builds upon presentations by, and discussions among, workshop participants who represented national governments, MEA Secretariats and implementing agencies, businesses, international governmental and non-governmental organisations, research institutes and other stakeholder groups.[1]

[1] All presentations made at the workshop, the agenda and a list of participants are available on the workshop website <www.oecd.org/env/investment/workshop>. For further reading, see particularly the sections “Background Report” and “Workshop Papers”.

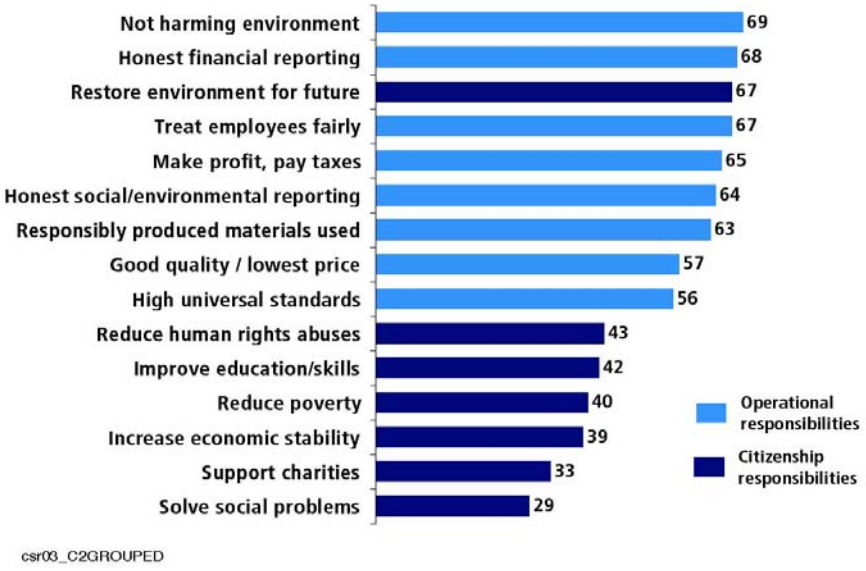
Why engaging the business sector in solving global environmental problems?

There is a clear need for enhanced co-operation between the public and private sectors in achieving MEA goals. Even though governments have the main responsibility in implementing MEAs, they may in most cases not be successful without the support and the engagement of other stakeholders, including businesses and civil society actors.

The business sector[2] has a significant impact on the way in which natural resources are used, and therefore on biodiversity, climate change, ozone depletion, etc. But it also plays a critical role in ensuring environmental sustainability: it is the primary driver of economic activity, through developing, spreading and transforming various business models. Business has much of the relevant knowledge and expertise when it comes to developing new environmentally sound technologies and is the key engine of product and process innovation. It influences government behaviour and public opinion, and is able to mobilise the relevant stakeholders.[3]

On the other hand, public opinion also directly influences business behaviour and is therefore a good driver for integrating environmental goals into day-to-day business operations. Among the public expectations of companies, several are related to environmental issues – two of which rank among the first three expectations (Figure 1).

Figure 1. **Public expectations of companies**



Source: Globescan, quoted by David Cooper, CBD.

2 In this report, the terms "private sector" and "business sector" are used interchangeably.

3 Stefan Wallin, Finnish Ministry of the Environment; David Cooper, CBD.

Collecting ideas – sharing experiences: How can private investment contribute to MEA implementation?

General considerations: Involving the private sector in MEA processes

Different MEAs need distinct approaches for fostering private investment: MEA objectives differ widely and so do entry points for business. However, some elements are common for all MEAs if the business sector is to be engaged more efficiently in solving global environmental problems (see Box 1).

Box 1. **"Carrots and sticks" for business sector involvement**

"Carrots"	***"Sticks"***
- improved profitability (win-win solutions)	- enforcement of environmental regulation
- new business opportunities	- penalties, fees and other sanctions (*e.g.* "offsets" if it is not possible to avoid/mitigate impacts)
- economic incentives (subsidies, tax rebates)	- economic instruments (*e.g.* taxes)
- enhanced reputation, image	

Source: adapted from Harro Pitkänen, NEFCO.

Businesses need a "trigger" to contribute to the implementation of MEAs. Besides complying with the law, their motivation may be to obtain a social "license to operate". In any case, environmental sustainability alone is not sufficient to drive businesses: environmentally sound business behaviour also needs to allow for economic profitability, *e.g.* as an indicator of good corporate governance or by maximising the long-term shareholder value through improved reputation and trust. Other drivers include "first mover" advantages and competitive advantages of best practice, as well as the attempt to access markets (for products, financial and human capital) and secure supplies.[4] However, it is not the business sector alone who needs to take initiative. Governments also need to take better account of the importance of the business sector in supporting MEA goals, and more directly provide incentives for business action in the respective field of interest. Figure 2 provides a collection of elements of success for private sector engagement in MEA implementation.

Figure 2. **Private sector engagement: Elements of success**

- Clear evidence of the problem (political consensus for action)
- Public/consumer awareness and acceptance (modest lifestyle changes)
- Simple (measurable) performance targets and indicators
- Actual or anticipated regulation (level playing field)
- Clear business costs and/or business opportunities
- Availability of cost-effective alternative technologies
- Long-term incentives (aligned with business planning horizon)
- Reward good performance, penalize adverse outcomes
- Equitable allocation of rights and responsibilities
- Leadership groups of companies (and govt's, NGOs) to pilot change
- Potential "no regrets" quick wins (*e.g.,* more efficient use of costly natural resource inputs)
- Low transaction costs (modest bureaucracy)
- Credible verification mechanisms (*e.g.,* 3rd party validation)
- Space for locally-defined standards
- Heterogeneous costs and/or benefits (a pre-requisite of market-based approaches)

Source: Joshua Bishop, IUCN.

[4] David Cooper, CBD; Lettemieke Mulder, Unilever.

It has been argued that voluntary corporate approaches, such as those underpinning the environmental or social responsibility agenda, may not be sufficient to spur better contribution by businesses to MEA implementation. In some cases, this is because it is not needed in the first place, and in others because it fails to adequately address some of the most difficult outstanding issues in the relationship between MEAs and the private sector. A more helpful basis for understanding the relationship between MEAs and business is to look at how MEAs contribute to an enabling environment for responsible business practices. An enabling environment needs to support market- and citizen-based activism, public participation and access to information in order to sustain the drivers of responsible businesses. Indeed, if responsible businesses are to be successful, they need to be able to innovate on a level playing field in which the most negative impacts of business activity are effectively prevented.[5]

How do MEAs facilitate business contribution to their objectives?

Some MEAs have been successful in involving the private sector in their processes. The *UN Framework Convention on Climate Change* (UNFCCC) and its *Kyoto Protocol*, for example, have put in place new and innovative approaches linked to the private sector such as the Clean Development Mechanism (CDM), Emissions Trading and Joint Implementation. Other approaches are: exerting pressure on governments to reduce greenhouse gas (GHG) emissions thereby helping to create new markets for cleaner technologies and opening up new opportunities for companies and investors; providing a stable long-term regulatory framework; and supporting new technology development through public financial institutions and export credit agencies.[6]

Box 2. **The CDM as an example for private investment delivering on MEA objectives**

The Kyoto Protocol's CDM is a pioneering instrument through which private investment is expected to help achieve the goals of an MEA. It allows private investors to undertake GHG-reducing activities in developing country Parties to the Protocol that do not have commitments to reduce GHGs. Those investors are then granted credits for the reductions they thereby achieve, in units that can be sold on international markets, or used to fulfil any emissions reduction obligations they may have in their home states.

Strengths and limitations of the CDM

A *strength* of the CDM seems to be the good performance of the market mechanism at delivering cost-effective emissions reduction credits to Annex I countries. A whole class of projects has emerged that was not envisaged when the CDM was created – opportunities that arguably only the market could have discovered and delivered. Clear *limitations* can be seen in the fact that some projects yield, by any measure, very little in the way of sustainable development benefits to non-Annex I countries. They have no local environmental or public health impacts, they create little employment or technology spillover impact. Their linkages in the local economy are pretty well non-existent. Also, there are signs of a culture clash between the bureaucrats administering the CDM and the private sector stakeholders who are using the system. The result is a much smaller volume of projects than the full potential and smaller than is needed to fulfil the market demand for Certified Emission Reductions (CERs).

Lessons learned

The lessons learned of the CDM experience to date are preliminary assessments only, based on an emerging, rather than a final, regime since the final shape of the CDM has yet to be determined.

1. It is important to ensure that the target is going to be achieved by the instrument (allow for flexibility and adaptive learning).

5 Halina Ward, IIED.

6 Katia Simeonova, UNFCCC.

2. There is a need for developing good channels of communication between users and regulators in design and implementation.

3. The CDM shows that it is possible to engage private investment in achieving climate change objectives. It is a critically important innovation, both in its contributions to the Kyoto Protocol and more broadly in the example it sets for other such attempts.

Source: Aaron Cosbey, IISD.

Other MEAs, such as the *UN Convention to Combat Desertification* (UNCCD), emphasise that there are also risks in involving the private sector since environmental and business goals may be conflicting: private investment may have harmful effects on drylands and their populations unless the interests of these populations are duly safeguarded. However, the UNCCD may just need different approaches in involving the private sector and ways can be found to mitigate the risks. Public-private partnerships (PPPs), for example, seem to be a viable alternative for direct private investment: foreign or domestic private capital is leveraged for projects that have long-term business and development potential but cannot get sufficient financing or technical expertise through market channels. PPPs will help to ensure that the socio-economic and environmental objectives of the participating developing countries are duly taken into account in business actions. Sponsorships is another potential form of private sector participation in the implementation of the UNCCD. These activities may include financial contributions such as grants and support to research, product donations and provision of expertise, scholarships and technical advisory services.[7]

Under the *Convention on Biological Diversity* (CBD) process, initiatives are already under way to enhance business contribution to its goals. At national level, for example, National Biodiversity Strategy and Action Plans (NBSAPs) are being developed and implemented, while approaches at international level encompass a stronger participation of business in intergovernmental meetings (such as COP, MOP, SBSTTA), participation in expert groups, implementation of the CBD programme of work, and voluntary partnerships. Other tools and initiatives to promote best practice which could be adapted by other MEAs as well, are the development of Biodiversity Benchmarks for specific sectors, Good Practice Guidance, the integration of biodiversity into existing standards (*e.g.* ISO 14001, US Securities and Exchange Commission (SEC) standards), offsets[8], "no net loss campaigns" or similar initiatives.[9]

The *Montreal Protocol*'s success relies to a very high degree on the involvement of industry to innovate, invest in, and transfer new technologies. The Protocol includes several measures that encourage private sector involvement and investment: (i) trade-related incentives (trade controls with non-Parties and import restrictions in certain markets; (ii) market development for alternatives to ozone depleting substances; and (iii) technology co-operation and technical and financial assitance for industries in developing countries. The opportunities for market creation under the Montreal Protocol have been the biggest driver for massive global investment by the business sector, leading to the development of a wide range of technologies in a very short time span, and to the creation of jobs. Lessons learned show that prioritising PPPs has created a major new market and leveraged finance from the private sector, while taking advantage of this sector's flexibility, innovation and pursuit of profitable investment. This kind of

7 Christian Mersmann, Global Mechanism of the UNCCD; UNCCD.

8 Offsets are defined as "conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects, so as to ensure no net loss of biodiversity".

9 David Cooper, CBD.

market-oriented innovation and collaboration could serve as an example and be replicated in the context of other MEAs.[10]

The *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES) has regulated trade in many of the world's most commercially valuable plant and animal species. Its activities are therefore directly linked to business activities in various sectors. For this reason, co-operation with the private sector is essential in supporting governments in designing, financing and implementing targeted strategies for the use of economic instruments which play an important role in managing and conserving wildlife. There is increasing consumer and industry interest in goods that meet quality and sustainability criteria, for example, products that provide some assurance to consumers of benefit sharing with local communities and other actors throughout the supply chain. CITES is exploring ways to improve its international structure for certification, tracking and monitoring of sustainably produced wild species commodities and considers the private sector as key in developing appropriate tools and instruments.[11]

The *Ramsar Convention on Wetlands* is another example of an MEA that is already collaborating with the business sector. In 1998, the Danone Group (through its water brand Evian) and the French Global Fund for the Environment agreed on the creation of a fund, financed by the private company in support of the Ramsar Convention. The Ramsar/DANONE partnership is an important tool for supporting the Secretariat activities to take action "from the mountains to the sea for water resources and their quality". The fund for water was created as an action plan for the implementation of Ramsar's Strategic Plan and includes four areas of action: (1) information (for all stakeholders), (2) communication and public awareness, (3) training and technology transfer and (4) courses and seminars. In this sense, the fund has allowed the Convention Secretariat to produce publications and make exhibitions to raise awareness on Ramsar's mission and philosophy. The fund also includes a programme of actions aimed at stakeholders and high-level decision makers with the goal to reduce the gap between the technical guidelines produced and their on-ground-implementation. At the level of sites managers, the MEA-private sector partnership also promotes transboundary technical and scientific cooperation through the creation of thematic networks of Ramsar sites. Training of sites managers is a vital piece of the process: due to the financial support by the fund, several training courses and workshops for selected groups of managers could be organised.[12]

What can business do to contribute to MEA objectives?

Businesses have increasingly aligned their business practices with environmental goals and established environment or departments dedicated to corporate social responsibility goals. These departments are responsible for overseeing the enterprise's compliance with environmental policies and for ensuring eco-efficient operations while watching that employees are treated well and human rights are respected. Unilever has the objective of "doing things right and doing the right things". Respecting the environment is often a prerequisite for staying in business, especially in resource intensive activities so that businesses focus on areas where they can make the most difference. Unilever, for example, whose operations affect the fisheries, agriculture and water sectors, has partnered with World Wildlife Fund (WWF) to develop the Marine Stewardship Council, an independent non-profit organisation that promotes responsible fishing practices ("No fish, no fish sticks"). While linking international operations to global environmental goal under MEAs may be difficult, companies could start linking local initiatives to national goals, such as NBSAPs in the case of the CBD. A commitment to goals and targets is necessary, but it is

10 Monique Barbut, UNEP DTIE.

11 Juan Carlos Vasquez, CITES.

12 Sebastià Semené Guitart, Ramsar Convention.

also important that companies report on progress and disclose their environmental performance against agreed criteria (benchmarks).[13]

Being open to co-operation and collaboration with governments, organisations, and experts in the field as well as sharing experience is often crucial to achieve desired objectives. CITES, for example, will review national policies regarding, *inter alia*, the use of, and trade in, CITES-listed species, production systems, consumption patterns, market access strategies, price structures, certification, taxation and subsidy schemes, and mechanisms for benefit sharing. The involvement and support of the business sector is essential to achieve the expected outcomes of this task.[14]

Box 3. **M-real Investment in biomass energy contributes to climate change mitigation**

Paper, board and pulp production requires a considerable amount of energy in various forms. M-real has continuously worked to improve the efficiency of its energy production and the use of energy at the mills in order to minimise costs and environmental impacts.

In 2003, M-real developed a comprehensive climate strategy. In addition to the energy efficiency measures, the strategy aims at increasing the use of CO_2-neutral energy sources such as process heat and biomass. Beyond this strategy, M-real buys CO_2 allowances to comply with the limits of the EU Emissions Trading Directive.

M-real invested in a biomass Combined Heat and Power Plant in Hallein, Austria, that will be taken into operation by mid-2006. The mill consists of a sulphite pulp mill and a paper mill. At present, energy at the mill is produced mainly by process liquor and natural gas. With ongoing investments, 35% of the natural gas usage will be replaced by biomass. In addition, it is possible to incinerate the process residues (bark and sludge) on site. The new power plant will have an output of 21 MW heat to the mill, 5 MW of electricity to grid and 3 MW of heat to district heating with investment of about EUR 36 million. The estimated reduction of CO_2 emissions will be 39 000 tonnes per year.

The main feasibility factors of the project include the reduction of waste disposal cost, the need to buy less CO_2 allowances, a subsidy for the production of "green" electricity and an investment subsidy for renewable energy. Private investment obviously requires profitability of all investments. Therefore, an investment subsidy alone does not affect the feasibility of the project if either the technology is not reliable or profitability is not assured in the long run. In general, many different factors influence the feasibility of a project and an evaluation should be balanced in terms of sustainable development comprising economic, social and environmental factors.

Source: Armi Temmes, M-real.

What is the role of governments in encouraging private sector involvement?

The business sector is the main financial investor worldwide and the key challenge is to ensure that these investments are compatible with global environmental objectives. Governments have an important role to play in encouraging business contribution to national commitments under MEAs, *inter alia*, by fostering environmentally sustainable investment, finance, trade and technology policies.

Businesses respond to both incentives and disincentives, and market-based signals are often a good means to motivate desired types of decision-making, such as property rights (*e.g.* tradable fisheries quotas),

13 Lettemieke Mulder, Unilever.

14 Juan Carlos Vasquez, CITES.

fee-based measures (*e.g.* user charges), deposit-refunds (*e.g.* batteries, waste toxics), liability and assurance regimes (*e.g.* bonds), and tradeable permits (*e.g.* SO_x and NO_x).[15]

Governments need to find a balanced approach that promotes economic performance and competitiveness, while at the same time allowing for public environmental objectives to become embodied into business management practices. Such approaches allow for (i) balancing investments between short-term actions and longer-term measures to promote transformational change; (ii) promoting long-term competitiveness through sustainability, while carefully weighing short-term impacts; (iii) working in partnership to lever funds and encourage appropriate responses from other governments, citizens and industry; (iv) promoting innovation and new technologies to drive economic growth and create new opportunities; and (v) acting efficiently to meet environmental objectives at the lowest possible cost.[16]

Box 4. **Lessons learned by the Canadian government on how to promote private investment that supports MEA implementation**

(1) Use economic instruments when:

- long-term behavioural change is desired and can be supported by using market signals that change the information on which decisions are made;
- flexibility of response from individual actors is acceptable;
- an end-point is difficult to define, but the desired direction is known; and
- the cost of abating pollution differs widely among sources.

Factors to balance when selecting economic instruments: environmental effectiveness and efficiency, distributional effects, flexibility, and political buy-in.

(2) Design of economic instruments:

- Build business sector support through consultation.
- Ensure that the private sector understands the objective of the economic instrument and why it represents the optimal choice to achieve the objective.
- Allow the private sector an opportunity to affect the instrument design.
- "Selling" an economic instrument as part of a package of measures may be easier than selling it on its own.

Design considerations: simplicity, degree of influence, innovation, free-riders, monitoring and enforcement, securing of short-term results, consideration of revenue-neutrality, mitigation of adverse economic impacts, co-ordination.

(3) Experience and conclusions:

- It is necessary to develop and communicate a "vision".
- It is important to develop domestic experience with what works and what does not: effectiveness of certain instruments and manner in which instruments are introduced.
- Experience is essential to overcome scepticism and to ensure appropriate design of economic instruments to ensure ongoing private sector participation.
- Such experience can only be gained through implementation, ongoing innovation and careful scrutiny of outcomes and lessons learned.

Source: Chris Hanlon, Environment Canada.

15 Stefan Wallin, Finnish Ministry of the Environment; Chris Hanlon, Environment Canada.

16 Chris Hanlon, Environment Canada.

Box 5. **The German National Climate Protection Programme**

The German government has put in place a National Climate Protection Programme that helps fostering private investment in support of national climate objectives. Among the measures put in place is the Renewable Energy Act which supports the renewable energy sector and renders electricity from solar, wind, geothermal, and biomass energy commercially attractive. By consistently supporting renewable energies, Germany has become leader on the technology market in wind energy and in the photovoltaic sector. Between 1998 and 2002, about 50 000 jobs were created in the private wind power sector alone. Other measures to facilitate, for example, the development of energy-efficient cogeneration are based on agreements between the federal government and German industry.

Selection of measures to promote private sector contribution to achieving the emissions reduction target[17] **(CO_2 reduction potential in million tonnes CO_2)**

	CO_2 Reduction Potential
Public Relations Campaigns, Counselling, Innovation	**0.7**
• upgrading of dena (Deutsche Energie-Agentur, German Energy Agency) as centre of expertise for energy efficiency • large scale public relations campaigns • training courses and quality improvement initiatives (investors, trade, planners, constructors) • increased research under the auspices of the Building and Transport Ministry for innovations to increase energy efficiency; improved building materials • further development of the energy savings contracting system on the heating market	
Financial Support Measures	**2.8**
• KfW bank loans for the building sector • Programmes to set market incentives in the biomass sector • Programmes to set market incentives in the solar energy sector • on-the-spot counselling • Upgrading of cities and towns in Eastern Germany, council housing	1.6 0.8 0.2 0.1 0.1
Regulatory Measures	**0.4**
• implementation of the Energy Savings Ordinance (EnEV) 2006 and introduction of energy passes • amendment of the Home Ownership Act (Wohneigentumsgesetz)	
Autonomous Reduction Effects*	**1.3-1.5**
Total of Quantifiable Measures	**5.3**

** The estimate of the autonomous reduction effects is based on energy prices of 29$ per barrel crude oil for the reference year 2000. The further development was calculated on the basis of a long-term mean real increase of 1.5% per year which amounts to a price of 45$ per barrel for the year 2030. The expected effects would change in relation to changes in energy prices.*

Source: Michael Kracht, German Federal Ministry for the Environment (BMU); Forschungszentrum Jülich (ed.) (2005) as reported in www.bmu.de/files/english/climate/downloads/application/pdf/klimaschutzprogramm_2005_en.pdf.

Besides selecting the right economic instruments and regulations, governments may have additional tasks to fulfil. This is especially the case in developing countries. Development objectives are often directly linked to environmental goals and natural conditions. In the case of countries affected by desertification, specially tailored solutions are needed to ensure the involvement of private investment. Governments need to ensure a minimum of infrastructure and facilities for development (roads, electricity, transportation, health services, etc.) in order to attract private investment that contributes to the implementation of MEAs. While there are opportunities for direct investment in these countries (such as in

[17] German emissions reduction target for the 2008-2012 (Kyoto) period: 120 million tonnes CO_2.

water supply and sanitation, eco-tourism, agriculture or livestock farming), the private sector may also make a contribution to environmental and development goals by engaging in PPPs or sponsoring activities (*e.g.* building roads and other infrastructure projects, or preserving natural parks, reserves or archaeological and historic sites).[18]

Improving co-operation between stakeholders and overcoming barriers

Many stakeholders are involved in the process of MEA implementation: national governments, MEA Secretariats and implementing agencies, intergovernmental and non-governmental organisations, experts, business, etc. Only if these stakeholders co-operate efficiently by sharing experiences, identifying synergies and common problems and elaborating solutions, will there be concrete advances in the implementation of MEAs.

What role can intergovernmental organisations play in promoting private investment?

For successful MEA implementation, sustainable investment needs to be made in the key economic sectors that MEAs address. New types of partnerships between the public and private sectors can help reshape and redirect private investment flows toward MEA objectives. Intergovernmental organisations can play a key role in stimulating these partnerships.

UNEP, for example, initiated and hosted the negotiations that gave rise to several MEAs. To support their implementation, UNEP has programmes and activities in place that: (i) strengthen national capacities with a view to making technology and investment decisions to meet compliance targets; (ii) build capacity to make informed decisions about investment services that assist especially developing countries and Countries with Economies in Transition; (iii) facilitate technology transfer; (iv) support the development of national policy frameworks that are conducive to promoting environmentally-friendly business behaviour; and (v) promote voluntary corporate approaches that reach beyond government regulations to improve industries' environmental performance.[19]

As an implementing agency of the Global Environment Facility (GEF), the World Bank encourages partnerships with the private sector. It has conducted an Overall Performance Study for the GEF recommending that "GEF should launch a private sector special initiative to look for good models of cooperation with the private sector and the pilot projects." The World Bank also works directly with the private sector to achieve development and environmental goals. It considers it important, however, that the "right" partnerships be built and therefore, the World Bank applies certain rules in selecting appropriate partners. They include "Guidelines for assessing potential business partnerships with the World Bank Group" (*e.g.*, Does the company have a good reputation, especially in areas of corporate social responsibility (CSR)? In the case of new companies or companies with past CSR troubles, are they committed to instituting/improving a sound CSR policy? Is the company willing to engage with the World Bank in a transparent manner without expecting an exclusive relationship?). Furthermore, the Bank distinguishes different "risk categories in private sector partnerships": (i) reputational risks (*e.g.*, selecting inappropriate private sector partners, for example, companies selling tobacco, firearms, etc., or partnership activities, for instance, where World Bank involvement is being solicited for subsequent commercial opportunities); and (ii) conflicts of interest risks (*e.g.*, between upstream policy advisory partnership work and subsequent consultant work for downstream preparation or procurement opportunities).[20]

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18 Fethi Debbabi, Sahara and Sahel Observatory.

19 Monique Barbut, UNEP DTIE.

20 Charles Di Leva, The World Bank.

NGO partnerships with business can make a difference

Some NGOs have developed partnerships with the private sector to explore mutual benefits for business and environment. Some issues emerging from existing activities of NGO-corporate partnerships need to be addressed to securing more effective engagement of the private sector in MEA implementation: it is important to "speak the same language" (*i.e.* to talk in the language of "business risk and opportunity"); secure senior management attention; find a consensus on priority areas for action and on how to monitor and measure environmental impacts at an operational and strategic level; and to explore ways of sharing the responsibility and cost of restoring legacy sites (*i.e.* sites/resources that have been used for industrial purposes, without paying the full cost of environmental and social harm) corresponding to the share of benefits accrued to society and business.[21]

Box 6. **Examples of successful NGO activities with business support in India**

The following NGO activities in India have led to improvements in environmental conditions and supported the implementation of several MEAs:

- Through continuous campaigning and lobbying by the New Delhi based NGO Centre for Science and Environment, the fuel regime in the entire city of New Delhi was transformed into one that contributes fewer GHGs to the atmosphere, thereby contributing to the objectives of the UNFCCC. While the judiciary played a pro-active role, in that it directed the government to take immediate action, only the participation of private manufacturers, such as Indraprastha Gas Ltd., in this initiative made the transformation possible.
- The three objectives of the CBD (conservation of biological diversity, sustainable use of the plant resource and sharing the benefits arising from the use of the plant resource) have been promoted through a partnership between Dabur India Ltd., a private company valuing traditional knowledge, farmers groups and community based organisations. The objective is to conserve the biological diversity especially of endangered medicinal plant species in remote locations in the mountainous areas of India. The partnership has also developed a system for sustainably using plant species and sharing the benefits with the local farmers.
- In consonance with the objectives of the UNCCD, a partnership between the Tata Group, India's largest private employer, and the NGO SPS (Association for Social Advancement) aims at working with communities in dry areas on conservation of land and water resources. The partnership thereby helps to counter the process of desertification and mitigate the adverse effects of drought situations. Efforts over the last 10 years have included drought-proofing, micro-irrigation, sustainable dryland agriculture, etc. They have resulted in the provision of additional one billion cubic metres of water storage in the region, drinking water security for 20 000 people, a threefold increase in irrigated land, a doubling of the agriculture output value, a 90% decrease in indebtedness and 80% decline in migration. Furthermore, a resource centre was established to train and support the activities of other NGOs and community based organisations to work on water resources management in other arid and semi-arid locations of India.
- Being a Party to the Montreal Protocol, India is committed to phase out chlorofluorocarbons (CFCs) by 2010. A lack of consumer awareness and political will, however, first impeded the changeover from conventional CFCs to other non-depleting substances such as hydrocarbons (HCs). The NGOs Greenpeace and CUTS, as well as Indian research institutions, have pioneered a sustained Ecofrig Campaign, aiming at promoting the production and use of environmentally-friendly refrigerators and raising awareness among consumers. The government at all levels supported the initiative and eventually, companies like Godrey and Videocon adopted HC technology in India.

Source: Rajeev Mathur, Consumer Unity & Trust Society (CUTS).

For an NGO-business partnership, it is important that: (i) the parties involved have a common understanding of the central purpose of the partnership; (ii) there be little or no conflict of interest between the partners; indeed, the interests of the different partners should actually complement each other; and (iii)

[21] Annelisa Grigg, Fauna and Flora International.

the initiative be taken up by one of the parties, and then joined by other parties to develop a coalition for realising the purpose of the partnership.[22]

Encouraging private investment means overcoming barriers and exploring new approaches

A number of barriers remain to engaging the business sector more fully within MEA processes and their implementation. These include: [23]

- *Language and culture barriers*: MEAs have been largely developed by governments and, as such, the style of working and language used to describe MEA requirements is often impenetrable to businesses.

- *Lack of resources and competing priorities:* Enterprises need to address many complex issues, such as climate change, human rights, transparency, corruption, human health or waste, that are not core to their business activities. They may simply lack the in-house expertise or resources that enable them to consider and address environmental issues when they are already engaged in a range of other issues perceived as more business-critical.

- *Lack of a clear business case:* The focus of many businesses has been on how to avoid or minimise private sector impacts on the environment. Until a clear business case to integrate environmental objectives in day-to-day business operations is established and communicated throughout the private sector, engagement in MEA implementation will remain limited.

- *Conflicting timeframes of business and environmental goals:* The timeframes for the pursuit of business objectives are often different from those of environmental goal such as the implementation of MEAs: in many cases, the timeframe for MEA implementation may be too long to fit readily with the private sector's *modus operandi*.

Why is business not taking long-term initiatives that would improve environmental conditions? Businesses mainly strive to achieve short-term objectives because long-term results do not show in their bottom-line: even if actions lead to a significant cash flow many years from now, the net-present-value may still be very small. A key issue in managing environmental issues, particularly natural resources, is the fact that they tend to be inappropriately valued within financial markets and by society as a whole. Therefore, the cost of ecosystem services is rarely factored into a company's cost of doing business or creating shareholder value, with the result that the potential loss of such services is often not perceived as an issue of concern to business. [24] In order to change this and to provide incentives for taking the long-term environmental implications of business operations into account, it is essential to develop tools that allow for the internalisation of costs to the global environment. MEA objectives can be best linked to decision-making processes if businesses need to take the cost of these externalities into account.

Another key question is how to "green" the main streams of global financing, such as commercial bank lending, capital markets, export credits or development financing. To date, there is still a lack of practical standardised tools to encourage those who control substantial capital flows to take account of environmental goals. The first step is to reduce financing of environmentally detrimental investments. The "Equator Principles", based upon the IFC Safeguard Policies, are already a good step in this direction.

22 Rajeev Mathur, CUTS.

23 Annelisa Grigg, Fauna and Flora International.

24 Annelisa Grigg, Fauna and Flora International.

However, the Safeguard Policies themselves do not contain any references to MEAs, but only to environmental issues in general.[25]

Within MEAs themselves, some changes are necessary to overcome the obstacles that businesses are confronted with, particularly the fact that working with MEA processes is often difficult. Improvements can be made, for example, by raising awareness of the importance of environmental goals and trends, exploring concrete opportunities and common objectives in partnership, tailoring MEA activity more to business activity (*e.g.* clear objectives, considering scale and coalition building), and acknowledging the concept of sustainability in a decision-making model.[26]

Box 7. **Markets for ecosystem services**

The development of markets for ecosystem services (MES) is an innovative and promising approach to attract private contributions, to introduce sustainable resource management practices compatible with MEA objectives and principles, and to contribute to the development of economic opportunities in poor, rural areas of the world. While these markets have been growing steadily in recent years, this development has taken place largely outside the framework of the MEAs, with the notable exception of the UNFCCC, through its CDM.

There appears to be a great potential for the development of MES within the framework of the Rio Conventions and their respective financial mechanisms. The development of a joint initiative to that effect would allow these MEAs to capture a share of this growing market, thereby enhancing their effectiveness in attracting and mobilising private capital, expertise and technology towards their goals. By positioning themselves in these markets, the Rio Conventions could also contribute to, and influence the development of, such markets. Moreover, the poverty alleviation dividends created by MES at the community level could also be instrumental in attracting development-oriented funds in the context of the Millennium Development Goals.

Source: Marc Paquin, Unisféra International Centre.

Efficient financial tools and instruments are important in facilitating business support for the implementation of MEAs

Among the many issues related to a successful implementation of MEAs (*e.g.*, capacity building, education and awareness, research and scientific co-operation), financial aspects are particularly relevant to the role of private investment and business engagement. Lack of financing is frequently mentioned as a reason for insufficient environmental action. The generality of this may be disputed and some argue that "there is not a lack of money but a lack of good projects".[27] However, in the case of environmental investment, a number of projects may fall below the requirements of private investors and lenders because of a lower return on investment and/or a higher risk.

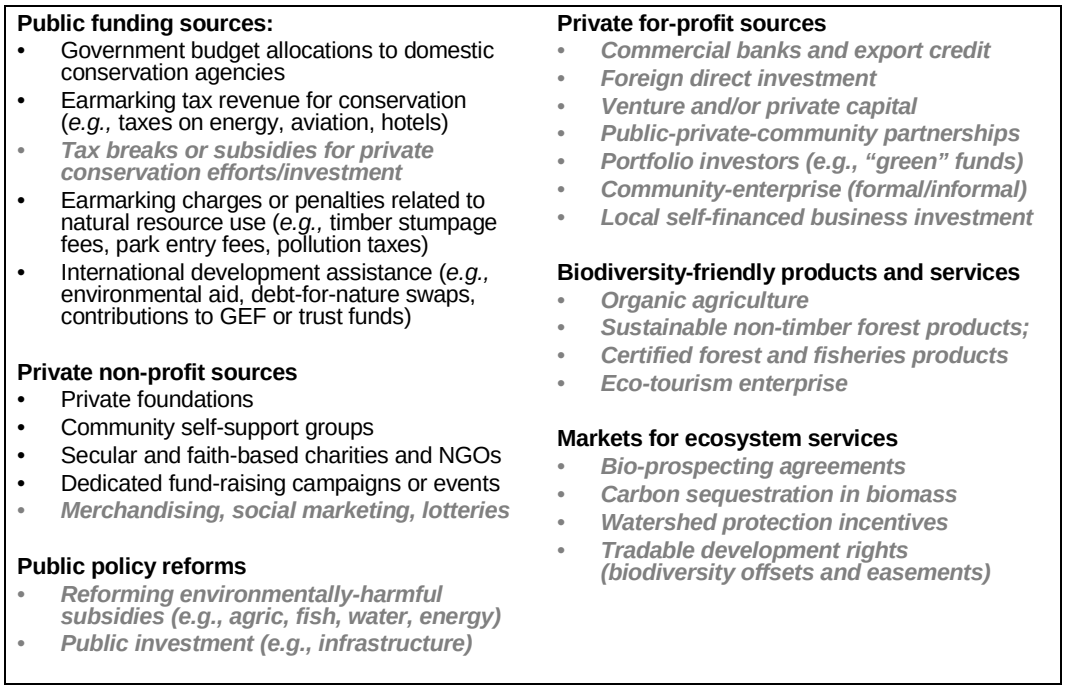
Financial mechanisms can play a key role in developing specialised financing instruments to foster more private investment in support of MEA objectives. Private and public financial institutions, including development banks and agencies, private banks and export credit agencies – through their leverage and the financial tools they offer – can also make important contributions.

25 Harro Pitkänen, NEFCO.

26 Lettemieke Mulder, Unilever.

27 Harro Pitkänen, NEFCO.

Figure 3. **A menu of** public **and** *private* **finance mechanisms**



Source: Gutman, P. (ed.) (2003), as quoted by Joshua Bishop (IUCN).

Financial mechanisms promote private investment in support of MEAs

Governments have put specific financing mechanisms in place to help implement various MEAs, *e.g.*, the Global Environment Facility, the Multilateral Fund for the Implementation of the Montreal Protocol or the Global Mechanism of the UNCDD. Among other objectives, these mechanisms aim to engage the business sector in the implementation of MEAs.

The *Global Environment Facility* (GEF) supports environmental projects and objectives in six focal areas (biological diversity, climate change, international waters, ozone depletion, persistent organic pollutants, and land degradation), with the private sector being an important partner. However, to date the experience of enabling private sector involvement in GEF projects has been at a small scale. Therefore, according to a GEF Council mandate, the goal is "to enhance the level of engagement of the GEF with the private sector as a means to generate global environmental benefits in a sustainable and cost-effective manner". Opportunities for private sector involvement promoted by the GEF include:

- GEF facilitation of supportive policy and institutional environment;
- financial support for incremental/transient risk in demonstration projects;
- access to worldwide experience and global information networks;
- assistance in identifying partnership opportunities; and
- enhancement of corporate image.[28]

The *Global Mechanism* (GM) of the UNCCD seeks to channel direct private investments to UNCCD implementation. COP 6 of the UNCCD specifically requested the GM to expand the supply side of the financing equation, particularly through the mobilisation of "new sources of financing such as private capital, foreign direct investment, funding from multilateral institutions, and grants from private

[28] Nicole Glineur, GEF.

foundations" (decision 5/COP.6). Given its mandate, the GM has a key role in: (i) promoting private investments to combat land degradation and poverty; (ii) fostering global participation and collaboration and build partnerships between public and private sector entities; and (iii) acting as a broker between public and private entities in industrialised and affected countries. With the experience gained and lessons learned so far, the GM confirms widespread interest from the private sector in both developed and developing countries. Globalisation trends are pushing large multinationals to increasingly consider alternative sources of supplies, lower production costs, new and emerging markets while taking care of the environment and their communities.[29]

Box 8. **GM efforts in enhancing private sector involvement**

The GM aims at promoting private sector participation, collaboration and partnership through:

- *engaging the private sector of the North:* GM's approach is to expand its resource mobilisation efforts in OECD countries. It has focused most of its efforts at detecting potential linkages between the core business, corporate social responsibility and environmental policies of private sector companies and the objectives of the UNCCD. The GM will pursue the strategy to mobilise resources in developed countries through continuing to focus on selected companies and foundations: energy companies, the most profitable large multinational companies who have a corporate socio-environmental policy and business operations in affected developing countries in which they have already invested on relevant activities, the largest foundations and charities, and fund-raising campaigns.
- *engaging the private sector of the South:* The GM will expand its resource mobilisation efforts in developing countries through partnerships with the local private sector (*i.e.* farmers, herders, traders, suppliers, microfinance institutions, transporters, agro-processors, commodity brokers and traders, construction companies, supermarkets, etc.), local NGOs and associations, local foundations and charity organisations.
- *public-private partnerships in the South and North:* The GM will continue to assist governments and private sector in the South to develop more effective policies and strategies to attract funding opportunities from the North, through identifying Foreign Direct Investment (FDI).
- *capacity building:* Institution strengthening to deliver services to local enterprises (*i.e.* information, technical assistance, financing) will be conducive to the development of a competitive private sector and to stimulating local entrepreneurship.
- *developing markets and trade:* The GM will promote private sector participation through the development of markets and trade at a local, domestic and international level.

Source: Christian Mersmann, Global Mechanism of the UNCCD; UNCCD.

What is the role of Multilateral Development Banks in promoting business contribution to MEA implementation?

Multilateral Development Banks (MDBs), such as the World Bank Group and the European Bank for Reconstruction and Development (EBRD), seek to foster sustainable development and eliminate poverty through financing of projects and giving policy advice. They leverage significant levels of additional financing from the private sector and build investor confidence in countries and projects, thereby shaping the development paths of recipient countries.[30] However, environmental considerations (and particularly MEA objectives) have been integrated in MDB activities to varying, but generally rather low, extents.

29 Christian Mersmann, Global Mechanism of the UNCCD.

30 Sohn/Nakhooda/Baumert (2005).

The EBRD has the mandate to facilitate the transition to market economies in Central and Eastern European Countries, as well as in the Commonwealth of Independent States. It is also an executing agency of the GEF. The EBRD is "directed by its founding agreement to promote, in the full range of its activities, environmentally sound and sustainable development". Environmental appraisal and monitoring processes ensure that: (i) all EBRD projects undergo environmental assessments, such as Environmental Impact Assessments or audits; (ii) appraisals include whether a project will meet policy requirements, including MEA commitments; and (iii) in case standards cannot be met initially, an action plan (including key issues and actions, implementation schedule and priorities, cost estimate) is developed and agreed upon to achieve EBRD requirements within a specified timeframe.[31]

Box 9. **MEA-related commitments in EBRD's Environmental Policy**

- Consideration of MEAs in all EBRD-financed projects:
  - support for the implementation of international environmental law through investments;
  - identification of relevant MEAs during project appraisal;
  - no financing of projects that would contravene country obligations under relevant MEAs;
  - public consultation;
  - an Environmental Exclusion List for financial intermediaries including MEA requirements (general clause: financial intermediaries may not finance activities conflicting with international environmental/labour law, in addition: specific list that includes activities conflicting with MEA requirements).
- Commitment to finance investments that support MEAs:
  - financing of projects with the primary objective of supporting MEA implementation;
  - expansion of partnerships with multilateral financing vehicles (*e.g.* GEF), other organisations, financial institutions, NGOs;
  - specific mandate to develop Joint Implementation and CDM projects.

Source: Alke Schmidt, EBRD.

In order to help developing countries address climate change and to implement the UNFCCC and the Kyoto Protocol, MDBs have developed specialised policies and lending programmes. One of the main areas of activity is to support the CDM of the Kyoto Protocol by creating and managing CDM funds that invest in GHG mitigation projects in developing countries while earning Certified Emission Reductions (CERs) for investors. The World Bank is the leader in CDM financing with its Prototype Carbon and BioCarbon Funds. The private sector at large plays a crucial role in mobilising financing for reasonable costs of GHG mitigation. Co-operation between MDBs and the private sector can be efficient in finding ways to meet these costs and in developing innovative business models that allow cost reductions.[32]

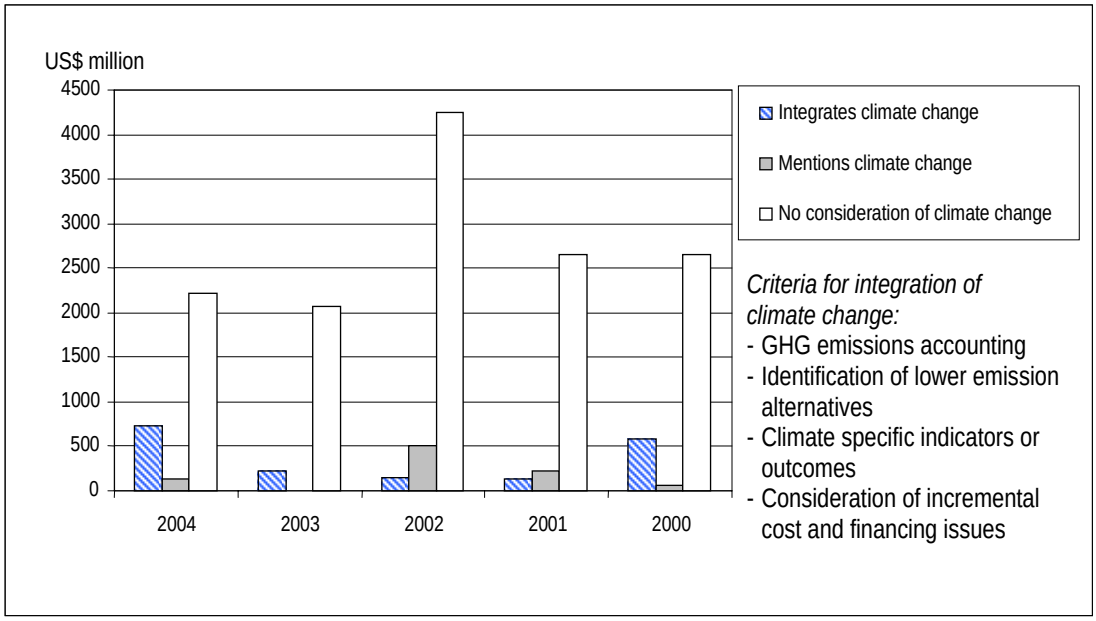
MDBs co-finance large-scale private investments in infrastructure and heavy manufacturing, and provide loans and grants for sectoral and regulatory reforms in key climate-related sectors such as energy,

31 Alke Schmidt, EBRD.

32 Jon Sohn, WRI; Sohn/Nakhooda/Baumert (2005).

transport, agriculture and forestry. However, they often do not systematically integrate climate change concerns into their operations.[33]

Figure 4. **Mainstreaming of climate change considerations in World Bank projects**



Source: Jon Sohn, WRI.

MDBs could better mainstream climate change considerations into their sustainable development and poverty reduction efforts by:[34]

- revising guidelines for country and sector strategies to explicitly integrate climate change considerations;
- developing a "Greenhouse Gas Accounting and Options Analysis Framework"[35] to assess alternative options or identify the cost of less-carbon-intensive paths;
- integrating this GHG Analysis framework into operations in key sectors; and
- initiating pilot work to reduce GHG emissions at the sector level in partnership with interested client countries.

How do other financial institutions take MEA objectives into account?

Export Credit Agencies (ECAs) grant loans and issue guarantees to enterprises and financiers. They are therefore in a position to play an important role in supporting MEA implementation. ECAs take account of environmental considerations in their activities primarily through the implementation of the

33 Jon Sohn, WRI; Sohn/Nakhooda/Baumert (2005).

34 Sohn/Nakhooda/Baumert (2005).

35 An assessment of alternative options for a proposed project should account for direct and indirect GHG emissions. It would identify and analyse alternative approaches to achieving project objectives that might significantly reduce emissions, including alternative technology paths, and would include a full financial and economic analysis of these options.

OECD Common Approaches for Export Credits[36], as well as through the legal and policy requirements of their respective governments. ECAs cannot devote a certain percentage of their portfolio or new business each year to exports in certain "environmentally-friendly sectors" (such as renewables), since they are reactive organisations that depend on enterprises' applications for using their services. There are, however, some ways in which ECAs can support environmental goals, including requiring applicants to inform about their environmental impact; applying agreed minimum standards, such as the World Bank's General Environmental, Health and Safety Guidelines; and improving the terms that are available to meet the needs of specific sectors, *e.g.*, extending the allowable repayment terms in the renewable energy and water sectors.[37]

There are also significant opportunities to achieve environmental goals and promote the implementation of MEAs through support by the *private financial sector*. In recent years, private financial institutions have increased their attention to the environmental, social and reputational risks of their operations, and have increasingly integrated environmental products and services into their portfolios, as well as environmental efficiency considerations into their management practices. Apart from "green" financial products and services, such as green lending and investment practices (*e.g.* commitment to the Equator Principles for project finance, sustainable asset management, or products and services specifically related to MEAs such as emissions trading), private financial institutions have also adopted new approaches aimed at changing internal processes (*e.g.* environmental management systems), as well as external communication (*e.g.* sustainability accounting, listing in sustainability market indices).[38]

Box 10. **Financing environmental investments and technology transfer: the case of NEFCO**

The Nordic Environment Finance Corporation – NEFCO:

- a multilateral financial institution established in 1990 by the five Nordic countries Denmark, Finland, Iceland, Norway and Sweden including the three autonomous territories of the Faroe Islands, Greenland and Åland;
- purpose: promote cost effective solutions to reduce the environmental impact from the adjacent region (Baltic Sea Region, EECCA);
- main focus: small and medium sized projects;
- provision of risk capital, risk loans, soft loans, carbon financing, grants (in special cases).

NEFCO instruments:

- NEFCO Investment Fund: an example of "green equity/patient capital";
- NEFCO focuses on the environmental results rather than maximising financial return (provided that a reasonable return on investment is foreseen);
- the Investment Fund seeks to maintain the real value of its capital while covering its costs;
- projects are assessed on the basis of environmental cost-effectiveness;
- NEFCO seeks to demonstrate the opportunities for win-win solutions and to implement the Polluter Pays Principle.

Eligible projects:

- demonstrate relevant positive environmental impacts: emission or effluent reduction, soil remediation, etc.;
- meet environmental standards defined by MEAs, EU directives, national environmental legislation;
- are economically, financially, institutionally and technically sound and viable.

36 Recommendation on Common Approaches on Environment and Officially Supported Export Credits, www.oecd.org/dataoecd/26/33/21684464.pdf. Also, according to the OECD Arrangement on Officially Supported Export Credits 2005 [TD/PG(2005)22/FINAL], environmental implications are an integral part of project appraisal.

37 Pekka Karkovirta, Finnvera; David Allwood, UK Export Credits Guarantee Department (ECGD).

38 Simone Gigli, OECD.

Type of projects:

- Modernisation of industrial production processes and energy systems: normally in existing plants, greenfield Investments only when good demonstration effects can be expected;
- Production of equipment for pollution abatement;
- Environmental services, waste management and water and sewage treatment;
- Renewable energy investments and energy efficiency: biomass, wind energy, geothermal, small scale hydro.

NEFCO experience:

- MEAs rarely influence investment decisions unless legislation, enforcement and incentives are in place.
- On the other hand, investments frequently have cross media effects, influencing multiple environmental parameters, and "unintentionally" tackling also MEA regulated emissions.
- Introduction of state of the art technology almost invariably leads to a reduction of the pollution load (in "brownfield" investments or when new facilities and systems displace old installations).

Source: Harro Pitkänen, NEFCO.

More ideas for improvements related to financing issues

Co-operation between stakeholders is essential to facilitate financial institutions' efforts to take account of MEA goals in their business activities. Governments have an important role to play in enforcing the implementation of MEAs. One way to do so would be to further encourage financial institutions to take their role in this process but it is important for governments to mainstream MEA commitments in their own projects and in their directives for providing financial support to other activities.

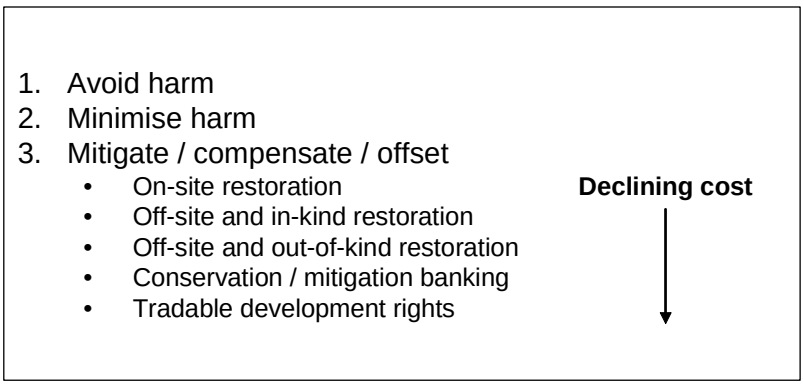
While MEA Secretariats already publish some practical information on their websites, they could further help by providing more concrete information such as mapping of protected sites, databases on regulated species or substances, or contact details for experts within Secretariats or implementing agencies. MEA Secretariats and governments could provide more advice on specific projects, to make financial institutions aware of the impacts of such projects on their business operations and *vice versa*.[39]

Derived from the CDM concept, which aims, *inter alia*, at engaging the private sector in climate change related objectives, a new idea concerns the possibility of creating a "green development mechanism" to support the implementation of the CBD. The private sector and biodiversity offsets can play a key role in this regard. If it is not possible to completely avoid environmentally harmful practices, offsets should be taken into account.[40] Figure 5 shows different kinds of offsets.

39 Alke Schmidt, EBRD.

40 Joshua Bishop, The World Conservation Union (IUCN).

Figure 5. **Biodiversity offsets: where do they fit in environmental mitigation?**



Source: Joshua Bishop, IUCN.

Several official biodiversity offset schemes already exist, for instance, the EU Environmental Liability Directive, the Canadian Fisheries Act, the Protected Areas Law in Brazil, or the Native Vegetation Management Framework in Australia. In addition, several voluntary corporate biodiversity offset initiatives have been established, such as the Energy and Biodiversity Initiative or the International Petroleum Industry Environmental Conservation Association.

In the US, for example, conservation or mitigation banking supports the idea of compensating unavoidable harm to biodiversity: 219 approved "wetland banks" already exist (as of 2001/02), 68% of which are private banks. The aim of wetland banking is to achieve "no net loss" of wetlands as a result of land development. For every hectare of wetland destroyed, at least one hectare of comparable wetland must be restored or re-created. As an alternative to on-site mitigation, developers can purchase "credits" from approved mitigation bankers for similar wetlands within a service area. Conservation banking works in a similar way aiming at ensuring recovery of threatened and endangered species by securing habitat. Compensation has to be paid to environmental agencies for every hectare of habitat destroyed in order to support species conservation efforts. Approved conservation banks provide credits for compensation payments.[41]

Promoting innovation and the transfer of environmentally sound technologies in support of MEAs

The technologies needed to achieve the objectives of MEAs are typically developed and owned by the private sector. To promote the development, transfer and diffusion of environmentally sound technologies[42], certain conditions are needed both on the supply (technology providers) and demand side (users). While the development and transfer of environmentally sound technologies can bring many advantages to businesses (*e.g.*, in the form of first-mover-advantages and expanded markets), there are also risks involved in the product and market development phases which can be key barriers to technological change. It is important to overcome such barriers and achieve a largest possible diffusion of environmentally sound technologies if MEAs are to be efficiently implemented.

41 Joshua Bishop, IUCN.

42 Agenda 21 defines environmentally sound technologies as those that "protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes. Environmentally sound technologies are not just individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organisational managerial procedures." (UNEP, Agenda 21, Chapter 34).

The importance of environmentally sound technologies

Environmentally sound technologies are especially important in developing countries and Countries with Economies in Transition. People in large parts of developing countries have no access to electricity or to non-traditional energy forms. Many rely almost exclusively on traditional fuel sources, such as firewood, kerosene and biomass for their energy supplies.[43] However, in the course of development activities, electrification of these regions will proceed rapidly in the years to come due to an increasing economic activity and further adoption of developed country lifestyles. The importance of diffusing environmentally sound technologies, especially clean energy as part of this development process, becomes apparent for achieving the goals of MEAs, such as the UNFCCC and the CBD: this approach can lower the rapidly rising trajectory of carbon emissions and reduce the loss of habitat.

Box 11. **Solar photovoltaic energy – a contribution to sustainable development**

Solar photovoltaic energy, for example, is a clean energy solution that is most suitable for the electrification of rural areas. Advantages of photovoltaic solar energy are:

- production of clean energy: no impact on fragile ecosystems, no emission of GHGs;
- use of sun energy as freely accessible and unlimited thus renewable source of energy;
- saving in transportation costs since electricity is produced in the same place where it is consumed;
- minimal maintenance costs;
- possibility of electrification of the most inaccessible places or places where other energy solutions are not viable;
- contribution to a sustainable development allowing for electrification, water supply, telecommunications and desalinisation.

The installation of photovoltaic systems in rural areas can bring huge environmental and social benefits. With an investment of about EUR 250 billion over a period of 15 years, photovoltaic systems could provide electricity to one billion people. In both the developed and the developing world, over two million jobs could be created, while cumulative CO_2 savings of 110 million tonnes could be achieved between 2000 and 2020.

Source: Ernesto Macías, Isofotón.

Reducing risks and enhancing opportunities: How can innovation and transfer of environmentally sound technologies be further stimulated?

Private investment will be essential for ensuring access to reliable and affordable energy services, especially to the poor. Greater diffusion of environmentally sound technologies is hampered by the need to ensure financial viability of utilities, and by a lack of financial resources. Although renewable energy systems have very low running costs, they come with high up-front costs. Therefore, enhanced co-operation between the private sector and financing institutions is crucial to reduce the gap of the initial investment cost through innovative financial mechanisms. Subsidies may therefore be necessary for accelerated deployment in some contexts. In addition, international tendering procedures may need to be reconsidered since the present ones do not seem to be suitable for projects such as the deployment of rural electrification with small renewable energy systems.[44]

43 Ernesto Macías, Isofotón.

44 Ernesto Macías, Isofotón.

Technological change toward cleaner energy products is often constrained by high product and market risks. *Product risks* include: (i) lack of appropriate products; (ii) rapid changes in design specifications; (iii) inadequate networks for project appraisal; and (iv) low competitiveness due to higher capital costs. *Market risks* include: (i) inadequate confidence in quality of installation, maintenance, and repair services; (ii) high marketing costs; (iii) new market players; (iv) discriminatory legal and regulatory frameworks (favouring current technologies); and (v) lack of market experience and infrastructure. These risks often crowd out private sector finance. On the other hand, smart risk-sharing strategies can stimulate a "crowd-in" of private investment (Box 12).[45]

Box 12. **Risk management strategies to "crowd-in" private investment**

Stimulating product development

Strategy	*Example*
Creating fora for feedback	
Enable engineering of *technologies* into *products*	Swiss project to develop clean-energy products for small and medium enterprises in India
Testing and certification facilities	Danish support for Centre for Wind Energy Technology in India

Stimulating market development

Strategy	*Example*
Procurement specifications	Microfinance institutions in Sri Lanka use common specifications to invite supply bids
Demand creation/bulk procurement	Bulk procurement of home appliances in USA and Scandinavia; renewable energy portfolio standards in India and China
"Branding" of clean energy products	IFC/GEF's "ELI" (Efficient Lighting Initiative) programme
Document and disseminate "learning-by-doing" experience	The World Bank's Carbon Funds

Stimulating financing

Strategy	*Example*
Facilitating project appraisal networks	OECD-based Green Funds find it difficult to appraise projects in developing countries
Providing partial-risk guarantees to investors	GEF support for World Bank and IFC credit for energy efficiency and geothermal energy projects
Credit extension services	Micro credit facilities in Bangladesh, India, and Sri Lanka; Onlending through energy-service companies
Enabling regulatory mechanisms	Feedlaw tariffs for renewables in Europe

Source: Ajay Mathur, SenergyGlobal.

Co-operation between governments, NGOs, and other stakeholders is essential for technology transfer

Co-operation between governments, business, NGOs, and other stakeholders is potentially a very efficient approach for the transfer of environmentally sound technologies. The conditions for successful transfer, such as enabling environment, capacity, country and community choice and appropriation, win-win situations, flexible frameworks, or indigenous knowledge consideration, can be best fulfilled through

[45] Ajay Mathur, SenergyGlobal.

networking and sharing of information. PPPs are one means to overcome existing barriers to technology transfer in developing countries, with ensuing advantages for both the public and private sectors.[46]

The Government of Australia, for example, works together with business to identify and implement win-win solutions in the area of technology transfer. Australia's regulatory practice on many categories of domestically produced and imported appliances and industrial equipment promotes the take-up of new technologies, and discourages the marketing of less energy-efficient technologies. Australia supports environmentally-friendly technologies through domestic initiatives, such as the Low Emission Technology Demonstration Fund, Renewable Energy Development Initiative and Solar Cities Trials, but also in bi- and multilateral partnerships.[47]

Successful voluntary initiatives to promote innovation and technology transfer in support of MEAs

A number of existing voluntary business approaches already support the implementation of MEAs by promoting the innovation and transfer of environmentally sound technologies. They can serve as examples for other enterprises and stakeholders to reflect about new concepts, technologies and business frameworks for sustainable private investments.

The Business Council for Sustainable Development, Brazil, is very active in stimulating private sector leadership as a catalyst for change towards sustainable development. It provides a basis for a multi-stakeholder dialogue with the goal to share and disseminate information and tools regarding general aspects, such as financing and legislative issues, communication and capacity building, corporate responsibility and eco-efficiency, and (more specifically) on issues directly related to MEAs, such as biodiversity and biotechnology, or climate and energy. The Business Council, together with its private sector partners, encourages actions for the best environmental practices, transparency and an improved relationship with communities regarding the implementation of technologies for prevention and control. Among the successful projects to date is the rehabilitation of areas affected by mining operations achieved through private sector research and technology development: since 1972 about 40 000 ha of exploited land have been reforested.[48]

Challenged by Greenpeace and supported by UNEP, three multinational enterprises (Unilever, Coca-Cola and McDonald's) have also formed the "Refrigerants, Naturally" initiative to ban ozone-depleting substances or substances with global warming potential (such as hydrofluorocarbons, HFCs) from their production processes. The objectives are: (i) to promote a shift in the point-of-sale cooling technology towards natural refrigerants with low or non global warming potential without a reduction in efficiency; (ii) to provide a working group and supportive environment for those committed to using natural refrigerants; and (iii) to communicate with a wider network including other industries, governments and global society. Unilever engaged in this initiative mainly because they saw a good fit with their corporate social responsibility targets and for marketing reasons (pressure from consumers reflected in changes in buying decisions). The initiative has since been well-covered in the media, in the mainstream press, as well as in trade and environmental journals. Other outcomes include increased awareness of alternatives to HFCs (especially among competitors and legislators); a strong message to suppliers and the trade in general; and a change in the debate from *if* HFCs will be replaced to *when* that will happen.[49]

---

46 Farid Yaker, Enda Europe.

47 Richard de Ferranti, Australian Greenhouse Office.

48 Joaquim Machado, Business Council for Sustainable Development, Brazil.

49 Alan Gerrard, Unilever.

The most effective incentives for the initiative were the threat from bad publicity for using environmentally-harmful substances, as well as the recognition that consumers are becoming more knowledgeable and demanding with regard to their environmental interests. However, there are no financial incentives or legislative demands for point-of-sale equipment to change HFCs (with Austria and Denmark being exceptions in the EU). Efficient co-operation between end users, suppliers, multinational organisations, NGOs, etc. has proven to be another important success factor. The development priorities of suppliers and the speed-to-market of new technologies were influenced by the small number of significant end users. In addition, the joint action helped overcome the barrier of high uptake costs for new technologies, while the involvement of IGOs and NGOs added to the credibility of the initiative, and helped to generate positive public relations.[50]

[50] Alan Gerrard, Unilever.

WORKSHOP PRESENTATIONS AND PAPERS

Barbut, Monique (United Nations Environment Program, UNEP DTIE):
"Improving cooperation and encouraging private investment to strengthen MEA implementation – How can intergovernmental organisations promote private investment that supports MEA implementation? The example of the United Nations Environment Program (UNEP)".

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"ECA's contribution to the implementation of MEAs".

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Machado, Joaquim (Business Council for Sustainable Development, Brazil):
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"Stimulating the Innovation and Diffusion of Clean Energy Technologies in Developing Countries (and promoting the implementation of the Climate Change Convention)".

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"Economic incentives and increasing business involvement in the conservation of fauna and flora – Complying with CITES is good business".

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"Opening Remarks by the State Secretary of the Environment".

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"Corporate social responsibility – a step towards stronger involvement of business in MEA implementation?".

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"Transferring Environmentally Sound Technologies through Public-Private Partnerships".

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Organisation for Economic Co-operation and Development

15-Jun-2005

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FOREWORD

This report summarises the findings of the Terrestrial Risk Indicators (TERI) Project, carried out under the OECD Pesticides Programme. It is based on individual reports prepared by participants of an expert group (Belgium, Denmark, Germany, Italy, Norway, and Switzerland) on their results of testing the selected TERI indicators with national pesticide sales and use data. These country reports, along with other documents from the OECD Pesticide Risk Indicators projects are available from the OECD web-site: www.oecd.org/env/pesticides.

This report was prepared by Flemming Møhlenberg of DHI Water & Environment, Denmark, and financed by the Danish Environmental Protection Agency.

The OECD Working Group on Pesticides (WGP) generally agrees with the conclusions from the TERI project and approved this report. The WGP wishes to emphasise the following: 1) the conclusion that the indicators tested in the project were primarily driven by the quantity of pesticide use – which was true for the pilot testing – may not apply to pesticide risk indicators in general; and 2) the conclusion that tremendous efforts in collecting actual use data might be justified only if pesticide risks are to be measured on a sub-national scale and for indicators that take account of varying exposure risks within a country, may be valid in some cases (e.g. in countries where pesticide sales and use data are not highly variable at the national level) but may not apply to cases of countries with a wide variety of crops and pesticide use patterns.

This document is published on the responsibility of the Joint Meeting of the Chemicals Group and Management Committee of the Special Programme on the Control of Chemicals of the OECD.

BACKGROUND

The initiative to develop Pesticide Risk Indicators was taken at the OECD Workshop held in Copenhagen in April 1997. The purpose of the indicators was to be used by government authorities to measure risk trends.

The workshop emphasised that indicators would be used to complement - not duplicate - pesticide risk assessment and registration. The workshop agreed on a set of principles for development of pesticide risk indicators. They included:

- indicators should be scientifically robust and user friendly;
- indicators should link hazard and exposure data with pesticide use data; and
- indicators should address risks to human health and to different compartments of the environment separately rather than having a single indicator reflecting the overall risk of pesticide use.

At the Second OECD workshop on Pesticide Risk Indicators held in Braunschweig in June 1999, the pesticide Aquatic Risk Indicators (ARI) were evaluated and the importance of certain of the Copenhagen principles were stressed:

- indicators should be neither too simple nor too complex;
- the methodology used in the indicators should be clear and the data put into them should be available and reliable;
- the outputs of indicators should be easily understood by government officials and stakeholders; and
- all terminology should be explained clearly.

The Risk Reduction Steering Group (RRSG) formed an Expert Group (EG) that carried out the ARI Project from 1998 to 2001. In the first phase of the project, EG developed, tested and evaluated three indicators for tracking aggregate aquatic risk resulting from agricultural pesticide use. In the second phase of ARI, six OECD countries tested and evaluated the indicators developed by the EG as well as indicators developed in member countries.

The project examined several issues such as: the impact of data gaps on indicator results; the use of sales statistics as a basis for estimating pesticide use; the driving forces of pesticide risk indicators; simplicity vs. complexity in indicator design; and presenting indicator results. Two workshops were organised. The final results were presented in the ARI project summary report.

The ARI project also produced a user-friendly computer program to maintain the required pesticide data and run the three indicators, and an accompanying user guide. Once the data have been entered, the program makes it easy to produce graphs showing risk trends calculated by the three indicators. The programme and all the reports (both ARI and TERI) are available at password-protected RRSG web site. The ARI project demonstrated that both simple and more complex indicators showed the same general trends in risks when used at a highly aggregated level, because they were driven by the same variables, i.e. pesticide sale and toxicity. It was further found that the use of complex indicators that are relevant to calculate risks at lower level of aggregation are often hampered by availability of data, e.g. pesticide use at a regional level.

Building on the ARI Project and on a survey of terrestrial indicators carried out in 2001, the RRSG initiated the pesticide Terrestrial Risk Indicators (TERI) Project in 2002. At the First meeting of the TERI Project held in Frick, Switzerland in May 2002, four indicators were selected for further evaluation based on the following set of criteria, that indicator should:

- be feasible;
- take into account pesticide toxicity, exposure and area treated;
- provide meaningful information;
- be coherent with the context of pesticide registration;
- aggregate at the right level;
- track temporal trends;
- communicate well;
- be ecologically relevant;
- be suitable as a policy tool; and
- be currently in use.

Three of the indicators selected, the Dutch, the Norwegian and the Danish Load Index, met most of the criteria listed above. In addition, the Danish Frequency of Application indicator was also included in the evaluation, due to its ease to use.

CHARACTERISTICS AND PURPOSE OF THE TERI INDICATORS

The indicators included in the evaluation have been used for several different purposes. The Danish **Frequency of Application** (FA) and the **Norwegian Indicator** (NI) are used as indicators of the general environmental impact of pesticide use. FA has been applied as an operational tool to set reduction goals for pesticide use in Danish agriculture. FA was developed in the mid-1980s, as it was realised that the increasing use of low-dose products was not reflected in the Danish statistics on sold amount of active ingredients. Thus, a drop in sales of active ingredient can easily take place, while the number of applications - and pesticide load on the environment - increases.

In addition to monitoring environmental risks, the NI (that also includes elements of aquatic risk and leaching potential) is used for applying different tax rates to pesticides according to their risk potential to human health and the environment. The **Danish Load Index** (DLI) has been used to track changes in the intrinsic properties of pesticides on the market, resulting from registration/re-registration procedures. The **Dutch Indicator** (DI) has been used to evaluate the extent of reduction in environmental impacts due to the reduction in pesticide use by nearly 50% after the adoption of the "Multi-Year Crop Protection Plan".

The indicators differ in complexity and especially in the amount of input data needed to calculate indicator values. For example, the Danish Indicators require little data while the Dutch and Norwegian indicators require much more input data (Table 1).

Table 1. **Data requirements of indicators**

Parameter	Danish FA	Danish LI	Dutch	Norwegian
Total usage/sale	(+)	+	+	
Sprayed area[1]	+			+
Dosage	(+)		+	+
Organic matter in soil (OM)			+	
PEC soil			+	+
Food intake of partridge			+	+
DT50				+
Plant cover				+
Log Kow				+
Toxicity earthworm		+	+	+
Toxicity bird dietary		(+)		+
Toxicity bird oral		+	+	+
Toxicity bee (contact)		+		+

[1]: Calculated as $Sprayed\,area = \frac{Total\,sale}{Dosage}$

The **Frequency of Application** (FA) is the calculated average number of pesticide applications per year. The indicator considers the quantities of each active ingredient sold, the standard dose of each active ingredient in each crop/crop type, and the area of arable land:

$$FA = \sum_{all\ active\ ingredients} \frac{\left(\frac{SA_{activeingredient}}{SD_{croptype}} \right)}{AGRA_{year}},$$

where;

SA denotes Sold Amount of individual active ingredients per year,

SD denotes a defined Standard Dose for each individual active ingredient in each crop/crop type, and

AGRA is the area of arable land.

FA is regarded as an indicator for the spraying intensity as well as an overall indicator of the environmental impact of pesticides. Because FA is based on a standard dose that relates to the biologically active field dose, it is assumed to reflect the direct effect on target organisms as well as the indirect impacts on ecosystems, which result from changes in the quantities and species found in the food chain.

The **Danish Load Index** (DLI) is the calculated number of toxic doses in the sold amount of pesticides. DLI calculates the ratio between *Total sale of different pesticides* and *Toxicity* that are summed for all active ingredients to follow if number of toxic doses has changed as a result of either changes in sales and/or toxicity:

$$DLI = \sum_{all\ active\ ingredients} \frac{Sales_{eachactiveingridient}}{TOX \cdot AGRA_{year}},$$

where TOX represents acute or long-term LC50 or LD50 values.

DLI is calculated separately for mammals, birds, earthworms, bees, (and fish, crustaceans, algae) using a value (average, min. or max.) for toxicity of individual pesticides. The calculated values are designated as "load indices for mammals", "load indices for fish", etc. DLI provides a relative measure of environmental load concerning specific type of toxicity. In line with most indicators, LI is not a measure of actual effects on populations or ecosystems in the field but calculates a relative risk that can be compared between years.

The **Dutch Indicator** (DI) encompass two separate indicators calculating the relative risks of pesticide use to earthworms and birds, where partridge is used as a model for bird exposure. The indicators are based on the quotient of the predicted environmental concentration (*PEC*), divided by the toxicity of the species and multiplied by the scaled area treated with pesticides:

$$DI = \sum_{all\ active\ ingredients} \frac{PEC_{ai1}}{TOX_{ai1}} \bullet \frac{AREA_{ai1}}{AREA_{tot}},$$

where;

PEC_{ai1} is the predicted environmental concentration of an active ingredient,

TOX_{ai1} represents acute or long-term LC50 of an active ingredient,

$AREA_{ai1}$ is the area treated with a particular active ingredient, and

$AREA_{tot}$ is the total arable area.

The predicted environmental concentration is basically calculated from sales and area treated, but modified according to properties of the soil (earthworm indicator only). The calculations of risks to earthworms rely on dose rates used on the fields that are treated and toxicity values corrected for differences in soil concentration of organic carbon. The daily intake of pesticides in partridge is calculated from the energy expenditure of a "standard-sized" bird. The calculated toxicity quotients are combined with the *relative area* treated with the different pesticides to arrive at a relative risk value for different pesticides that are subsequently summed for all the pesticides.

In contrast to the DLI and DI, the **Norwegian Indicator** (NI) is a compound indicator summing effects on earthworm, bird and bees, and taking account of persistence and bio-accumulation. In addition, while the DLI and DI calculate the "risk impact" monotonously by the ratio between predicted concentration and toxicity, the NI uses scores for each element (i.e. earthworm, bird, bees, persistence and bio-accumulation) which are added together, cubed and multiplied by the area treated:

$$NI = \sum_{all\ active\ ingredients} \left[\sum_{scoring} \left(Earthworm, Bird, Bee, Persistence, Bioaccumu. \right)^3 \right] \bullet Sprayed\ area$$

Prior to scoring for earthworm, the concentration of active ingredients in soil (PEC_{soil}) is calculated from the application rate (corrected for interception by crop canopy), mixing depth (e.g. 5 cm) and the soil density. The Toxicity Exposure Ratio (TER) for earthworms is then calculated by dividing toxicity (14 days LC50) by the PEC_{soil} and scored into 3 classes. The breakpoints between scores are adapted from EU's Uniform Principles.

The scoring for bees in NI rely on hazard quotients for oral exposure or for contact exposure of bees calculated as the application rate (g ha^{-1}) of an active ingredient divided by the oral or contact toxicity

respectively (LD_{50}, µg bee^{-1}). Using a threshold value of 50 (EU's Uniform Principles), hazard quotients are scored (1-4) using logarithmic distributed breakpoints.

The scoring for birds in NI is based on TER's calculated from Predicted Initial Environmental Concentration (PIEC = Application rate (kg ha^{-1}) x 30) and toxicity values (preferentially from diet studies, alternatively acute oral LD_{50} values may be used after correcting for daily intake). Using a threshold value of 10, calculated TER's are scored in 2 classes (2 & 4).

The scoring for persistence in NI is based on the half-life in soil (DT_{50}) and the application rate of pesticides. The scores varies from 0 (DT_{50} < 10 days) to 4 (DT_{50} > 365 days).

The scoring for bio-accumulation in NI relies on two properties of pesticides: log Kow and the persistence (DT_{50}) in soil that are linked by multiplication. The combined scores vary from 0 (DT_{50} < 1 day or log Kow < 3) to 4 (DT_{50} > 200 days and log Kow > 4).

PILOT TESTING OF THE TERI INDICATORS

At the Frick workshop, eight countries[1] agreed to participate in testing the selected TERI indicators using their national use data. The progress of pilot testing was discussed at two workshops held in Paris (January 2003) and in Bilthoven, Netherlands (September 2003). At a follow-up teleconference in December 2003, the TERI participants decided to conclude the project with preparing individual country reports on their final testing results by January 2004[2]. These country reports along with the report from the teleconference constitute the background for this summary report.

The overall scope of the national pilot tests is summarised in Table 2. The data on pesticide use were, with one exception, calculated from pesticide sales. Because of stockpiling of pesticides in certain countries (e.g. in anticipation of bans or increased tax) year-to-year variation in risk estimates can be expected. To that end, two countries used a 2-3 year running average of sales. In testing the indicators, the Swiss participants estimated pesticide use from interviews (accounting for 3-5% of the arable area) and GIS-supported routines to estimate pesticide use in the areas considered. Among the participants, Switzerland was the only country that tested the indicators at a local scale (3 lake basins). The remaining participants tested the TERI indicators at the national level.

The number of pesticides included in the pilot tests ranged from 20 to 259, representing between 75%-100% of sales for agriculture use. Importantly, however, several participants note that the most hazardous pesticides (or herbicides) were included. Most participants did not include copper (Cu), sulphur, mineral or vegetative oils, and none included seed dressing, though it was felt that seed dressings probably would pose the greatest risk to birds. While actual indicator values will depend on the inclusion or exclusion of certain compounds, temporal trends will be much less sensitive, provided that the same criteria for pesticide inclusions are used throughout a time series. The time span covered by individual participants was primarily limited by the availability of reliable data on sales or use.

[1] Belgium, Denmark, Germany, Italy, Netherlands, Norway, Switzerland, USA.

[2] Country reports were made available from September 2003 to 1 March 2004.

Table 2. **Overall scope of pilot tests carried out by participant countries**

Country	Use data[1]	Number of pesticides[2]	Time span	Geographical scope
Belgium	Sales (1)	259 (93-99%)	1982,1985,1988,1991-2002	National
Denmark	Sales (1-2)	110 (100%)	1992-2002	National
Germany	Sales (1)	20 herbicides	1987,1994,1998,2000	National
Italy	Sales (1)	244 (about 60%)	1992-1999	National
Netherlands	Sales (1)	156	1996-2001	National
Norway	Sales (3)	61 (76%)	1996-2002	National
Switzerland	Survey (1)	76-155[3]	1997-2001	3 lake basins

Notes:

1. Values in brackets denote the basis of calculations, i.e., 1 = actual years sale, 3 = running 3 year average.

2. Values in brackets denote the percentage covered of the total sale excluding seed treatment product

3. Depending on year and lake basin.

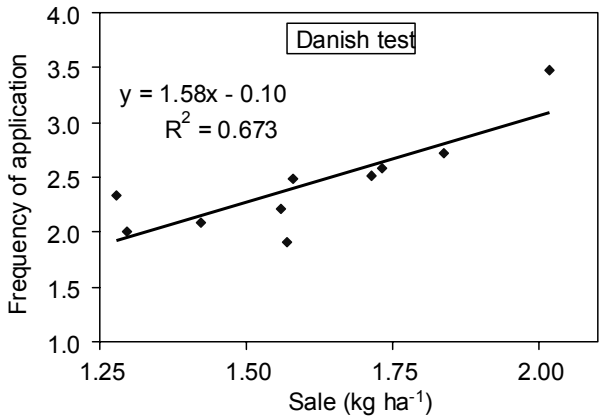
The six TERI participants (Belgium, Denmark, Netherlands, Italy, Norway and Switzerland) tested almost all the TERI indicators, which allows a comparison across indicators but within non-target species (i.e. earthworms, birds). Three participants (Belgium, Denmark and Norway) calculated indicators separately for herbicides, fungicides and insecticides, and three participants (Denmark, Italy, Norway) examined the relative importance of the different constituents of the NI. Finally, Denmark examined the robustness of indicators with variations in input data for toxicity and fate by combining data from the common data base to arrive at minimum or maximum impact.

In the following sections, the outcomes of the pilot testing are evaluated in quantitative terms by comparing the temporal variation of indicator values between years and their correlation to pesticide sales/use.

Correlation between pesticide sales and FA

The Danish and Norwegian data showed a highly significant correlation between pesticide sales (corrected for treated area) and FA (see Figure 1). This indicates that, on average, no major changes between low and high dose pesticides took place during the period 1992 - 2001. However, such correlation was verified only the Belgian sales data for fungicides. If major changes in pesticide use patterns occur, a simple linear relation between sales and FA would not be expected.

Figure 1. **Correlation between pesticide sale (ha^{-1}) and FA: Data from the Danish test (1992-2001)**

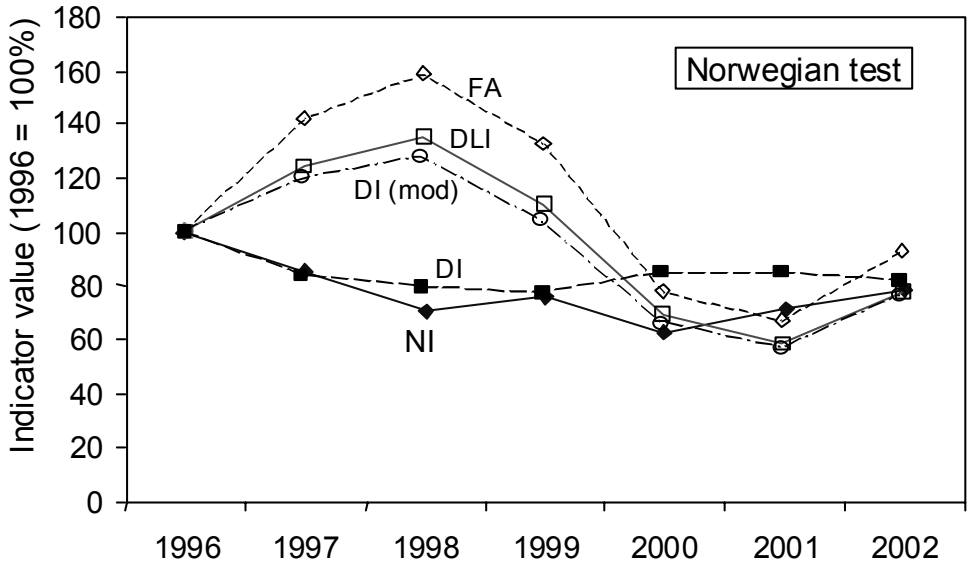


Correlation between the indicators for earthworms

Most tests on earthworm indicators showed a good agreement between FA (or Use) and DLI as demonstrated by the Norwegian test (Figure 2). In comparison, DI shows an opposite trend of the total area treated (= FA): the risk decreases when FA increases, and *vice versa*. In calculating the DI, the cumulative area treated with one compound is divided by the total area treated by all compounds (i.e. the indicator is scaled by fraction). This results in unreasonable risk variations if there are large year-to-year variations in sales data, such as in the Norwegian data. DI is strongly influenced by variations in high volume, but not necessarily high-risk pesticides. In reality, DI is an "unscaled" indicator, which calculates the average intensity of the pesticides used every year, not taking into account the total amounts used or sold. If "the area treated" is not divided by the "total area", when calculating DI, the trends (DI mod) closely tracks DLI and FA (Figure 2).

The earthworm component of the combined NI showed minor variation during the period 1996-2002, but was overall unrelated to FA or DLI. The contribution of the earthworm component was negligible in NI (< 1%) (see below), which may explain uncoupling to FA.

Figure 2. **Comparison of temporal variation in earthworm indicators and FA**



Notes:

Two versions of Dutch Indicators shown, DI = "unscaled" and DI (mod) omitting the division with the "total area".
Data are normalised values in 1996. From the Norwegian test.

The results of all testing efforts on earthworm indicators are summarised in Table 2. The direction of change in indicator values (and pesticide use) between consecutive years is indicated by " + " (for increase), by " — " (for decrease) and by " ± " for insignificant changes. Notice that only the direction of change and not the change in value of the TERI indicators is shown. In the lower part of the table, the summed agreement for each national test (or area) between individual indicators (DLI, DI, NI) and either FA or pesticide use, and the agreement between DLI and DI are shown.

Overall, the other participants' tests confirmed the results of the Norwegian test. Based on all observations between consecutive years (n = 36) the DLI was in agreement with FA (or Use) in 68% of the observations, while the corresponding agreement between DI and FA was 33%. The agreement between the direction of change of DLI and DI was 40%.

The correspondence between FA (use) and NI was in-between the DLI and DI at 50% (n = 22).

Table 3. **Earthworm indicator agreement on temporal variation**

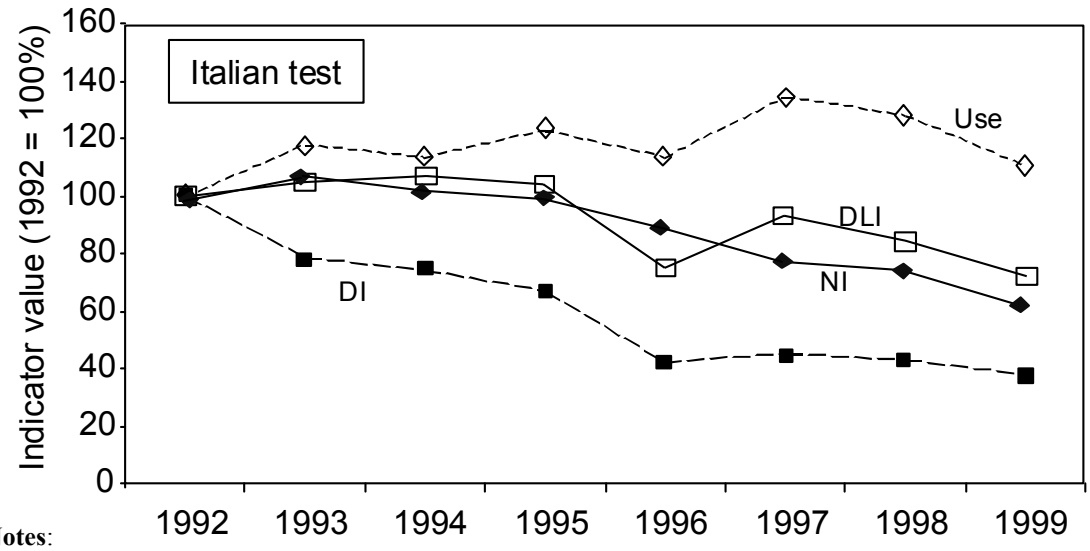
	Danish test				Italian test				Norwegian test				Swiss test (Lac de Morat)			Swiss test (Greifensee)			Swiss test (Baldeggersee)			German test		
Years	FA	DLI	DI	NI	Use	DLI	DI	NI	FA	DLI	DI	NI	Use	DLI	DI	Use	DLI	DI	Use	DLI	DI	Use	DLI	DI
1992-93	-	-	-	+	+	+	±	+																
1993-94	-	-	+	+	±	-	-	-																
1994-95	+	+	-	+	+	+	+	+																
1995-96	-	-	-	-	-	-	-	-																
1996-97	+	+	+	+	+	±	-	-	+	+	-	-										+	+	-
1997-98	-	-	-	-	-	-	±	-	+	+	-	-	-	-	+	+	-	+	±	±	+			
1998-99	+	-	-	-	-	-	-	±	-	-	±	+	-	-	-	±	+	±	±	+	-			
1999-2000	-	+	+	+					-	-	+	-	±	-	-	-	+	+	+	+	-	-	±	-
2000-01	+	+	+	+					-	-	±	+	-	+	±	+	±	-	-	-	+			
2001-02									+	+	±	+												
Agreement with FA/Use		7/9	5/9	5/9		5/7	3/7	4/7		6/6	0/6	2/6		2/4	1/4		0/4	2/4		3/4	0/4		½	1/2
Agreement between DI/DLI		7/9				4/7				0/6				2/4			1/4			0/4			0/2	

Notes:
FA = Frequency of Application
Use = Pesticide sale or application rate
DLI = Danish Load Index
DI = Dutch Index (unscaled)
NI = Norwegian Index (isolated values for earthworms)
+ = increase
- = decrease
± = insignificant change

Correlation between the indicators for birds

As for the earthworm indicator tests, most tests on bird indicators showed a good agreement between FA (or Use) and DLI as shown by the Italian test (Figure 3). DLI did decrease during the period 1992-1999, while the use (kg on field) showed a small increase. Importantly, except for 1994 the development was parallel and DLI tracked most dips and increases during the period. The overall reduction in DLI was explained by substitution by less toxic compounds during the period. In comparison, both DI and NI steadily decreased during the period.

Figure 3. **Comparison of temporal variation in bird indicators and Use (kg on field)**



Notes:

Data are normalised values in 1992. From the Italian test

The results of all testing efforts on bird indicators are summarised in Table 4, using the same approach as in Table 3. Overall, the other participants' tests confirmed the results of the Italian test. Based on all observations between consecutive years (n = 41), the DLI was in agreement with FA (or Use) in 68% of the observations, while the corresponding agreement between DI and FA was 44%. The agreement between the direction of change of DLI and DI was low at 24%.

The correspondence between the bird part of NI and FA (use), and between NI (bird) and DLI was high at 81% (n = 22).

Table 4. **Bird indicator agreement on temporal variation**

	Danish test				Dutch test				Italian test				Norwegian test				Swiss test (Lac de Morat)			Swiss test (Greifensee)			Swiss test (Baldeggersee)			German test[1]		
Years	FA	DLI	DI	NI	Use	DLI	DI	NI	Use	DLI	DI	NI	FA	DLI	DI	NI	Use	DLI	DI	Use	DLI	DI	Use	DLI	DI	Use	DLI	DI
1992-93	-	-	+	-					+	+	-	+																
1993-94	-	-	+	+					±	±	-	-																
1994-95	+	+	-	+					+	±	-	-																
1995-96	-	-	-	-					-	-	-	-																
1996-97	+	+	-	+	+	-	-	-	+	+	±	-	+	+	-	+										+	-	-
1997-98	-	-	+	-	+	-	-	-	-	-	±	-	+	+	-	+	-	-	+	+	-	±	±	±	-			
1998-99	+	-	-	+	-	-	-	-	-	-	±	-	-	-	±	-	-	+	+	±	±	±	±	+	+	-	-	-
1999-2000	-	-	+	-	-	-	-	-					-	-	+	-	±	-	-	-	+	+	+	+	±			
2000-01	+	+	+	+	-	-	+	-					-	-	-	-	-	+	±	+	±	-	-	-	±			
2001-02													+	+	-	+												
Agreement with FA/Use		8/9	2/9	8/9		3/5	2/5	3/5		6/7	1/7	5/7		6/6	1/6	6/6		1/4	0/4		1/4	2/4		3/4	0/4		½	1/2
Agreement between DI/DLI		3/9				4/5				4/7				0/6				2/4			2/4			1/4			2/2	

Notes:
1. Top 20 herbicides
FA = Frequency of Application
Use = Pesticide sale or application rate
DLI = Danish Load Index
DI = Dutch Index (unscaled)
NI = Norwegian Index (isolated values for birds)
+ = increase
- = decrease
± = insignificant change

Correlation between pesticide Use and the combined Norwegian Indicator

The Danish and Norwegian pilot test showed 100% match in trends between FA and NI, while tests by other participants were ambiguous (Table 5). In particular, the Swiss test on Greifensee showed heavy fluctuations in NI (100-300%), which was uncorrelated to pesticide Use (100-115%).

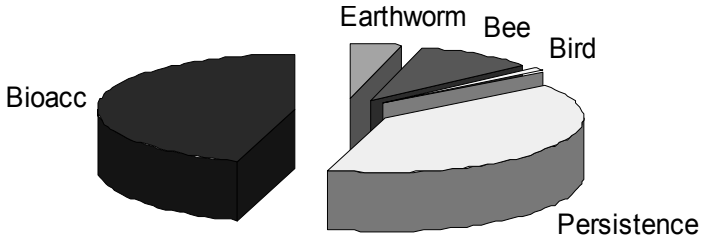
Table 5. **Agreement between FA (Use) and combined Norwegian indicator on temporal variation**

	Belgian		Danish		Italian		Norwegian		Swiss Lac de Morat		Swiss Greifensee		Swiss Baldeggersee	
	Use	NI	FA	NI	Use	NI	FA	NI	Use	NI	Use	NI	Use	NI
1991-92	+	-												
1992-93	-	-	-	-	+	+								
1993-94	-	-	-	-	±	-								
1994-95	+	+	+	+	+	±								
1995-96	±	+	-	-	-	-								
1996-97	-	-	+	+	+	+	+	+						
1997-98	+	+	-	-	-	-	+	+	-	±	+	-	±	+
1998-99	-	-	+	+	-	+	-	-	-	-	±	+	±	-
1999-2000	+	-	-	-			-	-	±	-	-	-	+	+
2000-01	-	±	+	+			-	-	-	+	+	-	-	+
2001-02	+	-					+	+						
Agreement between NI/FA(Use)	6/11		9/9		4/7		6/6		1/4		1/4		1/4	

Notes:
FA = Frequency of Application
Use = Pesticide sale or application rate
NI = Norwegian Index
+ = increase
- = decrease
± = insignificant change

The Norwegian TERI Indicator was dominated by persistence and bioaccumulation as demonstrated in both the Norwegian and Danish tests (Figure 4). As explained in the Norwegian report, the relative importance of persistence and bio-accumulation is lower when aquatic risk and leaching potential are included. These elements that are additional constituents of the national Norwegian indicator were not taken into account when modifying the indicator to the TERI project.

Figure 4. **Relative importance of the different constituents of the combined Norwegian risk indicator**



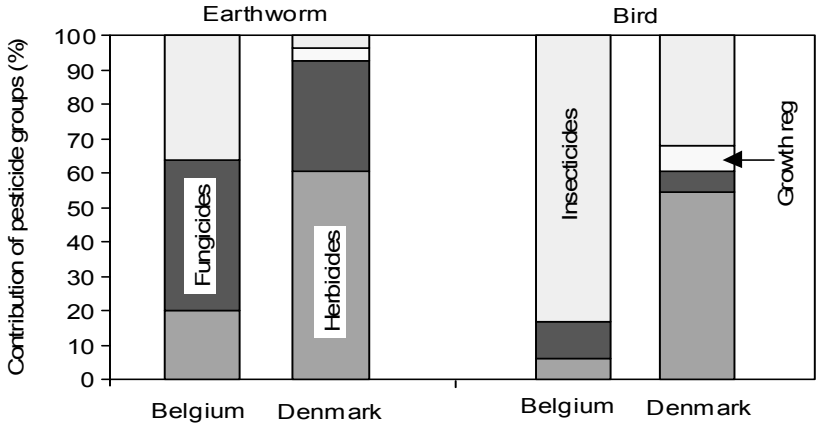
Notes:

Average for the period 1992-2001, from the Danish test

Pesticide types dominating the indicators

The types of pesticides dominating the indicators varied across participating countries, reflecting the composition of crops and thus the use of pesticides in terms of amounts and substances. In Norway and Denmark, high-volume low-toxicity herbicides with respect to earthworms and birds (applied on cereals) dominated the earthworm and bird indicators. In comparison, in countries where fruits, potatoes and vegetables play a larger role, insecticides were much more important for indicators (Figure 5). Several countries mentioned in their reports that several organophosphorus insecticides were banned during the period analysed. Given the high influence of insecticides, such changes in use patterns may be responsible for the "decoupling" of indicator values and the Use.

Figure 5. **Relative contribution of herbicides, insecticides, fungicides and growth regulators to the risk indicators for earthworm and birds**



Notes:

Average for the period 1991-2002 (Belgium) and 1992-2001 (Denmark)

Conclusion from Pilot Testing

When evaluating the outcomes of the Pilot Testing, it must be kept in mind that the indicators tested have been developed for different purposes. It should thus be remembered that indicators by their nature are crude tools that do not provide exact measures of real risks. Simple indicators requiring little data may be

adequate for policy purposes, e.g. tracking risk trends at the national level. Simple indicators are inherently easy to communicate and understand for non-specialists. On the other hand, if differentiation of risk trends between regions within a country is needed, it calls for indicators that take account of regional variations in pesticide use and exposure risks. As noted in the conclusions from the ARI project, the use of complex indicators can be hampered by lack of data.

All pilot tests except the Swiss tests were carried out at the national level and used pesticide sales as a substitute for pesticide use. Norway and Denmark used 2-3 year running averages of sales to level out the effect of stockpiling, and the Belgian participant noted that using a running 2-3 year average of sales probably would have lead to an improvement. Used at the highly aggregated (national) level, most pilot tests showed that indicators were primarily driven by the quantity of pesticide use.

Instead of relying on sales data and analysis carried out at the national level, the Swiss participant estimated pesticide use in three lake regions based on interviews. However, judged from the analysis of trends, the Swiss tests showed the least coupling between pesticide use and the TERI indicators (Tables 3-5). It is unknown to what extent the uncoupling is influenced by a small sample size (i.e. 2.5-5% of arable area represented in the three lake areas).

Theoretically, an improved measurement of risk trends would use real use data instead of sales data. However, tremendous efforts of collecting actual use data seem to be justified only if pesticide risks to be measured are on a regional scale, and the indicators take account of varying exposure risks. Germany, the Netherlands, Norway and Switzerland are following this path. Otherwise, simple indicators based on sales data reflecting risks at the national level can be sufficient for most purposes. As shown in the Pilot Testing, simple indicators can be improved if running averages of sales are used.

In the following section, each TERI indicator is discussed with reference to a suite of important criteria such as the Pesticide Use, species addressed and interpretability. A summary of these TERI characteristics is provided in Table 6.

Table 6. **Selected properties of the five TERI indicators: Danish Frequency of Application, Danish Load Index, the Dutch Indicator and the combined Norwegian Indicator**

	Danish Frequency of Application (FA)	Danish Load Index (DLI)	Dutch indicator (DI, scaled by number of hectares)	Norwegian Indicator (NI)
Does the indicator reflect changes in volumes used	Yes	Yes	Partly	Yes
Does the indicator reflect changes in intrinsic properties?	Field toxicity to target organisms	Toxicity to non target organisms (and other properties possibly)	Toxicity to non target organisms (other properties possibly)	Toxicity to non target organisms, LogKow, DT_{50} combined
Does the indicator include exposure?	Consumption, area treated, field dosages	Consumption only	Consumption, area treated, crop cover	Consumption, area treated, crop cover
Species addressed by the indicator	Target species (higher plants, fungi, insects)	Non target species (birds, bees, earthworms)	Non target species (birds, bees, earthworms)	Non target species (birds, bees, earthworms)
Is the indicator related to the agro-ecosystem reflecting risk of direct and indirect effects? ecosystem level	Yes	Yes/No* Not in general, as it does not include higher plants and fungi. May to some extent reflect indirect effects due to loss of food if bee and/or earthworm toxicity reflects effects on broader insect/worms groups that constitute major food items in the agro-ecosystem	Yes/No* Not in general, as it does not include higher plants and fungi. May to some extent reflect indirect effects due to loss of food if bee and/or earthworm toxicity reflects effects on broader insect/worms groups that constitute major food items in the agro-ecosystem	Maybe
Is the indicator easy interpret	Yes in terms of pesticide main groups: Yes in terms of spraying intensity. Yes in terms of number of toxic doses with respect to target organisms. Yes in terms of connection between FA and indirect effects. No in terms of the combined FA	Yes in terms of number of toxic doses with respect to birds, bees and earthworms.	Interpretation of risk trend not possible on the national scale (unless changes in use are small). In a scaled version, DI is similar to DLI, if so: Yes in terms of number of toxic doses with respect to birds, bees and earthworms.	The combined indicator is difficult to interpret, the constituents easy in terms of Toxicity to earthworm, birds, bees and persistence and bio-accumulation. The setting of breakpoints for scores will influence the responsiveness to changes in pesticide use and should be adapted to each country's specific needs.
Notes: * Depends on the non target group (e.g. less food and reduction of shelter is considered to be an indication of indirect effects)				

The Danish indicator **Frequency of Application** (FA) is the simplest among the indicators tested, as it just sums the number of recommended dosages used per treated hectare. The "recommended dosage" expresses the dosage necessary to control the pest and is derived from field tests. The "tests" thus specify the target pests and related species, which the compound at the recommended dosage can control to a certain degree. The greatest direct ecological impact is likely to be associated with effects on non-target species belonging to the same or closely related taxonomic groups. Unlike other TERI indicators, FA does not relate to direct toxicity of the used pesticides to birds and earthworms. FA does however include toxicity towards insects, higher plants and fungi, which constitutes important elements in the agro-ecosystem. Independent tests have shown that FA also reflects indirect effects on an ecosystem level. In Denmark FA has proven to be

an efficient instrument for setting tangible national reduction goals that can be understood and implemented at the farm level, by breaking the national goals down to reduction goals for each main crop.

A major obstacle for a widespread use of FA, as noted in the Italian report, is that the use pattern for each active ingredient has to be known. Such information may be difficult to obtain especially in (larger) countries with a diverse distribution of crops. To that end, the Danish pilot testing included a simplified version of FA (FA_{light}) based on the use pattern of pesticides by calculating the FA for that crop only, which dominated the area use of each pesticide, and subsequently summing FA for all pesticides. The Danish testing demonstrated a strong coupling between FA and FA_{light}, however, as FA_{light} was not tested by other partners, the general applicability is unknown.

The **Danish Load Index** (DLI) calculates the number of toxic units used at the *national* level per year for a given test species (e.g. earthworms, bees, birds). Being a national level indicator, DLI does not include estimates of exposure risks as these are assumed to be constant through time. DLI reflects the potential toxicity to the test species of the total pesticide consumption based on sales figures. As such, DLI indicates the average toxicity of the sold compounds per year and not the proportion of compounds posing a high risk. Area treated is not considered in DLI but it can be included. DLI can be seen as an indicator of the *average* intrinsic properties of the active ingredients used/sold on the market. The ecological relevance of trends in indicator values has to be considered when interpreting the indicator.

The **Dutch TERI Indicator** (DI) is related to DLI as it calculates the number of toxic units. In contrast to DLI, DI includes an exposure calculation based on soil organic carbon (earthworm) and dietary uptake after spraying (bird). As such, DI can be applied at a regional (or even field) level if exposure characteristics differ among regions. Used at the national level, exposure risks can be regarded as constants through time and their inclusion in the risk calculation is thus superfluous. The major deviation from DLI is that DI calculates the contribution of each active ingredient as a fraction of total use measured as treatments per hectare divided by total number of treatments per hectare. The indicator thus reflects the *relative use* of a pesticide, and DI does not take account of the amount of pesticide used. Therefore, in case the spraying intensity changes it will not be reflected in the risk values. If the calculation of treated area as a fraction of total treated area is omitted in DI, the development and the indicator trend over time closely follows the DLI. In the Dutch test, DI and DLI were almost identical because of low variations in pesticide use in the Netherlands. In the Danish, Italian and Norwegian tests, DI deviated markedly from DLI because the use pattern changed during the period analysed.

The **Norwegian TERI Indicator** (NI) differs from the other indicators tested because it; 1) relies on scores, 2) includes persistence and bio-accumulation potential, and 3) combines the different elements including toxicity into one index value. The scoring implies that the index does not count reductions below the "no significant environmental impact limits", assuming that the calibration of the scoring breakpoints is correct. As noted in the accompanying user manual for this indicator, the breakpoints can be changed according to specific needs. The Pilot Tests that "broke down" the NI into its constituents showed a total dominance of persistence and bio-accumulation, while the toxicity elements were of negligible importance. The Danish and Norwegian Pilot tests showed an overlap of active ingredients dominating the combined NI and the toxicity to bees (primarily pyrethroids), while herbicides were without importance. Therefore, NI does not reflect the risk from herbicide applications as important constituents of the agro-ecosystem. Again, breakpoints and weighting can be adapted to account for this. Overall, the combined indicator is not easy to interpret and understand due to the integration of several components and the relative weighting of the components.

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Switzerland: *"OECD terrestrial risk indicators for the use data from the three lake regions Baldeggersee, Greifensee, and Lac de Morat in Switzerland"* by Andreas Fliessbach

"Thoughts about the differences between the indicators" by Robert Luttik

These reports are available at: www.oecd.org/env/pesticides.

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OECD Series on the Safety of Novel Foods and Feeds No. 13

Consensus Document on Compositional Considerations for New Varieties of Alfalfa and Other Temperate Forage Legumes: Key Feed Nutrients, Anti-nutrients and Secondary Plant Metabolites

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

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No. 5, Report of the OECD Workshop on the Nutritional Assessment of Novel Foods and Feeds, Ottawa, February 2001 (2002)

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Series on the Safety of Novel Foods and Feeds

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Environment Directorate

Organisation for Economic Co-operation and Development

Paris 2005

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FOREWORD

The OECD's Task Force for the Safety of Novel Foods and Feeds decided at its first session, in 1999, to focus its work on the development of science-based ***consensus documents,*** which are mutually acceptable among member countries. These consensus documents contain information for use during the regulatory assessment of a particular food/feed product. In the area of food and feed safety, consensus documents are being published on the nutrients, anti-nutrients or toxicants, information of its use as a food/feed and other relevant information.

This consensus document addresses compositional considerations for new varieties of *Alfalfa and other Temperate Forage Legumes: Key Feed Nutrients, Anti-nutrients and Secondary Plant Metabolites*. A general description of these components is provided. As well, there is background material on the production, processing and uses of Alfalfa and other Temperate Forage Legumes and considerations to be taken when assessing new Alfalfa and other Temperate Forage Legumes varieties.

Canada and the United Kingdom served as lead countries in the preparation of this document.

This document is published on the responsibility of the Joint Meeting of the Chemicals Group and Management Committee of the Special Programme on the Control of Chemicals of the OECD.

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PREAMBLE

Food and feed products of modern biotechnology are being commercialised and marketed in OECD Member countries. The need has been identified for detailed technical work aimed at establishing appropriate approaches to the safety assessment of these products.

At a Workshop held in Aussois, France (OECD, 1997), it was recognised that a consistent approach to the establishment of substantial equivalence might be improved through consensus on the appropriate components (e.g., key nutrients, key toxicants and anti-nutritional compounds) on a crop-by-crop basis, which should be considered in the comparison. It is recognised that the components may differ from crop to crop. The Task Force therefore decided to develop consensus documents on phenotypic characteristics and compositional data. These data are used to identify similarities and differences following a comparative approach as part of a food and feed safety assessment. They should be useful to the development of guidelines, both national and international and to encourage information sharing among OECD Member countries.

These documents are a compilation of current information that is important in food and feed safety assessment. They provide a technical tool for regulatory officials as a general guide and reference source, and also for industry and other interested parties and will complement those of the Working Group on Harmonization of Regulatory Oversight in Biotechnology. They are mutually acceptable to, but not legally binding on, Member countries. They are not intended to be a comprehensive description of all issues considered to be necessary for a safety assessment, but a base set for an individual product that supports the comparative approach. In assessing an individual product, additional components may be required depending on the specific case in question.

In order to ensure that scientific and technical developments are taken into account, Member countries have agreed that these consensus documents will be reviewed periodically and updated as necessary. Users of these documents are invited to provide the OECD with new scientific and technical information, and to make proposals for additional areas to be considered.

THE ROLE OF COMPARATIVE APPROACH AS PART OF A SAFETY ASSESSMENT

In 1990, a joint consultation of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) established that the comparison of a final product with one having an acceptable standard of safety provides an important element of safety assessment (WHO, 1991).

In 1993 the Organisation for Economic Co-operation and Development (OECD) further elaborated this concept and advocated the approach to safety assessment based on substantial equivalence as being the most practical approach to addressing the safety of foods and food components derived through modern biotechnology (as well as other methods of modifying a host genome including tissue culture methods and chemical or radiation induced mutation). In 2000 the Task Force concluded in its report to the G8 that the concept of substantial equivalence will need to be kept under review.

The Joint FAO/WHO Expert Consultation on Foods Derived from Biotechnology in 2000 concluded that the safety assessment of genetically modified foods requires an integrated and stepwise, case-by-case approach, which can be aided by a structured series of questions. A comparative approach focusing on the determination of similarities and differences between the genetically modified food and its conventional counterpart aids in the identification of potential safety and nutritional issues and is considered the most appropriate strategy for the safety and nutritional assessment of genetically modified foods. The concept of substantial equivalence was developed as a practical approach to the safety assessment of genetically modified foods. It should be seen as a key step in the safety assessment process although it is not a safety assessment in itself; it does not characterise hazard, rather it is used to structure the safety assessment of a genetically modified food relative to a conventional counterpart. The Consultation concluded that the application of the concept of substantial equivalence contributes to a robust safety assessment framework.

A previous Joint FAO/WHO Expert Consultation on Biotechnology and Food Safety (1996) elaborated on compositional comparison as an important element in the determination of substantial equivalence. A comparison of critical components can be carried out at the level of the food source (i.e., species) or the specific food product. Critical components are determined by identifying key nutrients, key toxicants and anti-nutrients for the food source in question. The comparison of key nutrients should be between the modified variety and non-modified comparators with an appropriate history of safe use. The data for the non-modified comparator can be the natural ranges published in the literature for commercial varieties or those measured levels in parental or other edible varieties of the species (FAO and WHO, 1996). The comparator used to detect unintended effects should ideally be the near isogenic parental line grown under identical conditions. While the comparative approach is useful as part of the safety assessment of foods derived from plants developed using recombinant DNA technology, the approach could, in general, be applied to foods derived from new plant varieties that have been bred by other techniques.

INTRODUCTION TO ALFALFA AND OTHER TEMPERATE LEGUMES USED AS ANIMAL FEED

Forage legumes are an essential component of agricultural systems in temperate regions of the world. The benefits of forage legumes include providing top quality animal feed, suitable ground cover, and a valuable source of nitrogen. The nitrogen fixing ability of the legume occurs through inoculation with rhizobia. The root nodules contain the rhizobia, which have a symbiotic relationship with the legume allowing for the fixation of nitrogen for the plant. In return, the legumes supply the rhizobium bacteria with a source of fixed carbon derived from the photosynthetic process. This allows the legumes to survive and grow with little or no nitrogen added to the soil. When legumes are used as cover crops they contribute large amounts of nitrogen to the soil for uptake by the subsequent crop.

Leguminosae is one of the largest plant families in the world. The genera *Trifolium* and *Medicago* are prominent in sustainable farming systems within temperate regions. In Canada, for example, more than 26 million hectares are devoted annually for livestock grazing and forage production. Of this, 4 million hectares are tame or seeded pasture and 6.5 million hectares are cultivated tame hay and fodder crops.

Legumes are favoured by ruminants, whether for grazing or as well preserved silage or hay. The lower content of structural fibre and the higher protein content of legumes when compared to grasses results in an improved voluntary intake and digestion process as well as a more efficient absorption of nutrients (Ulyatt *et al*., 1977, Beever and Thorp, 1996). By feeding legumes, animal production response is also improved mainly due to the high concentration of protein and minerals within legumes. Legumes are generally grown in combination with grasses to reduce the persistent, high-viscosity foam (bloating hazard) that occurs with low fibre, high protein legume species (Howarth *et al*., 1991; Popp *et al*., 2000). Although there is contradictory evidence (Majak *et al*., 1980, Clark and Reid, 1974), saponins have also been implicated in bloat (Klita *et al*., 1996). The presence of condensed tannins in legume forages disrupts the foam and prevents bloat (Tanner *et al*., 1995; Lees, 1992).

This document will review alfalfa, the most common forage legume grown in the temperate regions, and will introduce the other prominent legumes.

SECTION I – ALFALFA (*MEDICAGO SATIVA* L.)

A. PRODUCTION

Alfalfa, also known as lucerne, is a herbaceous perennial legume that grows throughout the world in a variety of climates. It is widely distributed in temperate zones including, USA, southern Canada, Europe, China, southern Latin America and South Africa. More than 33 million hectares of alfalfa are cultivated throughout the world. This was one of the first forages to be domesticated and with its high yield potential, it soon became a popular choice for livestock feeding.

Alfalfa breeders recognise three types of cultivated alfalfa (lucerne) as members of a single species, *M. sativa*. The three subspecies are ssp *medicago (*purple alfalfa), ssp *falcata* (yellow alfalfa) and spp *varia* (variegated alfalfa). Ssp *varia* is a probable hybrid between ssp *medicago,*and ssp *falcata*. Common purple alfalfa is a high yielding, early maturing yet less hardy species. Yellow alfalfa has a lower yield but a higher level of hardiness than common purple alfalfa. Cultivars used in drier, cooler regions of Canada have a higher proportion of *M. falcata* germplasm, conferring winter dormancy and hence winter hardiness and a higher tolerance to grazing than those bred from mainly ssp *medicago* germplasm (Frame *et al*., 1998).

Alfalfa is believed to have originated in Iran, however related plants are found throughout central Asia and Siberia. Its cultivation around Lake Lucerne in Switzerland is thought to have resulted in the crop taking the name, lucerne. Until the early 1900's, alfalfa was not grown successfully in the Northern hemisphere due to the lack of cold hardiness. Wendelin Grimm introduced the hybrid variegated lucerne from Germany which formed the basis of cultivars capable of surviving the cold winters in the northern US and Canada (Frame *et al*., 1998). Alfalfa is the world's most important forage crop (Michaud *et al*., 1988).

A wide range of soil and climatic conditions are suitable for alfalfa production, however, well-drained soil with a neutral pH and good fertility produce an optimum forage. This long-lived perennial is more drought-tolerant than most other temperate forage legumes, including birdsfoot trefoil and red clover (Peterson *et al*., 1992), which become dormant under severe drought conditions. Alfalfa also has a tolerance for alkaline soils and a high salt content. However, it is intolerant of acidic soils with a pH below 6, poor drainage, or water logging (Sheaffer *et al*., 1988).

Unlike other forage legumes, alfalfa is generally grown in monoculture, although it can be mixed with other legumes and/or grasses. A grass/alfalfa sward may reduce weed invasion, provide a more balanced nutrient composition for successful ensiling, or the grass may utilize transferable nitrogen from alfalfa (Chamblee and Collins, 1988). However, mixtures may not always improve dry matter yields relative to alfalfa monoculture.

Alfalfa stands decline in yielding ability with age under irrigation and "optimum" management conditions (Hayman and McBride, 1984). Progressive annual decline in alfalfa dry matter yields has been attributed to many factors -competition from companion grasses, weed pressure, injury or loss of plants from pests and/or diseases, winter damage, poor drainage, or management factors such as uncontrolled grazing, over- frequent cutting, or inadequate fertilization.

It has a poor persistence if continuously stocked; sufficient regrowth between defoliations is critical to ensure stand survival. Alfalfa is best used in a rotational grazing system.

One of the important functions of alfalfa is its ability to fix nitrogen from the atmosphere and enhance the nitrogen balance of the soil, which the plant utilises in turn. This eliminates the need for nitrogen fertilizer. *Rhizobium meliloti* is one of the main bacterial groups that infects and induces nitrogen-fixing nodules on the roots of alfalfa plants. Estimates of nitrogen fixation by alfalfa vary widely but are generally higher than for other temperate forage legumes (Frame *et al*., 1998). Soil mineral nitrogen or fertilizer nitrogen imposes a restriction on nitrogen fixation. The deficiency of certain minerals such as potassium, calcium or magnesium or excessive soil acidity may also limit nitrogen fixation (Frame *et al*., 1998).

B. PROCESSING

In addition to its use in grazing systems, alfalfa is primarily used for hay, silage, artificially dried forage, and pelleted meal. Cutting alfalfa at the 10% bloom stage and then at 5-7 week intervals was shown to maximize dry matter (DM) production, provide forage of reasonable nutritive value and helped to maintain sward longevity in Minnesota (Sheaffer *et al*., 1988). In certain regions under ideal conditions, six to nine cuttings per year may be achieved, whereas in other regions two to five cuttings may be the maximum. To ensure plant survival through the winter, the last harvest should be early enough to allow plants to build up carbohydrate and nitrogen reserves before cessation of growth, but not allow a heavy canopy to develop prior to winter. Studies demonstrated that three cuts per year yielded more than four cuts, although the forage was of lower nutritive value (Brink and Marten, 1989).

Before processing, alfalfa is cut and allowed to dry to varying moisture content in the field. Hay should be dried to approximately 85% dry matter. The optimum dry matter content for chopped silage is 30% when stored in bunker silos, 35% in concrete tower silos and 45% in oxygen limiting silos. Composition of alfalfa hay compared with silage is shown in Table 1. To produce dehydrated alfalfa, a regular supply of forage with a high protein content is required, as well as cutting before the growth reaches the bud stage. Proper dehydration of alfalfa can increase the utilization of forage protein by ruminants.

Alfalfa meal or alfalfa leaf meal is hay that has been dried (either naturally or artificially) and ground. Alfalfa leaf meal is of better quality, and contains not more than 18% crude fibre. Alfalfa meal includes stem fractions and therefore higher fibre. Alfalfa leaf meal and alfalfa meal are good sources of carotene. When processing alfalfa, it is important to retain the nutritious leaf fraction as much as possible during handling.

Table 1. Quality of alfalfa hay or silage made from the same second cut crop (Broderick, 1995).

Component	*Silage*	*Hay*
DryMatter(DM) gm/kg	413	850
NDF gm/kg DM	354	352
ADF gm/kg DM	265	257
CP gm/kg DM	212	197
NPNgm/100gm of totalN	49.4	7.7

Within the alfalfa plant, the leaves have a higher concentration of nutrients than stems, with the exception of potassium. Magnesium concentrations decline with crop maturity. In late-cut hay, Mg may be restricted to levels well below the minimum for animal requirements if soil potassium levels are high due to preferential uptake of potassium by the plants (Frame *et al*., 1998). Alfalfa has a low concentration of sodium, therefore, salt supplementation of cattle and sheep on alfalfa pasture has been beneficial to their health and production (Jagusch, 1982).

C. TRADITIONAL CHARACTERISTICS SCREENED BY ALFALFA DEVELOPERS

For registration/public release of new varieties of alfalfa in the US and Canada, only phenotypic characteristics are required to be considered. Main indicators of alfalfa quality for livestock feeding include the proximates, acid detergent fibre, neutral detergent fibre, lignin, and minerals (summarized in Table 2, Forage Genetics Inc., 2003). Published values of these components vary widely in the literature, depending on geographical location, environmental conditions, variety, time of harvest, and storage conditions. Therefore, it is important to make comparisons only with appropriate comparators, e.g., near isogenic lines, reference cultivars, or commercial varieties grown at the same time under similar conditions and locations.

Table 2. Constituents typically monitored in forages for livestock feeding (Forage Genetics, 2003, personal communication).

Constituent	***Importance***
Moisture	Feeding value
Proximates: Protein Fat Ash	Nutrition/feeding value
Acid Detergent Fibre	Digestibility
Neutral Detergent Fibre	Digestibility
Lignin	Digestibility/anti-quality factor
Minerals: Ca Cu Fe Mg Mn P K Na Zn	Nutrition

SECTION II – NUTRIENTS IN ALFALFA

Tables 3-6 summarize proximate, amino acid, fatty acid and mineral composition of alfalfa from a variety of databases.

Table 3. Proximate, lignin, acid detergent fibre (ADF), and neutral detergent fibre (NDF) composition of late vegetative/early bloom alfalfa. Data except for dry matter presented on a % dry matter basis.

%	NRC71[1]	NRC82[2]	Ensminger[3]	NRC96[4]	Monsanto[5]	Range
Dry matter	90.1	23.0	91.0	19.0	17.9 – 29.2	17.9 – 91.0
Crude Protein	19.7	19.0	17.9	25.0	15.3 – 25.8	15.3 – 25.8
Crude fat	2.2	3.1	2.6	2.9	1.3 – 3.2	1.3 – 3.2
Crude fibre	29.8	25.0	25.8	-	-	25.0 – 25.8
NDF	-	40.0	36.8	39.3	26.5 – 35.7	26.5 – 40.0
ADF	-	31.0	29.0	-	23.1 -33.4	23.1 – 33.4
Lignin	7.7	7.0	5.8	7.9	3.9–9.7	3.9 – 9.7
Ash	8.7	9.5	8.4	9.2	8.8 – 15.3	8.4 – 15.3

[1] NRC, 1971
[2] NRC, 1982
[3] Ensminger *et al*., 1990
[4] NRC, 1996
[5] Monsanto, 2003

Table 4. Amino Acid Composition of Alfalfa. Data presented on a % of dry matter basis.

	Hay NRC82[1]	Hay NRC01[2]	Hay Literature[3]	Hay Monsanto[4]	Hay Range	Silage Range[5]
Ala	-	-	.70	.79-1.59	.70 – 1.59	.69-.94
Arg	1.14	1.18	.62	.71–1.54	.62 - 1.54	.27-.51
Asp	-	-	1.40	1.75-3.52	1.40 – 3.52	1.83-1.95
Cys	-	.32	.20	.18-.35	.18 - .35	-
Glu	-	-	1.20	1.52-3.03	1.20 – 3.03	1.27-1.48
Gly	1.03	-	.60	.71-1.47	.60-1.47	.67-.76
His	.50	.44	.28	.37-.74	.28 - .74	.14-.28
Ile	.96	.97	.50	.66-1.26	.50 – 1.26	.55-.76
Leu	1.64	1.68	.90	1.11-2.25	.90 – 2.25	.90-1.23
Lys	1.27	1.17	.59	.99-1.81	.59 – 1.81	.32-.74
Met	.36	.36	.18	.24-.48	.18 - .48	.06-.21
Phe	1.07	1.09	.65	.72-1.59	.72 – 1.59	.53-.79
Pro	-	-	.70	.75-1.34	.70 – 1.34	.89-1.14
Ser	.97	-	.60	.75-1.36	.60 – 1.36	.57-.67
Thr	1.08	1.00	.60	.61-1.15	.60 – 1.15	.63-.72
Trp	-	.35	-	.16-.31	.16 - .35	-
Tyr	.74	-	.50	.50-1.16	.50 – 1.16	.25-.41
Val	1.22	1.20	.60	.79-1.55	.60 – 1.55	.76-.94

[1] NRC, 1982.
[2] NRC, 2001.
[3] Cunningham *et al*., 1994; Phuntsok *et al*. 1998.
[4] Monsanto, 2003.
[5] Christensen, 2004a; Phuntsok *et al*., 1998.

Table 5. Fatty Acid Composition of Alfalfa.

	Hay gm/100 gm of FA[1]	Silage gm/100 gm of DM[2]
C12:0	0.70	0.01-0.03
C14:0	2.90	0.01-0.02
C16.0	27.6	0.41-0.47
C16.1	0.20	0.04-0.05
C17:0	2.15	0.01-0.11
C18:0	36.5	0.06-0.07
C18:1	4.11	0.06-0.07
C18:2	0.75	0.34-0.42
C18:3	-	0.14-0.63
Other	24.90	0.35-0.92
Total	100	2.09-2.10

[1] gm/100gm fatty acids; Bas *et al*., 2003
[2] gm /100 gm dry matter; Christensen , 2004b

Table 6. Mineral Composition of late vegetation to early bloom alfalfa (expressed on dry matter basis).

	NRC71[1]	NRC82[2]	Ensminger[3]	NRC00[4]	Preston[5]	NRC01[6]	Monsanto[7]	Range
Na g/100gm	.15	.19	.15	.12	-	.03	.02-.21	.02 - .21
K g/100gm	2.08	2.09	2.56	2.51	2.50	2.56	1.39-4.31	1.39-4.31
Ca g/100gm	1.40	1.96	1.63	1.41	1.41	1.56	.90-1.53	.90-1.96
P g/100gm	.21	.30	.22	.22	.26	.31	.22-.45	.22-.45
Mg g/100gm	.30	.27	.34	.34	-	.33	.11-.45	.11-.45
Fe mg/100gm	.02	.03	.02	.02	-	.021	.02-1.54	.02 -1.54
S g/100gm	.30	.37	.30	.30	.27	.33		.27-.37
Cu mg/kg	13.4	10.0	12.6	12.7	-	10.0	5.3-10.2	5.3-13.4
Co mg/kg	.01	.13	.29	.29	-	.65		.01-.65
Mn mg/kg	31.5	43.0	36.2	36.0	-	49.0	34.6-109.5	31.5-109.5
Zn mg/kg	-	18.0	30.2	30.0	22.0	26.0	18.1-36.0	18.0-36.0
Se mg/kg	-	-	.55	.55	-	.20		.20-.55
Cl g/100gm	.38	.47	.38	.34	.38	.55		.34-.55

[1] NRC, 1971
[2] NRC, 1982
[3] Ensminger *et al.*, 1990
[4] NRC, 2000
[5] Preston, 2003.
[6] NRC, 2001
[7] Monsanto, 2003

SECTION III –ANTINUTRIENTS AND SECONDARY METABOLITES IN ALFALFA

Bloat potential in ruminants

Legumes are unusual in that the very characteristics that make them valuable as ruminant feed (a high content of readily digestible protein and carbohydrate), can predispose animals to bloating, a potentially serious condition that can result in death. The etiology of bloat and plant and animal risk factors are reviewed in Clark and Reid (1974), Colvin and Backus (1988), Howarth *et al*. (1991), and Popp *et al*. (2000).

The condition and its incidence

Primary bloat or frothy bloat (tympanites) is the over-distension of the rumen caused by the accumulation of fermentation gases in a stable protein foam or froth (Tanner *et al*., 1995), and usually occurs as an outbreak in several animals on pasture that contains high levels of leguminous plants. Primary bloat can also occur in feedlot cattle. When an animal is experiencing pasture bloat, the stable froth is produced in the rumen in a "layer" on top of the ruminal contents (mostly liquid), and prevents the gas bubbles from rising to the top and dispersing their contents. Once the froth has formed and natural eructation is prevented, the rumen motility is initially increased, causing further frothing. Finally there is a loss of muscle tone and rumen motility. Death is a result of several factors, including the depressive effect of rumen distension on the heart and lungs and absorption of toxins from the rumen.

The main risk factor in pasture bloat is the rapid ingestion of immature/fast-growing legumes in pre-flowering stages. Alfalfa, red clover, and white clover have similar bloat potential. Other forage legumes are considered to be of low risk.

Ingestion of only the most succulent parts of the plant is an important risk factor, in addition to the sward type. Frost and growth of alfalfa at low temperatures have been shown to increase bloat risk by increasing the leaf cell constituents (soluble protein, pectic polysaccharides) implicated in pasture bloat (MacAdam and Whitesides, 1996). Wetness of the pasture has also been suspected to be a risk factor for bloat. It is, however, more likely that the real risk is the fast growth brought on by wet and favourable weather.

Several animal factors contribute to bloat (Mendel and Boda, 1961, Howarth *et al*., 1991). Young animals are considered more susceptible to acute and severe bloat than older animals, and it is suspected that animals can adapt to eating bloating pastures and are less susceptible after exposure. Fasting has also been shown to predispose animals to pasture bloat, but the mechanism is not established. Since there are individual differences in the ability of cattle to tolerate rumen distension and the presence of contributory factors in any given situation, some animals only suffer sub-clinical or mild bloating. While the toleration of mild bloat allows adaptation to new pastures, sub-clinical and mild bloat have been recognised as causing major losses on clover dominant pastures in the form of reduced feed intake and subsequent lower weight gains (Latimori *et al*., 1992; Rossi *et al*., 1997)

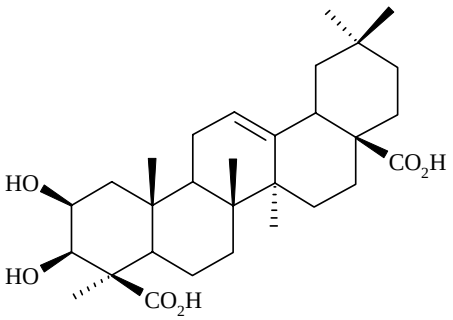
Bloat is a common problem in all areas in which temperate legumes are used as ruminant feed and has long been recognised as a major problem in countries like New Zealand, where clover forms an

important part of the pastures (Carruthers *et al*., 1987). Due to its association with clover, bloat has been considered a risk factor on organic farms, where clover often constitutes more than 50% of the sward content. However, research both in the UK and elsewhere in Europe on organic farms suggests that the incidence of clinical bloat is not higher than on conventional farms (Weller *et al*., 1996; Frankow-Lindberg, and Danielsson, 1997).

Although there is no widely recognised test for bloating potential, selection for a low initial rate of digestion (to four hours) has been successfully used as the criterion in developing a "bloat-reduced" cultivar of alfalfa AC Grazeland Br (Coulman *et al*., 2000). In addition to the initial rate of digestion, a number of other factors known to influence the bloat potential of forages can be measured, such as leaf venation pattern, fibre content and digestibility, cell wall thickness, ease of nucleation of rumen bacteria, and preferential synthesis of protein and reduction in lipids in chloroplasts (Lees *et al*., 1982; Howarth *et al*., 1979; Fay *et al*., 1981; Lees, 1984; Stifel *et al*., 1968).

Saponins

Saponins are divided into two groups, including the steroidal saponins, which occur as glycosides in some pasture grasses, and the triterpenoid saponins that occur in many temperate legumes, particularly alfalfa. Because saponins have a distinct foaming characteristic (Marston *et al*., 2000), historically they have been considered a primary cause of bloat in animals grazing temperate forages. The development of low saponin varieties of alfalfa that still caused bloat suggests the importance of other factors as the main causal agent(s) (Majak *et al*., 1980).



The monodesmodosidic medicagenic acid

A total of some 24 saponins have been identified in alfalfa (Bialy *et al*., 1999) but the soyasapogenols, zanhic acid glycosides and medicagenic acid are quantitatively the most important (Table 7; Oleszek *et al*., 1992; Massiot *et al*., 1988; 1991). Saponins can have a positive or a negative role in plants. Supplementation with saponins has been shown to decrease ammonia production and protozoal count, and improve growth rates in lambs (Makkar and Becker, 2000). The toxicity of the various saponins to animals differs (Hostettmann and Marston, 1995). Triterpenoid saponins may reduce feed palatability and feed degradation in the rumen and their presence greatly limits the use of alfalfa in some non-ruminant diets (Lu and Jorgensen, 1987; reviewed in Oleszek, 1996). Poultry rations containing 10% alfalfa meal depress chick growth and egg production due to saponins (Birk, 1969; Bondi *et al*., 1973; Pedersen *et al*., 1972). Saponins are highly toxic to fish and amphibians (Cheeke, 1971; Khalil and El Adawy, 1994; Makkar and Becker, 2000)), but not to ruminants and swine (Bins and Pedersen, 1964). Symptoms of saponin toxicity, believed largely due to the medicagenic and zanhic acid content in alfalfa, include irritation to mouth and digestive tract, increased membrane permeability and, in acute cases, haemolysis (Oleszek, 1996). Zanhic acid glycosides may also cause production of intestinal gases. Ensiling of alfalfa can reduce the total saponin and medicagenic acid content (Kalac *et al*., 1996).

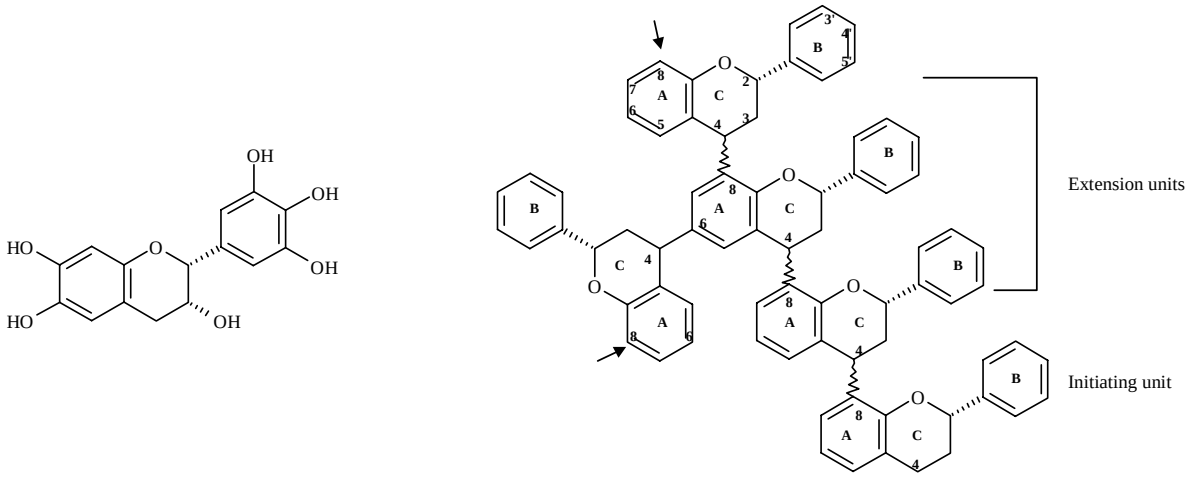
Table 7. Crude saponin and medicagenic acid content in various cultivars of alfalfa grown in Mexico (data from Pérez *et al*., 1997).

Cultivar	Crude saponin (g/kg dry matter)	Medicagenic acid (g/kg dry matter)
Sundor	17.7	0.023
Maxidor	11.7	0.027
Valenciana	8.8	0.165
Condor	8.5	0.024
Puebla 76	8.3	0.097
Inia 76	6.8	0.115
NK-819	5.9	0.013
Pierce	4.9	0.031

A number of analytical methods for various saponins have been used with varying success. Biological methods have been used but are dependent on the inhibition of the growth of the fungus, *Trichoderma viride*; these methods measure exclusively medicagenic acid glycosides. A high pressure liquid chromotography method was developed by Oleszek (2004), but the method has not been sufficiently modified to make it a practical routine procedure. There does not yet appear to be enough reliable data in the literature for meaningful comparisons with database values. It is important that analysis of appropriate comparators be conducted if saponin analysis is to be undertaken.

Condensed tannins

Condensed tannins (proanthocyanidins) derive from the flavonoid biosynthesis pathway and are essentially oligomers of flavan-3-ols of varying size and complexity. The chemistry, biochemistry and molecular regulation of these plant metabolites have been reviewed recently in Marles *et al*. (2003). They are widespread in the plant kingdom. A universal characteristic of condensed tannins is their ability to bind reversibly or irreversibly to proteins in feed, saliva and microbial cells, with microbial enzymes, and with endogenous proteins or other feed components and to inhibit ruminant microorganism activity (Bae *et al*., 1993; Hagerman *et al*., 1993; Jones *et al*., 1994; Tanner *et al*., 1994; Molan *et al*., 2001). The protein binding capacities among oligomers from different plant species and developmental stages differ with variations in proanthocyanidin and protein structure (Hagerman and Butler, 1981; Butler *et al*., 1984). Condensed tannins are also metal chelators and strong antioxidants (Muir, 1997; Stoutjeskijk *et al*., 2001; Slabbert, 1992). They have the potential to eliminate pasture bloat, improve the efficiency of conversion from plant to animal protein (ruminal bypass protein), reduce greenhouse gases, reduce gastrointestinal parasites, and inhibit insect feeding (Waghorn, 1990, Waghorn and Shelton, 1992; Neizen *et al*., 1995; 1998; Broderick and Albrecht, 1997; Aerts *et al*., 1999; Muir *et al*., 1999; McMahon *et al*., 2000; Butter *et al*., 2001; McSweeney *et al*., 2001). Tannins and saponins can act in an additive fashion in the rumen (Makkar *et al*., 1995).



A flavan-3-ol (epigallocatechin) monomer and a model proanthocyanidin oligomer showing the mechanism of extension through additional 4-8 and 4-6 inter-flavonoid linkages.

Condensed tannin levels exceeding 40-50 g kg^{-1} dry matter in forages may reduce protein and DM digestibility of the forages by ruminants and, consequently at high concentrations condensed tannins may be regarded as "antinutritional" compounds (Barry, 1989). However at low to moderate levels (20-40g kg^{-1} dry matter) tannins can increase the quantity of dietary protein, especially essential amino acids, flowing to the small intestine increasing production without any effect on feed intake (Aerts *et al*., 1999).

Although having a potential detrimental effect on protein digestibility, generally, legumes that contain condensed tannins in excess of 50 g kg^{-1} DM do not cause bloat (Table 8). Dietary condensed tannins may provide a means to beneficially manipulate protein digestion and/or prevent pasture bloat in ruminants. Research efforts are currently being directed to genetically modify alfalfa to derepress its anthocyanidin biosynthetic pathway, or to isolate genes encoding steps of this pathway and introduce them into alfalfa and clover from other plant species (reviewed in Marles *et al*., 2003). Within the past two years, a host of new condensed tannin biosynthetic and regulatory genes have been discovered to contribute to these strategies (reviewed in Marles *et al*.,2003). In addition, the *Lc* anthocyanin regulatory gene from maize induces small amounts of condensed tannin in alfalfa forage (Ray *et al*., 2003), and the forage has a reduced initial rate of digestion and reduced gas production *in vitro* (Wang *et al*., 2003).

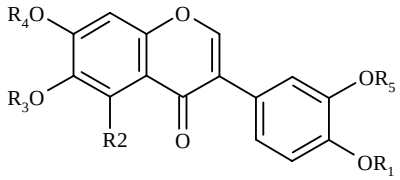
Table 8. Extractable and bound condensed tannin in bloating and bloat-safe temperate legumes measures by the butanol-HCl method (from Barry and McNabb, 1999).

Forage	Condensed tannin (g kg^{-1} dry matter)		
	Extractable	Bound	Total
Bloat safe			
Big trefoil (*Lotus pedunculatus*)	61	15	77
Birdsfoot trefoil (*Lotus corniculatus*)	36	11	47
Sulla (*Hedysarum coronarium*)	33	12	45
Sainfoin (*Onobrychis vicifolia*)	29	-	-
Potentially bloating			
Red clover (*Trifolium pratense*)	0.4	1.3	1.7
Alfalfa (*Medicago sativa*)	0.0	0.5	0.5

Oestrogen agonists and antagonists

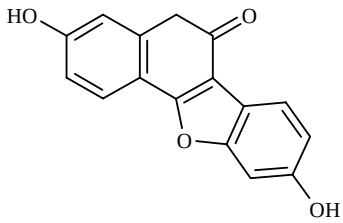
Adverse effects on reproductive health of farm animals grazing legumes have been recognised since the early 1940s when there was a substantial outbreak of infertility in Australian sheep grazing subterranean clover. This was subsequently shown to result from the presence of a variety of naturally occurring oestrogen mimetics, the so-called "phytoestrogens". Two types of phytoestrogens are now recognised; the coumesterols (coumestrol) related to the coumarins and quantitatively more important in alfalfa, and the isoflavonoids more widely distributed in *Trifolium* spp (Livingston, 1978). These compounds can also be induced in alfalfa with pathogen stress (Latunde-Dada and Lucas, 1985). Levels of coumestrol in alfalfa forage range from 2.99 – 104.37 ppm (Monsanto, 2003). The structure of the more important isoflavonoids recognised in red clover are shown in Table 9. Other isoflavone conjugates have been identified (Klejdus *et al*., 2001). Phytoestrogen infertility appears to be species-specific, and ruminants such as cattle and sheep are more susceptible than other animals (Stob, 1983; Moule *et al*., 1963; reviewed in Howarth, 1988).

Table 9. Structure of the isoflavonoids identified in red clover (from He *et al*., 1996)



Compound	R_1	R_2	R_3	R_4	R_5
Daidzein	H	H	H	H	H
Daidzin	H	H	H	Glucose	H
Genistein	H	H	OH	H	H
Genistin	H	H	OH	Glucose	H
Formononetin	CH_3	H	H	H	H
Ononin	CH_3	H	H	Glucose	H
Biochainin A	CH_3	H	OH	H	H
Sissotrin	CH_3	H	OH	Glucose	H
Trifoside	Glucose	H	H	CH_3	H
Calycosin	CH_3	H	H	H	OH
Pectolinarigenin	CH_3	OH	OCH_3	H	H
Pratensein	CH_3	OH	H	H	OH
Pseudobaptigenin	$-CH_2^-$	H	H	H	$-O^-$

Formononetin and biochainin A are the two isoflavones found in the greatest amounts in forage legumes (Smolenski *et al*., 1981) and together can reach 15g kg^{-1} dry matter in some red clover cultivars. Concentrations in white clover are usually substantially lower (0.5g kg^{-1} dry matter). The major metabolic transformation of the isoflavones occurs in the rumen. Biochainin A is demethylated to genistein and via ring cleavage to 4-ethylphenol and organic acids with the loss of all oestrogenic activity. Formononetin is mainly demethylated to daidzein and then to equol by hydrogenation and ring cleavage (Lundh, 1995). However, unlike the end products of biochainin A metabolism, equol is a more potent oestrogen mimetic than either of its parent compounds.

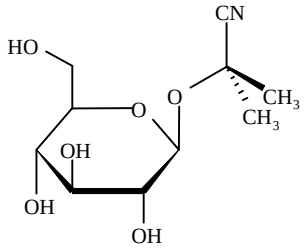


Coumesterol (coumestrol)

Coumesterol, present as the major phytoestrogen in alfalfa but also occurring in white clover, is not metabolised by the rumen flora and is absorbed in its original form. Coumesterol is known to be approximately 30-fold more effective than genistein in mice and to cause oestrogen-related disorders in animals. Concentrations in healthy plants rarely exceed 30-60 mg kg^{-1} dry matter, but coumesterols can accumulate in plants subject to fungal attack. Significant genetic variation exists in alfalfa for coumesterol (Hanson *et al*., 1965). In addition, doses showing no effects in the short term, may induce hormonal effects if consumed over a longer period.

Cyanogenic glycosides

The cyanogenic glycosides are composed of an α-hydrozynitrile type aglycone and a sugar moiety which is usually D-glucose. They are widely distributed in the plant kingdom but, within the temperate forage legumes, are considered a cause for concern only in some cultivars of white clover and *Lotus corniculatus* (Vetter, 2000). In populations of white clover, plants that produce HCN following damage of the leaves, and plants that fail to do so, co-exist within the same population. The difference in cyanogenic glucoside content is caused by variation in two genes: *Ac* regulating the production of the cyanogenic glucosides linamarin and lotaustralin, and *Li* regulating the production of the hydrolysing enzyme linamarase. Only plants that contain at least one active allele of each of the genes *Ac* and *Li* are cyanogenic. White clover and *Lotus corniculatus* contain varying amounts of both kinds of metabolites (reviewed in Smolenski *et al*.,1981).



Linamarin a cyanogenic glucoside from white clover

Ruminant animals are more susceptible to HCN poisoning than non-ruminants due to fast microbial breakdown of cyanogenic glycosides (Smolenski *et al*., 1981). Hydrocyanic acid released from linamarin and lotaustralin is further metabolised within the grazing animal to inorganic thiocyanate, which is goitrogenic. North American cultivars of white clover have a notably lower HCN-generating potential than most European cultivars although there are considerable differences among cultivars bred within countries (Wheeler, 1989). In Switzerland, cultivars with a mean HCN content above 370 mg HCN kg^{-1} dry matter are excluded from the national list. The HCN potential is also greatly affected by environmental factors and is increased by moisture stress, predation, low light intensity cool grazing conditions and low soil phosphorus supply (Vickery *et al*., 1986).

Other secondary metabolites

The occurrence of a wide range of secondary metabolites in temperate legumes has been documented in various natural product databases and resources (see for example http://www.ars.usda.gov) (Duke, 1992; Chapman and Hall, 1982-1998). This is particularly true for alfalfa and for *Trifolium pratense*, both of which have elicited interest as herbal products with claimed health benefits. However, in most instances, quantitative data is not available and would have to be generated as part of a comparative assessment. Measurement of known secondary metabolites would only be justified if there were reason to suspect some change to the metabolic pathway involved in their generation or if they were of known toxicity. Canavanine is a potentially toxic structural analogue of L-arginine that is a stored by many legumes including alfalfa (Rosenthal and Nkomo, 2000). Under normal conditions L-canavanine is found in seeds, cotyledons and the emerging shoots and only in very low amounts in older vegetative tissues. However, its cytotoxicity might warrant its inclusion in a comparative analysis.

SECTION IV – FEED USE OF ALFALFA AND ALFALFA PRODUCTS

Alfalfa is rich in protein, vitamins and minerals and is a main component in livestock rations. The natural phenolic defence compounds of alfalfa include a simple alkaloid, saponins, coumestans (which are increased by exposure to the pea aphid), isoflavones (pterocarpans and medicarpan, both of which are induced in response to fungal infection) and flavones (Massiot *et al*., 1988; 1991; Oleszek *et al*., 1992; Stochmal *et al*., 2001; Ray *et al*., 2003; reviewed in Howarth, 1988). Other natural components can be found in natural product databases (eg. Duke, 1992). Alfalfa accumulates only trace amounts of condensed tannins in forage (Goplen *et al*, 1980; Ray *et al*., 2003).

Throughout the world, alfalfa is recognised as a premium forage for feeding to dairy cattle and horses. It can also be a valuable feed for beef cattle, sheep and other livestock with high nutrient requirements such as lactating ewes and dairy goats or backgrounded calves. However, alfalfa is a forage legume with high bloat potential (Howarth *et al*., 1991; Popp *et al*., 2000). AC Grazeland Br is the world's first bloat-reduced variety (60-80% bloat-reduced), and was selected for a lower initial rate of digestion (Coulman *et al*., 2000). Plants of this variety have a thicker cell wall and fast regrowth (Goplen *et al*., 1993; Najda, 2002).

Alfalfa meal is not a suitable feedstuff for use at high dietary levels by non-ruminant animals except horses, rabbits and gestating sows. The problems associated with alfalfa use by monogastric animals include low protein digestibility, low digestible energy, moderately high fibre, saponins and phenolics content, and low palatability.

The feeding value of alfalfa is largely determined by the stage of growth as the nutritive value decreases as the plant matures. The leaves of the alfalfa plant are abundant in nutrients including protein, vitamin E and K, calcium, magnesium, potassium and carotene. The dry matter yield of alfalfa increases with advancing maturity but the nutritive value is reduced. Plant maturity results in a decline of the leaf:stem ratio, an increase in lignin content of the stem and leaf loss through leaf shatter.

In ruminants, the utilisation of alfalfa protein is inefficient and causes problems because of rapid turnover in the rumen and a high proportion of protein nitrogen which is lost as ammonia, although ruminal protein degradability declines with plant maturity (Amrane and Michaeletdoreau, 1993). The crude protein content is generally higher in ensiled alfalfa than in hay, due mainly to greater leaf loss in hay making; however, much more of the nitrogen comprises non-protein nitrogen (NPN) in silage (Broderick, 1995).

Compared with grass, alfalfa has higher intake characteristics and a higher animal production response per unit of DM ingested. The potential reasons are the rapid passage of digesta out of the rumen (which stimulates appetite), high concentration of soluble protein (which assists in microbial synthesis in the rumen), the stimulation of cellulose digestion, a low concentration of cell wall in the dry matter, and an adequate supply of minerals and vitamins (Conrad and Klopfenstein, 1988).

Specialty protein extracts of alfalfa are also used in livestock feeding; for example, xanthophyll is sometimes used to impart a yellowish colour to poultry eggs and flesh.

SECTION V – FOOD USES OF ALFALFA

The use of sprouted seeds as food has a very long history. Currently, in North America, sprouted mung bean and alfalfa seeds are often available in the fruit and vegetable sections of grocery stores and a wider range of sprouted seeds or seeds for sprouting, including mung beans and alfalfa as well as adzuki bean, Chinese cabbage, clover, lentil, onion and radish, are sold in natural and health food stores. Although only sprouts of alfalfa and clover from the list of forage legumes discussed in this document were identified as used for food in a brief search of the internet, it should not be assumed that other forage legumes might not at some stage be considered for sprouting for human food use. In addition to sprouts, protein extracts of alfalfa (e.g. rubisco) are receiving attention for possible use in various food applications.

Most people in a North American dietary context would be expected to consume minor quantities of these foods, roughly 60 mL (8-20 g serving, depending on the type of sprout) and only on an occasional basis. Among the small segment of committed users amounts of 1-2 cups per day may, however, be common.

A decision regarding the importance of assessing the nutrient composition of forage legumes used as sprouted seeds in human diets should be guided by the frequency and quantity of such sprouts in a given country and their contribution to nutrient intake. The fact that they are often promoted as being highly nutritious may also be a consideration in requesting data.

Table 10 shown below, showing composition of alfalfa sprouts, is extracted from the USDA National Nutrient Database for Standard Reference, Release # 16. This database provides data for sprouted alfalfa, kidney beans, mung beans, navy beans, pinto beans, lentils, peas, radish seeds, soybeans and wheat.

A comparison of the nutrient composition of one cup of alfalfa sprouts to recommended intakes of these nutrients suggests that the contribution is minor. A suggested minimum compositional analysis where alfalfa is likely to be sold for food use would be the analysis of fresh forage or sprouted alfalfa seed for the parameters listed in Table 11 with the addition of vitamin C, beta-carotene, folate and phytoestrogens to provide a basis for assessment of potential unintended effects with relevance to human food use.

Table 10. Composition of raw sprouted alfalfa seeds (Source: USDA National Nutrient Database for Standard Reference, Release 16, 2003).

NUTRIENT	UNIT	Value per 100 g	Value per 240 mL (33 g)	Sample Count	Standard Error	Value per 100 g dry matter
Water	g	91.140	30.076	10	1.226	
Energy (calculated)	kcal	29.000	9.570	0		327.314
Protein	g	3.990	1.317	10	0.563	45.034
Total lipid (fat)	g	0.690	0.228	10	0.141	7.788
Ash		0.400	0.132	10	0.044	4.515
"Carbohydrate,by difference"	g	3.780	1.247	0		42.664
"Fibre, total dietary"	g	2.500	0.825			28.217
"Sugars, total"	g	0.180	0.059	3	0.012	2.032
Calcium	mg	32.000	10.560	10	4.659	361.174
Iron	mg	0.960	0.317	10	0.114	10.835
Magnesium	mg	27.000	8.910	10	3.978	304.740
Phosphorus	mg	70.000	23.100	10	7.914	790.068
Potassium	mg	79.000	26.070	10	9.79	891.648
Sodium	mg	6.000	1.980	10	1.094	67.720
Zinc	mg	0.920	0.304	10	0.273	10.384
Copper	mg	0.157	0.052	10	0.017	1.772
Manganese	mg	0.188	0.062	10	0.019	2.122
Selenium	mcg	0.600	0.198	0		6.772
Vitamin C	mg	8.200	2.706	10	0.678	92.551
Thiamin	mg	0.076	0.025	10	0.005	0.858
Riboflavin	mg	0.126	0.042	10	0.017	1.422
Niacin	mg	0.481	0.159	10	0.044	5.429
Pantothenic Acid	mg	0.563	0.186	10	0.069	6.354
Vitamin B-6	mg	0.034	0.011	10	0.005	0.384
"Folate, total"	mcg	36.000	11.880	10	0.8	406.321
Vitamin B12	mcg	0.000	0.000	0		0.000
Vitamin A (carotenoids)	IU	155.000	51.150	0		1749.436
Vitamin E	mg	0.020	0.007	0		0.226
Vitamin K	mcg	30.500	10.065	0		344.244
Threonine	g	0.134	0.044	1		1.512
Isoleucine	g	0.143	0.047	1		1.614
Leucine	g	0.267	0.088	1		3.014
Lysine	g	0.214	0.071	1		2.415
Valine	g	0.145	0.048	1		1.637

SECTION VI – IDENTIFICATION OF KEY PRODUCTS AND SUGGESTED ANALYSIS FOR NEW FORAGE VARIETIES

Forage legumes are an essential component of the livestock feed industry. They also provide several environmental benefits including a reduction in soil erosion and the ability to fix nitrogen from the atmosphere. Forages are an excellent source of crude protein, carbohydrates, vitamins, calcium, magnesium, potassium, iron, cobalt and carotene. It is important that these nutrients are considered when evaluating novel legumes.

These plants are introduced into the growing environment as seeds and if the conditions are favourable, growth begins. An important stage of plant growth is the initiation of flowering or inflorescence. It is recommended that the forage legume be cut or grazed at this time, due to its optimum nutritive value and yield. After this point, the proportion of lignin increases and digestibility decreases. Forages are well adapted to the environments in which they grow. Plants have been selected to withstand frost and winter damage, drought, salinity, acidity or alkalinity.

Forage legumes can be processed in a variety of ways including hay, silage, pelleted meal or dehydrated cubes or simply remain as pasture. With the exception of pasture legumes, forages are processed to preserve nutrients and assist with handling of the product. These processes may influence the structure of the plant and the nutritive value for the animal.

The chemical composition of forages varies with physiological age and therefore forage quality analyses are essential. Analyses listed in Table 11 should be considered for new varieties. Additional analyses to be further considered, on a crop by crop basis are listed in Table 12. When evaluating a novel forage, the compositional analysis should be conducted on material sampled at the late vegetative/early bloom stage of growth, when hay and silage cuts are normally taken.

The risk of bloat and the presence of saponins within forage legumes are the main factors that limit the use of these plants.

Table 11. Suggested minimum compositional parameters to be analysed in hay or fresh forage legumes used for animal feed.

Parameter	Fresh Forage/Hay
Crude protein	X
NDF	X
ADF	X
Lignin (ADL or other)	X
Crude Fat	X
Ash	X
Minerals (Ca, P)	X
Amino acids	X

Table 12. Additional compositional parameters to be considered for analysis in hay, silage or fresh forage for legumes used for animal feed, on a crop by crop basis.

Parameter	Fresh Forage/Hay	Silage
Total condensed tannins	X	X
Total saponins	X	X
-Medicagenic acid	X	-
-Zanhic acids	X	-
Phytoestrogens		
-Coumesterol (and its methyl derivatives)	X	X
-Formononetin	X	X
-Daidzein	X	X
Cyanogenic glycosides		
-Liminarin	X	-
-Lotaustralian	X	-
Canavanine	X	-

SECTION VII – FORAGE LEGUMES OTHER THAN ALFALFA

The information presented in the review of alfalfa in this paper is largely applicable to all temperate legumes. The remainder of this paper serves to introduce other important forage legumes used in livestock feeding. Key components to be analysed in new forage varieties are identified in Table 11.

Red Clover (*Trifolium pratense* L.)

The *Trifolium* species are widely distributed. Within this genus there are 240 species found in most temperate regions. The total area where they can be found in the United States is believed to exceed that of alfalfa (Smith *et al*., 1985). Alfalfa and clovers collectively meet the legume pasture, hay and silage production requirements of temperate, humid and subhumid regions (Rumbaugh, 1990).

Red clover (*Trifolium pratense* L.) is an important forage legume grown in northern temperate areas of the world, especially Europe and North America. In the 1980's, 7 million hectares of red clover were grown in North America out of a world total of 20 million hectares (Smith *et al*., 1985). Red clover is thought to have originated in southeastern Europe and Asia Minor.

Physiology

Red clover is adapted to a wide range of soil and environmental conditions, especially poorly drained soils and is relatively tolerant of lower soil pH and lower soil fertility. A deep tap root allows red clover a high degree of resistance to drought although not as much tolerance as alfalfa or sainfoin. The optimum temperature for growth is 20-25°C and the optimum pH is 6-7.5. Although generally considered a short-lived perennial, improved U.S. types of red clover are relatively productive for three and sometimes four years.

Carbohydrates are important in red clover for the plant's survival overwinter. The polysaccharide starch is the principal storage carbohydrate, which accumulates in the roots during the growing season and is depleted during winter. Taking more than one autumn harvest reduces carbohydrate accumulation, and therefore reduces yield at the first harvest in the following year.

Red clover grown in monoculture or in combination with grasses is a major hay crop in several regions of the world. In North America, it is grown in the humid northeast and in the Pacific northwest of the US under irrigation and used as an annual in southeast U.S. (Taylor and Smith, 1995). For red clover, the yield potential is high; red clover varieties tend to have slightly lower forage yields than alfalfa in the area south of the U.S. - Canada border (Undersander *et al*, 2002). Red clover plants survive better in severe winters when sown with a grass, rather than as monoculture (Belzile, 1987). It is commonly grown for silage and pasture, and not commonly harvested for dry hay due to its slow drying rate. A common production practice in parts of North America is to harvest the second-cut crop for seed, following a first cut-crop for forage or silage. Silage management for red clover-dominant swards includes a first cut at the early flowering stage and a second cut 6-8 weeks later. Traditionally, red clover was regarded as a "difficult" crop for silage making due to low dry matter, low water soluble carbohydrate contents, and a high buffering capacity, which slowed the attainment of low pH for good fermentation. A satisfactory silage fermentation is more likely to result from red clover/grass mixtures because of higher dry matter and

water soluble carbohydrate concentrations and lower nitrogen contents (Frame *et al*., 1998). Red clover has high bloat potential (Howarth *et al.*, 1991).

Nitrogen fixation

Rhizobial inoculation is not usually carried out in European countries, since most soils contain *R. leguminosarum* bv. *trifolii*. If red clover use is extended to soils without a previous history of clover growth, rhizobial inoculation of the seed is essential.

The total amount of nitrogen fixed by red clover and the contribution it makes to the nitrogen content of the soil can vary. The factors for variation in nitrogen fixation include, climatic and soil conditions, presence and efficacy of *Rhizobium*, companion species, and stage of plant development. Nitrogen fixation can contribute up to 80% of total nitrogen assimilation in red clover (Heichel *et al*., 1985). However, the rate of N_2 fixation may be greatly reduced due to drought, accumulation of inorganic nitrogen in soil, soil acidity, or plant defoliation (Maag and Nosberger, 1980).

Feed

Red clover has a high nutritive value for ruminants. It can improve the quality of autumn-saved forage for out-wintered livestock where the climate allows this practice. The digestibility of red clover's primary growth declines with advancing maturity in a linear fashion and is related to the declining leaf:stem ratio. The decline in digestibility is associated with increasing lignin content and a reduction in degradability of polysaccharides other than starch (Taylor and Quesenberry, 1996).

Nutrient composition of red clover is shown in Tables 13 and 14. Compared with grasses, red clover is usually higher in concentrations of pectin, lignin, nitrogen, calcium, magnesium, iron and cobalt (Frame *et al*., 1998). Alfalfa and red clover have similar nutrient content. One of the main differences is that red clover contains polyphenol oxidases, which are enzymes that play a role in inhibiting plant proteases (protein degrading enzymes) and proteolysis (protein breakdown) in the silo. As a result of the polyphenol oxidase action, red clover protein is not broken down during silage fermentation to the same extent as alfalfa protein. Therefore, red clover has more undegradable protein (bypass protein 25-35%) than alfalfa (15-25%). Additional research has shown that when red clover and alfalfa are of similar fibre content, red clover may be more digestible than alfalfa, providing a more energy-dense forage to the diets of lactating dairy cows (Hoffman and Broderick, 2001). Unfortunately, red clover does not stand up to continuous stocking, but works well in a rotational stocking system. Red clover does not accumulate condensed tannins in forage (Sarkar *et al*., 1976). As discussed in the antinutritional factors of alfalfa section, isoflavonoids are more common in clover species than alfalfa.

Table 13. Proximate, lignin, acid detergent fibre (ADF), and neutral detergent fibre (NDF) composition of Red Clover (*Trifolium pratense L.)* Harvested at Early Bloom Stage (expressed on dry matter basis).

%	Hay NRC71[1]	Hay NRC82[2]	Hay Ensminger[3]	Hay NRC96[4]	Hay Hoffman[5]	Range for Hay	Silage Lit Range[6]
Dry matter	87.3	89.0	87.0	89.0		.87 - .89-	21.1-53.5
Crude protein	21.4	16.0	21.4	20.8	18.4	16.0 – 21.4	14.9-22.5
Crude fat	3.9	2.8	3.9	3.0	-	2.8 – 3.9	4.3
Crude fibre	20.4	28.8	20.4	-	-	20.4 - 28.8	-
NDF	-	-	-	48.0	34.9	34.9 – 48.0	31.7-50.5
ADF	-	-	-	-	24.4	24.4	24.9-37.0
Lignin	-	10.0	-	16.67	4.3	4.3 – 10.0	4.2-4.3
Ash	9.7	8.5	9.7	7.0	-	7.0 – 9.7	1.9-11.5

[1] NRC, 1971
[2] NRC, 1982
[3] Ensminger *et al*. 1990.
[5] Hoffman *et al*., 1993
[6] Dewhurst *et al*., 2003; Broderick *et al*., 2001; Coblentz *et al*., 1998; Hoffman *et al*., 1997; Hoffman *et al*., 1993; Al-Mabruk *et al*., 2004

Table 14. Mineral Composition of late vegetation to early bloom Red Clover (*Trifolium pratense L.)* (expressed on dry matter basis).

	NRC71[1]	NRC82[2]	Ensminger[3]	NRC01[4]	Range
Na, mg/100 g	-	.19	-	.18	.18 - .19
K, mg/100 g	2.57	1.62	3.24	1.81	1.62 – 3.24
Ca, mg/100 g	1.77	1.53	1.55	1.38	1.38 – 1.77
P, mg/100 g	.31	.25	.37	.24	.24 - .37
Mg, mg/100 g	.51	.43	.39	.38	.38 - .51
Fe, mg/100 g	-	.018	.073	.024	.018 - .073
S, mg/100 g	-	.17	-	.16	.16 - .17
Cu, mg/kg	-	11.0	21.1	11.0	11.0 – 21.1
Co, mg/kg	-	.16	.23	.16	.16 - .23
Mn, mg/kg	-	73.0	86.7	108.0	73.0 – 108.0
Zn, mg/kg	-	17.0	52.0	17.0	17.0 – 52.0
C1, mg/100 g	-	.32	-	.32	.32

[1] NRC, 1971
[2] NRC, 1982
[3] Ensminger *et al*., 1990
[4] NRC, 2001

White Clover (*Trifolium repens* L.)

On a world basis, white clover (*Trifolium repens* L.) is the most important true clover species for grazed swards within the genus *Trifolium*. White clover is used primarily in Western Europe and North America, New Zealand and Australia. There are approximately 15 million hectares of pasture with white clover in Australasia and 5 million hectares in the United States. This legume is thought to have originated in the Mediterranean area (Taylor *et al*., 1980).

Production

White clover is usually grown in association with suitable grass species such as perennial ryegrass, or in the United States, Kentucky bluegrass (*Poa pratensis*). Grass/clover swards may be utilised successfully by a range of grazing systems for both intermittent (rotational), continuous grazing, or a blend of both types in the same season. In Atlantic Canada, white clover is allowed to stockpile from late summer for use in late autumn thus extending the grazing season (Fraser *et al*., 1993; Kunelius and Narasimhalu, 1993). White clover has high bloat potential (Howarth *et al*., 1991), likely due to the large amount of foliage.

White clover plays an important role in arable cropping particularly in sustaining or building up soil fertility whether as a green manure or as a legume-rich phase within a crop rotation (Barney, 1987; Ten Holte and Van Keulen, 1989). It also has a role, when undersown in arable crops such as corn (maize), in protecting the soil from erosion and minimising damage from harvesting operations (Lampkin, 1990). In monoculture or in combination with grass, white clover acts as a protective ground cover or soil-stabilization plant (Parente and Frame, 1993). There is increased interest in the use of white clover as an understorey to supply the nitrogen requirements of a cereal crop.

Physiology

White clover is capable of spreading and establishing itself in suitable niche situations in grazed pastures. It can tolerate severe defoliation better than other types of legumes, is more persistent, and has the ability to colonise bare spaces (Burdon, 1983). White clover is adapted to a wide range of soils but it does not thrive in poorly drained soils (McAdam, 1983), shallow drought-prone soils (Foulds, 1978, Thomas, 1984) or saturated, unamended peat (Burdon, 1983). Unlike red clover and alfalfa, white clover has a continual generation of new leaves.

Nitrogen fixation

For nitrogen fixation, rhizobial populations of the strain *Rhizobium leguminosarum* bv. *trifolii* infect the roots of white clover and are highest in soils in which Trifolium species have been or are currently prevalent. Otherwise, white clover needs to be inoculated with effective and competitive strains of Rhizobia (Newbould *et al*., 1982).

Feed

Nutrient composition of white clover is shown in 15 and 16. The digestibility of white clover is higher than that of other temperate forage legumes. White clover is almost always grown in association with grasses; approximately 10 - 20% white clover allows for optimal animal productivity (Curll, 1982; Stewart, 1984). Dry matter intake by a variety of livestock has been shown to be higher for white clover than for grass, regardless of feed form (fresh, dried, hay or silage) (Thomson, 1984). The physical, chemical and plant anatomical features all contribute to the superior intake quality of white clover. Sheep spend less time masticating white clover, and the weight per bite is heavier due to a greater bulk density (Edwards *et al*., 1995). Heifers spend a longer time grazing and ruminating on grass than clover (Orr *et al*., 1996). The rate of particle degradation in the rumen is faster with white clover than with ryegrass (Moseley and Jones, 1984, Ulyatt *et al*., 1986) and there is enhanced ruminal digestion with the legume (Beever and Thorp, 1996). In addition to a faster rate of intake for white clover than for grass at comparable digestibility levels, ingested nutrients in white clover may be utilised more efficiently (Beever *et al*., 1985) and more efficient use made of metabolizable energy (ME) for animal production (Rattray and Joyce, 1974). White clover does not accumulate condensed tannin in forage, but accumulates these polymers in

flowers (Sarkar *et al*., 1976; Foo *et al*., 1982). Some white clover cultivars can contain cyanogenic glycosides.

Table 15. Proximate, lignin, acid detergent fibre (ADF), and neutral detergent fibre (NDF) composition of White Clover *(Trifolium repens L.)* Harvested at Late Vegetative / Early Bloom Stage (expressed on a dry matter basis).

%	NRC71[1] Hay	NRC82[2] Hay	Ensminger[3] Hay	NRC96[4] Hay	Range Hay	Dewhurst[5] Silage
Dry matter	17.7	90.0	89.0	89.0	17.7 – 90.0	24.2
Crude protein	28.2	22.0	22.4	22.4	22.0 – 28.2	26.1
Crude fat	3.3	2.7	2.7	2.7	2.7 – 3.3	-
Crude fibre	15.7	21.2	20.8	-	15.7 – 21.2	-
NDF	-	-	36.0	36.0	36.0	26.9
ADF	-	32.0	32.0	-	32.0	27.4
Lignin	-	7.0	6.6	7.0	6.6 – 7.0	-
Ash	11.9	10.1	9.4	9.4	9.4 – 11.9	10.0

[1] NRC, 1971
[2] NRC, 1982
[3] Ensminger *et al*., 1990
[4] NRC, 1996
[5] Dewhurst *et al*., 2003

Table 16. Mineral Composition of late vegetation to early bloom White Clover *(Trifolium repens L.)* (expressed on DM basis).

	NRC71[1]	NRC82[2]	Ensminger[3]	NRC01[4]	Range
Na, g/100 g	.39	.13	.13	.13	.13 - .39
K, g/100 g	2.13	2.62	2.44	2.44	2.13 – 2.44
Ca, g/100 g	1.40	1.35	1.45	1.45	1.35 – 1.45
P, g/100 g	.51	.31	.34	.33	.31 - .51
Mg, g/100 g	.45	.48	.47	.47	.45 - .48
Fe, g/100 g	.034	.041	.047	.047	.034 - .047
S, g/100 g	.33	.21	.21	.21	.21 - .43
Cu, mg/kg	-	10.0	9.40	9.41	9.40 – 10.0
Co, mg/kg	-	.16	.16	.16	.16
Mn, mg/kg	307.2	95.0	123.1	123.0	95.0 – 307.2
Zn, mg/kg	-	17.0	17.0	17.9	17.0 – 17.9
C1, g/100 g	.61	.30	.30	.30	.30 - .61

[1] NRC, 1971
[2] NRC, 1982
[3] Ensminger *et al*., 1990
[4] NRC, 2001

Alsike Clover (*Trifolium hybridum* L.)

Alsike clover (*Trifolium hybridum* L.) is grown in temperate and subartic areas of Europe, Asia, North and South America and some regions of Australasia. This legume tends to yield and grow better in cooler climates. It is thought to have originated in northern Europe. This short-lived perennial has similar persistence to red clover.

Production

This legume grows best in cool temperate conditions, but is adaptable to wet, infertile or acid soils that are unsuitable for red clover or alfalfa (Townsend, 1995). However, it is intolerant of drought or salinity. Alsike clover tends to be very tolerant of cold and frost and therefore, allows for its establishment and growth in cooler climate areas. The majority of the world's alsike clover seed is produced in North America, including Alberta, Idaho and Oregon.

This forage legume is usually grown in combination with grasses and other legumes. In North America, it is recommended to grow alsike in a mixture with red clover and a grass such as timothy (Townsend, 1995). The agronomic and management requirements of alsike clover are similar to those of red clover, and the forage causes bloat (Howarth *et al*., 1991).

Feed

As with other legumes, alsike clover is rich in protein and minerals although it declines in digestibility as the plant matures. It is very palatable for livestock and continues to bloom throughout the season. It is used for pasture and hay although the high moisture content makes it difficult to dry for hay production. The regrowth after taking a cut of hay is excellent for use in a fall grazing system. It is important to note that hay or pasture containing more than 5% alsike clover is not recommended for horses; it is associated with alsike clover poisoning characterized by liver damage and photosensitization in horses. The causal toxin in not known, and may originate with an associated fungus rather than the clover itself (Knight and Walter, 2003). Alsike clover composition is shown in Tables 17 and 18.

Table 17. Proximate Analysis of Alsike Clover (*Trifolium hybridum L.)* Harvested at Late Vegetative / Early Bloom Stage (expressed on a dry matter basis).

	NRC71[1]	Ensminger[2]	NRC82[3]	Range
Dry matter	87.4	88.0	19.0	19.0 – 88.0
Crude protein	14.2	14.2	24.1	14.2 – 24.1
Crude fat	2.7	2.8	3.2	2.7 – 3.2
Crude fibre	30.1	29.9	17.5	17.5 – 30.1
Ash	8.7	8.7	12.8	8.7 – 12.8

[1] NRC, 1971
[2] Ensminger *et al*., 1990
[3] NRC, 1982

Table 18. Mineral Composition of late vegetation to early bloom Alsike Clover (*Trifolium hybridum L.)* (expressed on a dry matter basis).

	NRC71[1]	Ensminger[2]	NRC82[3]	Range
Na, g/100 g	.46	.46	.46	.46
K, g/100 g	2.74	2.22	2.62	2.22 – 2.74
Ca, g/100 g	1.29	1.30	1.32	1.29 – 1.32
P, g/100 g	.26	.25	.28	.25 - .28
Mg, g/100 g	.32	.45	.31	.31 - .45
Fe, g/100 g	.045	.026	.046	.026 - .046
S, g/100 g	.21	.19	.17	.17 - .21
C1, g/100 g	.78	.78	.77	.77 - .78
Cu, mg/kg	6.0	6.0	6.0	6.0
Mn, mg/kg	117.0	69.0	117.0	69.0 – 117.0

[1] NRC, 1971
[2] Ensminger *et al*., 1990
[3] NRC, 1982

Subterranean clover (*Trifolium subterraneum* L.)

Subterranean clover (*Trifolium subterraneum* L., also known as subclover) is a winter annual that is very important in the drylands of Australia. This legume is thought to have originated in the Mediterranean region and was developed for pastoral use and soil improvement especially in Australia, where it is used in rotation with cereal cropping. It is also used in the northwest United States, southern Europe, Latin America and New Zealand to a lesser degree. It is adapted to regions with hot dry summers and moist winters with mild temperatures (6-14^{O} C) and abundant rainfall.

Production

Subterranean clover germinates rapidly in the moist autumn, grows during winter and spring, flowering and seeding occur in late winter/early spring and then survives the dry summer as a dormant seed. This efficient system is designed to escape the damaging summer drought. This legume grows best when soil fertility levels are relatively high especially with high phosphorus and sulfur, regardless, it is valued for its ability to grow in less fertile, acidic soils (Frame *et al*., 1998).

Along with its use in grazing, this legume is used for erosion control, hydro-seeding road side banks and as a green manure or weed smothering cover in horticultural and orchard situations (Caporali *et al*., 1993).

Nitrogen fixation

If a pasture is being renewed by sowing with subclover or in a mixture with grass, inoculation with a rhizobium strain is advisable unless there has been a long history of satisfactory subclover growth. Using the correct strain of *Rhizobium leguminosarum* bv.*trifolii* has a positive impact on establishment and performance of subclover.

Feed

Subclover is outstanding among annual forage legumes for its tolerance to grazing (Caporali *et al*., 1993). An annual seed crop is essential for subclover persistence in pasture. Therefore, it is important that the sward's potential to produce a seed crop is not jeopardized by overgrazing. In common with other

legume species, subclover is rich in crude protein compared to grasses. The protein concentration declines steadily with advancing plant maturity, as does the digestibility.

Grazed subclover in irrigated swards has high digestibility and nitrogen content and low NDF, ADF and lignin content (Frame *et al*., 1998). Effective rumen-degradable protein in the leaf can be so low that microbial protein synthesis in the rumen is limited, adversely affecting animal production (Mulholland *et al*., 1996). Table 19 shows proximate composition of Subterranean clover.

Table 19. Proximate Analysis of Subterranean Clover (*Trifolium subterraneum L.)* Harvested at Early Bloom Stage (reported on dry matter basis).

%	NRC71[1]
DM	90
CP	30.5
Fat	3.7
CF	10.1
Ash	11.1

[1] NRC, 1971

Birdsfoot Trefoil (*Lotus corniculatus* L.) and Greater Lotus (*Lotus* spp.)

The species within the *Lotus* genus are referred to as pioneer legumes because they are suitable for developing pastures on acidic, infertile soils in cool, moist areas of the world (Frame *et al*., 1998). Both perennials and annuals are components of this genus. There are a large number of species of *Lotus* Zandstra and Grant, 1968; USDA Plants Database, 2003). Three examples used for forage include birdsfoot trefoil (*Lotus corniculatus L.*), marsh birdsfoot trefoil (big trefoil or lotus) (*Lotus uliginosus* Schkuhr. also called *L. pedunculatus*) and narrow-leaf birdsfoot trefoil (*Lotus tenuis*).

Birdsfoot trefoil was not introduced to North America until the early 1900's, however, it was very common in Europe, Africa and Asia. The majority of species are found in the Mediterranean region and this is thought to be their area of origin. Approximately 1.2 million hectares are grown in northeastern North America on acidic, infertile and low-input management systems (Beuselinck and Grant, 1995). Greater lotus can be found in Britain, France and Germany as well as the northwestern United States.

Production

Birdsfoot trefoil is suited to clay soils which are too wet or too acidic for alfalfa. Birdsfoot trefoil is drought tolerant, even more so than alfalfa (Peterson *et al*., 1992). It also persists in poorly drained soil more than alfalfa or red clover (Barta, 1986) and is highly tolerant of saline soils (Schachtman and Kelman, 1991). Narrow-leaf birdsfoot trefoil is adapted to poorly drained soils and sown in central Europe and northern United States especially on saline and alkaline soils. The *Lotus* species are slow to become popular due to their slow establishment, slow growth rate and poor competitive ability (McKersie *et al*., 1981). The greater lotus species is not winter hardy. Birdsfoot trefoil is very winter hardy once established, although less than alfalfa, but it does not survive in harsh Canadian prairie conditions. Unlike alfalfa, which has a significant period of flower-free growth, lotus plants have a short non-flowering period.

Birdsfoot trefoil is very useful on marginal land, and is a non-bloating legume (Howarth *et al*., 1991) due to the presence of forage condensed tannins (Foo *et al*., 1982; Sarkar *et al*., 1976). Big trefoil also contains tannins (Foo *et al*., 1982). A number of reports from different areas of the world confirm the use of lotus species, especially birdsfoot trefoil, for pasture renovation in a variety of situations, ranging

from lowland grazing to alpine pastures (Frame *et al*., 1998). If this legume is used for a combination of hay and pasture, the hay crop should be taken at the early bloom stage and the subsequent regrowth grazed at the first flower. Weed control is very important, especially in the establishment year, since birdsfoot trefoil is not competitive in a weedy stand (Beuselink and Grant, 1995). This legume produces less forage with hay yields of 25-30% less than alfalfa. It is recommended that birdsfoot trefoil be used only in areas that are not suitable for alfalfa production because of soil acidity, poor drainage or low fertility.

Feed

There is little information available on the chemical composition of Lotus trefoil forage, but birdsfoot trefoil nutritive value is similar to that of alfalfa (Marten and Jordan, 1979). Composition of birdsfoot trefoil is shown in Tables 20 and 21. The lignin content of birdsfoot trefoil is lower than in other legumes such as white clover, red clover or alfalfa. The *Lotus* species contain varying amounts of floral and forage condensed tannins (Sarkar *et al*., 1976; Foo *et al*., 1982; Muir *et al*., 1999; Muir, unpublished), as well as varying amounts of flavonols (Harney and Grant, 1964; 1965) and cyanogenic glycosides (Grant and Sidhu, 1967). *Lotus uliginosis* has a moderate condensed tannin content ranging from 40-245 $mg.g^{-1}$ dry weight (Lees *et al*., 1994; Muir *et al*., 1999). *Lotus corniculatus* produces small-to-moderate amounts (Muir *et al*., 1999). Some *Lotus corniculatus* plants have very high levels of cyanogenic glycosides (Zandstra and Grant, 1968).

The more upright types of birdsfoot trefoil are suited to hay and silage production with a possibility of 2-3 cuts per season. This legume is of major importance for hay, silage and grazing in the northern United States and eastern Canada (Beuselinck and Grant, 1995). Birdsfoot trefoil is highly palatable to livestock, even though it accumulates condensed tannins. Therefore, these pastures are best used in a rotational stocking system (Van Keuren and Davis, 1968, Van Keuren *et al*., 1969). Early spring grazing or continuous stocking will weaken and eliminate a stand of birdsfoot trefoil. Birdsfoot trefoil is persistent, and will last for several years if managed properly.

Table 20. Proximate, lignin, acid detergent fibre (ADF), and neutral detergent fibre (NDF) composition of Birdsfoot Trefoil *(Lotus corniculatus L.)* Harvested at Late Vegetative / Early Bloom Stage (expressed on a dry matter basis).

%	NRC71[1]	NRC82[2]	Ensminger[3]	NRC96[4]	Hoffman[5]	Range
DM	89.0	92.0	91.0	91.0	100	89.0 - 100
Crude protein	16.0	16.3	15.3	15.9	17.0	15.3 – 16.3
Crude fat	2.2	2.5	2.1	2.1		2.1 – 2.5
Crude fibre	29.6	30.7	32.3			29.6 – 32.3
NDF			47.0	47.5	44.4	44.4 47.5
ADF		36.0	36.0		35.8	35.8 – 36.0
Lignin		9.0		9.1	9.8	9.1 – 9.8
Ash	7.6	7.0	7.4	7.4		7.0 – 7.6

[1] NRC, 1971
[2] NRC, 1982
[3] Ensminger *et al*., 1990
[4] NRC, 1996
[5] Hoffman *et al*., 1993

Table 21. Mineral Composition of early bloom Birdsfoot Trefoil *(Lotus corniculatus L.)* (expressed on DM basis).

	NRC71[1]	Ensminger[2]	Range
Na, g/100 g	.07	.07	.07
K, g/100 g	1.92	1.92	1.92
Ca, g/100 g	1.70	1.7	1.70
P, g/100 g	.27	.23	.23 - .27
Mg, g/100 g	.51	.51	.51
Fe, g/100 g	.023	.023	.023
S, g/100 g	.25	.25	.25
Cu, mg/kg	9.0	9.3	9.0 – 9.3
Co, mg/kg	.11	.11	.11
Mn, mg/kg	29.0	28.7	28.7 – 29.0
Zn, mg/kg		77.2	77.2

[1] NRC, 1971
[2] Ensminger *et al*., 1990

Sainfoin (*Onobrychis viciifolia* Scop.)

Sainfoin (*Onobrychis viciifolia scop*.) is also known as St. Foin, cock's head, esparcet, holy clover or holy grass. In French, sainfoin, is interpreted to mean "healthy hay", which is probably referring to its non-bloat characteristics. This perennial legume is indigenous to temperate western Asia and southern Europe. It can be found on dry calcareous soils of the western United States and Canada (Miller and Hoveland, 1995), although its lack of genetic variability has prevented it from becoming agriculturally important in either country.

Production

Sainfoin grows well on calcareous soils having a pH of 6 or higher, which tend to be too dry or too barren for clover or alfalfa. It is even more drought-resistant than alfalfa; however, it yields less (Rogers, 1976). Sainfoin yields best on deep, well-drained soils, and will not withstand wet soils or high water tables. It is somewhat intolerant of saline soils and tends to grow well on soils that are low in phosphorus. Sainfoin requires soil rich in lime and can withstand cold temperatures. It is not as winter hardy as the locally-recommended cultivars of alfalfa, and tends to be very susceptible to invasion from weeds because of its slow growth during the establishment year.

Grown in monoculture or in combination with grasses such as fescue or cocksfoot, this legume competes poorly with creeping, rooted grasses. The stage of growth at the time of cutting determines the quality of the hay or silage, cutting at mid-flowering for hay and early flowering for silage. Growth after the first harvest is nutritious and preferred by livestock. However, overgrazing should be avoided since re-growth will be limited, especially if grazing is intensive. Sainfoin is very palatable and is grazed by livestock in preference to alfalfa. Forage dry-matter yields of sainfoin are about 20% lower under dryland conditions compared with alfalfa, and may be 30% or more lower in irrigated areas.

Unlike alfalfa, sainfoin does not drop its lower leaves; stems remain succulent as the plant matures so that quality does not decrease as rapidly. Unfortunately, use of sainfoin has been limited by the cost and availability of seed. Seed supplies have been inadequate, primarily because reliance on native insect pollinators provides inconsistent seed yields. Also, with the increase in cheap sources of N fertilizer, this legume's popularity has declined.

This legume is recommended only for short term rotations in pure stands or for planting in grass legume mixtures (along with alfalfa, birdsfoot trefoil, meadow bromegrass or orchard grass) that persist after sainfoin declines. The seeding of sainfoin with a noncompetitive grass may help to boost yields and reduce weed pressure. The advantages of sainfoin for pasture use include excellent quality and palatability that give superior animal performance without the danger of bloat (Howarth *et al*., 1991). Addition of 10-20% sainfoin to an alfalfa diet also suppressed most of the bloating in steers (McMahon *et al*., 1999).

Nitrogen Fixation

The nitrogen fixation abilities in sainfoin are poor in comparison with alfalfa and clovers. For good establishment and growth, sainfoin must be inoculated with a special rhizobium prior to planting. Nitrogen-fixing bacteria may be short-lived or ineffective so that nitrogen fertilisation may be required for this legume.

Feed

Sainfoin is rich in protein similar to other legumes, however, its digestibility is limiting. It has lower crude protein and digestibility than alfalfa (Karnezos *et al*., 1994). Sainfoin is rich in minerals compared to grasses, but its calcium and sodium contents are much lower than in other forage legumes (Spedding and Diekmahns, 1972).Sainfoin is higher in carbohydrates than alfalfa, and lower in crude protein, fibre and ash. Sainfoin forage and flowers contain moderate levels of condensed tannin ranging from 27-75 mg.g-1 dry weight (Koupai-Abyazani *et al*., 1993; Marais *et al*., 2000). Substantially lowered beef production costs occur when cattle are raised in alfalfa mixed pastures that include sainfoin as a source of condensed tannin (Popp *et al.*, 2000.).

Cicer milkvetch (*Astragalus cicer*)

Cicer milkvetch (*Astragalus cicer*) is a long-lived perennial that is native to the European continent. This legume is grown in a wide variety of environments, since it performs well on poor, infertile soil. Cicer milkvetch is grown in Canada on a small scale.

Production

This pasture legume is a hardy forage plant with deep roots and a creeping growth habit. It is tolerant to drought, slight acidity and alkalinity, but is intolerant to waterlogged soils. Cicer milkvetch is more accepting of late spring and early frosts than alfalfa.

Two years are required after establishment to produce any hay or pasture. Cicer milkvetch tolerates grazing and grows well throughout the season. An advantage to this legume is its bloat-safe property, which occurs because of its reticulate leaf veins and epidermal thickness (Howarth *et al*., 1979; Lees *et al*., 1982). Yields for this legume are comparable to alfalfa in a longer growing season area. Due to its slow spring growth and slow recovery after harvest, it may only be harvested 2 or 3 times per season. It is competitive in combination with grasses and therefore requires an equally competitive grass if the legume is to be equally maintained. These grasses include creeping foxtail, meadow bromegrass, orchard grass and tall fescue.

Feed

The protein content of cicer milkvetch equals or exceeds that of other legumes. This high protein level is due to the leaf:stem ratio, which is 40% higher than alfalfa as well as its ability to hold its leaves during the drying and baling processes. The moisture content, when harvested, is on average 4-8% higher than alfalfa or sainfoin. This results in an extended drying time that is approximately three days longer than

other legumes. It is especially well suited for use in a pasture environment and resists damage from overgrazing. Cicer milkvetch tends to be readily consumed by all classes of livestock either in the form of hay or pasture. No cases of bloat have been reported for cicer milkvetch.

Sweet clover (*Melilotus officinalis*)

Sweet clover (*Melilotus officinalis*) is a hardy, drought-tolerant biennial that has adapted to a wide range of soils. This legume is tolerant of alkalinity but not acidity (Gorz and Smith, 1978). The yellow type of sweet clover is more drought-tolerant, shorter in stature, and earlier maturing than the white type of sweet clover (*Melilotus alba*).

Production

This legume is used in Canada and the United States cornbelt, in areas with alkaline soils, for both hay and pasture, as well as an aid for erosion control with its deep root system. Sweet clover should be cut prior to the bud stage for good quality hay. For grazing, regrowth will occur if a 30 cm stubble is maintained.

Feed

As with other clover species, this legume has the potential to cause problems with bloat, although the potential is not as high as alfalfa and clovers (Howarth *et al*., 1991). Sweet clover produces coumarins, a sweet-smelling phenolic that develops into dicoumarol under sub-optimal hay-curing conditions (wet, mouldy). Dicoumarol is an anti-coagulant that causes livestock death from internal bleeding (sweet clover disease). Low-coumarin varieties have been developed (Goplen, 1971; 1981).

Serradella (*Ornithopus* spp)

Serradella is a summer annual which is native to south-western Europe. This legume is a winter or cool season annual when it is grown in mild regions, such as southern Australasia. There are two species, Pink or French serradella (*Ornithopus sativus* Brot.) which is cultivated for forage in some parts of Europe, Australia, high altitudes in Kenya and South Africa; and Yellow serradella (*Ornithopus compressus* L.) which occurs widely in natural pastures in countries surrounding the Mediterranean on non-calcareous soils.

Production

It grows on all soil types on which subterranean clover is grown but also on sandy, gritty soils where clover cannot grow (Gladstones and McKeown, 1977). The yellow type of serradella is confined to areas that receive at least 500 mm of rainfall per year.

Feed

Similar to most legumes, the crude protein and digestibility decline with advancing plant maturity, although the rates of decline are slower than for alfalfa or red clover (Iglesias and Lloveras, 2000).

Once established, serradella can be grazed in systems similar to those for subclover with similar stocking rates but it can also be cut for silage (Taylor and Hughes, 1978). The dry matter yields for this legume are quite variable and are dependent on several factors. The pink serradella variety tends to have a high nutritive value (Gladstones and Barrett-Lennard, 1964). In north-western Spain, pink serradella, planted in early fall, can be used alongside corn in a double-cropping system (Iglesias and Lloveras, 1998).

Serradella is used as an understorey for grazing in agroforestry situations in New Zealand due to its nitrogen fixing ability. It can also be used as an understorey in vineyards, growing while the vines are dormant, controlling weeds and supplying nitrogen to the vines (Lloveras, 1987).

Sulla (*Hedysarum coronarium* L)

Sulla (*Hedysarum coronarium* L.) is also known as Italian sainfoin, French honeysuckle or sweet vetch. This short-lived perennial is thought to have originated in the western Mediterranean region and North Africa (Duke, 1981).

Production

Sulla is the main legume in southern Italy with approximately 250 000 hectares used for grazing and hay (Martiniello and Ciola, 1994). It has been evaluated for use in North America but at the present time occupies few acres of commercial production (Allen and Allen, 1981). Sulla is mainly sown alone, but can be grown with a cereal or in a mixture with other legumes and on soils with a pH greater than 6-6.5.

Feed

The forage is of high nutritive value (especially the leaflets), and therefore it is important that sulla is cut prior to the onset of flowers for an optimal hay product. With respect to grazing this legume is best utilised in a rotational grazing system. *Hedysarum* species contain floral and forage condensed tannins which eliminate the risk of bloat (Skadhauge *et al*., 1997)

SECTION VIII – REFERENCES

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Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development

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ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT
Paris, 2005

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FOREWORD

This report presents the main generic management system standards (i.e. those MS standards used internationally and across business sectors) with special reference to the chemical industry. It also addresses the potential benefits achievable from integrated management of safety, health, environment and quality (SHE&Q). The report has been prepared by a consultant, Mr. *Ian M. Waldram*, Director of the SHEQuality Ltd., Scotland, United Kingdom.

The report comes within the framework of the current project on development of guidance for the implementation of integrated management of SHE&Q, in the OECD Programme on Chemical Accidents.

This report was originally prepared for OECD in mid-2004 and most of the text reflects the status of Integrated Management Systems (IMS) at that time. However minor revisions have been incorporated to take account of key publications and other global developments up to mid-2005, when the document was formally approved as an OECD publication.

The report builds from existing documents on Occupational Safety & Health Management Systems (OSHMS) and Integrated Management Systems, and adds evidence from focussed interviews with a number of experienced management system stakeholders. Whilst much of the information is generic, application to the chemical industry is a particular focus, as the work was commissioned by the OECD Working Group on Chemical Accidents.

The common elements of all MS models are summarised, and some differences between Quality, Environment and Safety & Health MS are highlighted. The history of the most commonly used MS standards in these three areas is outlined, together with some IMS and Business Risk Management standards. The report then considers a number of practical issues in MS implementation, and illustrates the relevance of these with examples from the interviews.

It is concluded that, whilst appropriate implementation of suitable MS standards can result in continual improvement of OSH results, there are also examples where MS implementation has minimal effect. In particular, if IMS are used in the absence of competent OSH advisors and auditors, OSH results are likely to be variable, even though there is excellent management commitment and employee involvement, as required by the OSHMS standards.

Ten good MS practices are then identified, based on the interviews and other evidence, implementation of which will aid continual improvement of results and ensure MS are efficient in use of resources. One such practice is for chemical sector organisations to use the Responsible Care MS, a sector-specific global standard which incorporates most of the other identified good practices.

The OECD Working Group on Chemical Accidents recommended that this report be forwarded to the Joint Meeting of the Chemical Committee and Working Party on Chemicals, Pesticides and Biotechnology, for consideration as an OECD publication. The Joint Meeting agreed that it should be made available to the public.

This document is published on the responsibility of the Joint Meeting of the Chemicals Group and Management Committee of the Special Programme on the Control of Chemicals of the OECD.

1. INTRODUCTION

The OECD Working Group on Chemical Accidents has held Workshops and issued previous reports about aspects of Occupational Safety & Health Management Systems (OSHMS) – see for example refs. 1, 2 and 3. In particular ref. 3 is a very thorough survey of issues to do with practical implementation of OSH-MS in organisations, and the advantages and disadvantages of integration.

This report builds from such references, and does not attempt to repeat them. In particular this report utilises additional material, both publications and also data collected from focussed interviews with a range of organisations accessible to the author – some in the chemical industry, some in other sectors.

1.1 Q, S, H & E Management System similarities

There is no doubt that, in theory, most formal Management Systems (MS) are highly compatible – all are derived from Deming's original "Plan-Do-Check-Act" cycle for continuous improvement. Most systems use a visual 'model' as one means to communicate their contents and, even when these models look quite different, they can all be shown to be compatible with Deming's simple 4-stage cycle (see for example ref. 4, sections 1 and 2).

At a more detailed level, there are tables which 'map' the contents of one standard or guidance against the others, thereby identifying synergies and similarities. In particular, for the chemical industry, the Responsible Care Guidance includes a 'road map' showing how it relates to EMAS/ISO 14001; OHAS 18001 and ISO 9001 (ref. 5, Appendix 2) and also how it relates to the EFQM Business Excellence Model (ref. 6).

The wide range of relevant standards and guidance is covered in more detail in section 2.

1.2 Q, S, H, E Management System differences

However there are also important differences between the various Q, S, H & E standards and the issues they cover. Firstly, although all are about identifying risks and ensuring appropriate controls are in place, the main 'beneficiaries' if the MS is effective are very different.

- For Safety and for Health the 'prime beneficiaries' are workers in the business, with neighbours and product users as possible 'secondary beneficiaries' – these people can readily speak for themselves if given an opportunity, and an effective OSH-MS needs to allow for this;
- For Environment the 'prime beneficiaries' are mostly non-human - plants and animals impacted by contaminated ground, water, air, or noise, radiation, etc. though there can be direct effects from these on human populations too. The 'spokesmen' for Environmental concerns tend to be NGO pressure groups, and also local regulators – if adequately resourced;
- For Quality the 'prime beneficiaries' are customers – for some types of product or service they have strong links with and influence over the supplier, in other areas their views may be difficult to feed back.

It is vital that all MS are 'owned' by line managers, but they also need expert advisors – both to help identify accurately the hazards which give rise to risks which the MS is then designed to manage, and also to inform the organisation on current good practices (or 'controls') which should be implemented to ensure the resulting risks are acceptably low. This is a second important area of potential difference

between MS. Depending on the size and type of work within an organisation and the range of products/services it provides, identifying hazards and suitable controls in the four separate disciplines of S, H, E and Q may be quite simple, or extremely complex. The need to ensure availability of competent advice on the full range of hazards and controls is further discussed in section 3.1.

This issue of line management ownership whilst also using expert advisors can lead to a third area of difference. Whilst it would be almost universal for quality advisors and environmental advisors to report to the main business line management, safety and health may be viewed as 'people' issues and thus report via Human Resources (HR). Unless reporting lines of all the discipline specialists who advise about details of the respective MS are similar, it is unlikely that much integration can occur – the same issue is evident when organisations begin to manage and report their Corporate Social Responsibility (CSR) results, and there are strong parallels between CSR and IMS.

A fourth area of difference relates to legislation. Most jurisdictions, though not all, have detailed local laws and guidance related to Safety, Health and Environment which set minimum standards - but nothing similar for Quality. This can present problems both when a single organisation operates in different legislative regimes (these may be within a single federal nation as in Canada, USA or Australia, or across national boundaries). Even where legislation is framed so as to set uniform standards, e.g. in EU, it is often interpreted or enforced differently at different locations. The fact that S, H and E standards are set at least partially by legislation and enforced by regulatory bodies adds a dimension to SHE-MS compared with QMS which can make full integration difficult.

2. MANAGEMENT SYSTEMS (MS) STANDARDS

A huge number of documents could potentially be listed as 'MS Standards'. This section covers only the main generic standards (i.e. those used internationally, and across business sectors), but with special reference to the chemical industry. Relevant data is included about their origin, content, planned revisions, etc.

The style of documents varies considerably. Some are specifically written as Standards, in a format which readily permits assessment against their provisions. Others are titled Guidance, but have a very similar format. Yet others are more narrative in style – in some cases there are linked documents designed to allow easier assessment against the main standard, in some cases there are no supporting documents and assessment is more subjective. In this report, they are all referred to as 'standards' whether or not that word appears in the title.

2.1 QMS Standards

ISO 9001

The ISO 9000 family of international quality management standards and guidelines (ref. 7) has earned a global reputation as the basis for establishing quality management systems. The 2000 edition marked an important change to a 'process approach' compared to the 'procedural approach' described in the 1994 versions, and organisations certified to the previous standard were allowed a 2-year transition phase.

A criticism of earlier ISO 9000 editions was that excessive documentation was created which added little value but was required by assessors before award of a certificate. Another criticism was that ISO 9001 scope is limited to the 'products' of an organisation, i.e. does not cover 'non-product' processes

and results, for example those relating to people or to waste. Again this is not so for the 2000 version, though many businesses which seek certification choose to limit the scope to product issues (see section 3.5).

The 2000 revision is quite major – 20 elements in the 1994 edition have been reduced to 5 main chapters. Also there are now 2 main standards: ISO 9001: Quality management systems – Requirements; ISO 9004: Quality management systems – Guidance for performance improvement. The revised ISO 9001 addresses the quality management system requirements for an organization, to demonstrate capability to meet customer requirements and enhance customer satisfaction. The revised ISO 9004 is intended to lead beyond ISO 9001 towards a Total Quality Management (TQM) approach, based on meeting the expectations of all interested parties. The ISO website also emphasises that ISO 9001 can be used to improve business processes without the need for external assessment and certification – but in practice this approach seems rare.

EFQM – Excellence model

The European Foundation for Quality Management first issued their Excellence Model in 1992. The current version is dated 2003, there is an ongoing review process targeted at the next edition for 2006. Details of the model, research underpinning its structure and supporting documents are available on the EFQM website (ref. 8) – the eight foundation principles have now been adopted into the ISO 9000:2000 series (with minor rewording), but are arguably better embedded in EFQM-based processes than in many ISO 9000-certified organisations.

The EFQM framework looks rather different from other MS models, with 5 criteria titled 'enablers' and 4 'results'. It is designed as a generic non-prescriptive framework to encourage continuous improvement via self-assessment, rather than achievement of a threshold 'standard' judged by an external certifier. There is a well-defined 'path to excellence' with 5 different award levels based on detailed scored audits carried out by a trained team – the lower two levels are self-assessed, the top three require external assessment of a portfolio of written evidence (increasingly detailed at each level) plus an external on-site audit/assessment team.

Fundamental to the EFQM model is the concept of an organisation managed by linked 'business processes' which use a range of inputs to deliver desired outputs.

2.2 EMS Standards

ISO 14001

In practical terms there are no other competing global standards. There was a separate European EMAS (Eco-Management and Audit Scheme) standard, which some users believed had a better emphasis on continual improvement of results, but EMAS MS standards are now based on ISO 14001, though EMAS also requires public reporting in addition to robust internal processes.

Like ISO 9001, there are in fact a range of ISO 14001 standards and supporting documents (ref. 9). A new edition of ISO 14001 was published in November 2004. Details of the changes basically parallel those in ISO 9001: 2000.

2.3 S&HMS (or OSHMS – Occupational Safety & Health MS) Standards

This is the area of greatest MS diversity though, as noted in section 1.1, the similarities between systems are much greater than their differences. Although "health & safety" are almost always treated together, most national and international workplace legislation and standards in fact concentrate much

more on safety hazards (= prevention of injury) than on health hazards (= prevention of illness). However there is growing evidence, as living standards and life-expectancy improve, that the true personal, social and financial costs of work-related illnesses are in fact much more significant than the costs of injuries – though harder to identify and quantify, because the causes of ill-health are rarely unique to the workplace and the effects may not be seen for many years.

HSG65

This is the publication reference of guidance on 'Successful health and safety management' originally issued by Health and Safety Executive (HSE), UK in 1991, and revised in 1997 (ref. 10). The purpose of HSG65 is to demonstrate that H&S can and should be managed with the same degree of expertise and to the same standards as other core business activities, so as to effectively control risks and prevent harm to people. In 1991 this was a relatively novel message, though today it is widely accepted in many regulatory regimes. The 2nd edition of HSG65 was a significant update, and there is now some pressure within HSE for a further revision, but no firm plans to do so (ref. 11)

HSG65 is based on a high-level 6-element continuous improvement MS and contains a wealth of generic practical guidance. However it is (probably deliberately) not structured to be readily transformed into an assessed standard, and HSE have published no linked documents comparable to those issued by ISO in support of ISO 9001 and 14001. Thus, while many organisations, particularly those based in UK, claim to have based their internal OSHMS on HSG65, it is difficult to see how this can readily be verified.

BS 8800

A new and revised edition of this UK standard was published during compilation of this report (ref. 12), replacing the original 1996 version and taking account of changes in recognised national and international good practices. The main text has been simplified, but is supported by Annexes which provide detailed practical OSHMS implementation guidance. The Annexes, some of which are new and some revised, cover activities such as risk assessment and control, accident investigation, measurement of performance and audit, demonstrating the links from these essential activities into a comprehensive OSHMS. In addition, the first Annex compares and contrasts the various recognised MS (ISO 9001, ISO 14001, ILO OSH-MS 2001 and OHSAS 18001) in more detail than provided in this report.

There are many close linkages between BS 8800 and HSG65 and in combination they represent a rich source of guidance about good OSHMS practices, both high-level and operational. As with HSG65, BS 8800 is not an OSHMS specification against which existing management systems can be assessed and certified.

OHSAS 18001 and National Standards

During drafting of the original BS 8800 a major division of opinion arose as to whether or not independent assessment and certification of an organisation's OSHMS should be encouraged, as for QMS and EMS. Some viewed such certificates as valuable, particularly in the context of effective supply chain management, others believed that existing certification processes: added minimal value, required excessive resources and resulted in unused manuals – so new certification processes should be resisted. It proved impossible to reconcile these views within BS8800, which was structured and published as a non-certifiable standard.

As a result, an international consortium of certification bodies, including the commercial arm of BSI, produced the OHSAS 18001 specification in 1999 (ref. 13), followed by implementation guidelines OHSAS 18002 in 2000 (ref. 14). Neither document is an official British Standard, but OHSAS 18001 either is, or is likely to become, a national standard in other countries, notably in Pacific Rim. A recent

survey by BSI (ref. 15) identified that over 8000 OSHMS certificates have been issued in 70 countries, to many different standards and guidance, and that some 46% are to OHSAS 18001.

With the revision of BS 8800, from which it is derived, it might be presumed that OHSAS would be updated automatically. A review is indeed planned, but the decision on when to publish a revision will take into account other factors (ref. 15), including the needs of current new users to have time to 'bed down' their internal processes before revising them to meet an improved standard. When a revision is agreed, it is likely to include some alignment with other high-quality national standards such as AUS/NZ 4801 (ref. 16), to aid recognition as a truly global standard.

A new US standard was published in 2005: ANSI/AIHA Z10 – Occupational Health and Safety Systems (ref. 35). The format includes both a standard and associated guidance, but is not intended as a basis for certification. It is fully compatible with ISO 9001/14001 and takes account of the other national/global OSHMS documents outlined in this section.

ILO OSHMS Guidelines

In late 1990's there was a campaign to get OHSAS 18001 accepted as an ISO standard, to complement ISO 9001 and 14001. After much lobbying, it was eventually agreed that, because the 'primary risk targets' for OSH hazards are the workforce (see section 1.2), it is important that any such global standard should emanate from a body with wider representation than ISO. Accordingly ILO, which includes representation from Labour Inspectors, Employers and Employees, took over the work on a global standard, and issued Guidelines in 2001 (ref. 17).

The Guidelines provide a sound basis for an OSHMS, with a stronger emphasis on workforce involvement and consultation than some others. They include a simple model showing how they can be customised ('tailored') as a national, sectoral, or corporate standard, but the author is not aware of this having happened to any significant extent.

There are no ILO supporting documents to aid Certification to the Guidelines, and to date there seems to be no market for such Certification.

2.4 Integrated MS (IMS) Standards

Because so many of the elements of these different MS are common or very similar, efficiency considerations drive many organisations to try to merge them. Most common is a combined EHS-MS, but some advocate a fully integrated QuEnSH-MS. BSI has published a framework for managing the operational risks any organisation faces in its day-to-day business (ref. 30). The aim is to provide a structure by which an organisation can efficiently and effectively manage its operations through one system. A further BSI publication (ref. 31) gives an approach for integrating the management of quality, occupational safety and health and environmental aspects within one MS. This 'how to do it' manual includes flowcharts, questionnaires and examples, and takes readers through the model outlined in ref. 30.

The likely advantages and disadvantages of such approaches are considered in sections 3.6 and 3.7. In this section some of the publicly available integrated systems are summarised.

Combined Certification

One method is to request that the assessing body issues a combined certificate, typically to ISO 14001 and OHSAS 18001, less often including ISO 9001 as well. This approach may be marketed as a possible way to reduce assessment costs, and that issue is also considered in section 3.6.

Global sectoral standards

Sectors where many organisations operate internationally in a range of regulatory regimes (e.g. upstream oil and gas, ref. 18) or where there are pressures for global consistency in the absence of detailed regulations (e.g. shipping, ref. 19; food sector, ref. 25; US pharmaceutical sector – all suppliers must submit to Food and Drug Administration (FDA) audits) have developed their own standards. Over time, these may become mandatory, via either governmental or supply chain pressures. This is the case for international shipping, via the International Maritime Organisation.

Responsible Care (RCMS)

This standard is specifically designed for the chemical industry. It fully integrates EMS and OSHMS, and includes much of the scope of a QMS. Responsible Care originated in North America and currently operates in 47 countries. All national RC models have the same 8 fundamental features, but are then customised to meet the needs of local stakeholder groups. An international review of RC has been undertaken recently, and it is likely that greater international harmonisation will follow in a near future.

The current UK RCMS (ref. 5) and the associated self-assessment guidance (ref. 20) include all the constituents of both ISO 14001/EMAS and the various OSHMS outlined in section 2.3. Compliance with this national voluntary sector standard requires, as a minimum: an internal MS compatible with the published model; annual reporting to the RC standard; a self-assessment to the standard at least every 3 years. It is not compulsory for a UK chemical manufacturer to belong to Chemical Industries Association (CIA), but most do – so RCMS implementation, self-assessment and reporting is in effect mandatory for most UK chemical manufacturers. (However, this does not cover chemical distributors, or non-chemical sectors with often very similar hazards - e.g. storage of significant quantities of hazardous materials). Similarly, in 2003 the US RC standard changed from one based on six linked Codes of Practice to an integrated RCMS, with mandatory independent certification. Full implementation of this change is required from all American Chemical Council member companies by end-2007.

For the UK RCMS, there is a good range of supporting guidance, and the main documents (ref. 5, 6, 20) are available as a single publication. They include a wealth of practical guidance, flowcharts and checklists, specifically targeted at the chemical industry. There are also 21 UK regional self-help 'cells', most of which meet quarterly and encourage RC users share experiences and good practices.

RCMS operates with two key underlying principles – working to standards that are 'more than compliance', and ensuring continual improvement of measured Q, E, S & H results. Whilst the basic UK implementation model is for self-assessment, independent certification is also available – currently 5 UK sites out of some 200-300 are certified, with another 30 due for certification in 2004. The RCMS self-assessment guidance (ref. 6) identifies 5 broad performance levels. External certification gives assurance that full compliance with level 3 is achieved, but self-assessment and continual improvement are the only means to achieve the higher levels 4 and 5.

2.5 Business Risk Management (BRM) Standards

With the growing emphasis on holistic management of business risks, and assurance in public reporting that such risk management is effective, certification to further MS standards is a trend. In most cases there is no attempt to integrate the standards, rather the structure and methodology of each MS is similar and the Certification is 'additive'. Such individual standards include:

Investors in People

This UK-originated scheme aims to maximise contributions to organisation from all employees (ref. 21). It is widely used in both public and private sectors, in all sizes of organisation, and delivered at a regional level. Internal advisors and external assessors require mandatory training, and certificates are awarded by independent panels based on assessor's reports.

Current evidence is that, once the required standard is achieved, few organisations have an ongoing continual improvement process, but instead rely mainly on the 3-yearly review visits to stimulate any improvements. IIP recognises this deficiency and has added 3 additional 'tools' to stimulate further improvements in specific areas, and also a 4-level 'Profile' tool which aims to drive continual improvement via both self-assessment and benchmarking data – IIP certificates are based on assessment of Level 1 performance (ref. 21).

There is strong emphasis in IIP on effective communications with employees, including with representative groups where appropriate, and also on development of employee capabilities, including provision of appropriate training. However this is all expressed generically, with no specific mention of OSH in the standard. Thus IIP is fully compatible with any OSHMS, but unlikely on its own to result in improved OSH results.

Information Security MS – ISO 17799/BS 7799-2:2002

Loss of security, particularly in IT systems, is a growing concern for many businesses. Risks from security breaches can be a significant factor in business continuity planning, and certification to this standard is an option being actively marketed by Certification bodies. Using a Business Risk Management approach, but with separate certificates for each major risk area, is further discussed in section 3.6.

BRM Standards

To date, there are few published standards in this area, though much activity. For example the latest draft UK regulations on 'materiality' (i.e what Company Law requires to be included in annual reports to investors) include reference to possible OSH risks for the first time (ref. 22). However it may be some time before this begins to alter BRM practices.

Of the current published standards, AS/NZS 4360 (ref. 23) is generic, clear, comprehensive and includes helpful examples and tools as Appendices. OSH and E risks are among those listed in ref. 23, Appendix D. In contrast, the widely available UK document (ref. 24) is more a management guide to BRM principles, with no tools or specific reference to OSH risks.

3. PRACTICAL ISSUES IN MS IMPLEMENTATION

The primary reason for attempting to manage anything systematically, as distinct from unsystematically, is a belief that the business results of a systematic approach will be better. In particular, using the Plan-Do-Check-Act model for systematic management implies an expectation that results will continually improve. It is important to note that these results are of two types:

Output measures: These are the 'products' of work processes – in the case of health and safety, output measures include: injuries and illnesses, and also their severity – deaths, time lost, permanent/ temporary disabilities, etc; also damage/loss – fires, spills/releases, equipment damage, etc. It is worth noting that these measures are all of 'health and safety system' failures. Because MS are successful most of the time, it is common to measure their results in terms of failure, rather than success – for example typical QMS output measures are: numbers or rates of defects; customer complaints; etc. and EMS output measures are: tonnes discharged to air, water, landfill; numbers of spills/releases, etc. All these output measures are used to monitor improvements in system effectiveness (or reductions in ineffectiveness), i.e. "is the MS successful in producing the desired results?"

Input (or system) measures: These measurements are generated within work processes, particularly by monitoring the resources needed to operate the processes – and are a measure of system efficiency, i.e. "is the effort/resource required sustainable, and in balance with the results and improvements obtained?" Note that continual improvement of system efficiency should be just as important a goal as continual improvement of system effectiveness – and efficiency criteria become more important as effectiveness nears the limit of 'flawless operations'.

The following 8 sub-sections address practical issues linked to MS implementation, considering how each may support, or impede, the goal of continual improvement of both effectiveness and efficiency, and also how an integrated (IMS) approach may affect the issue. Included in these sections are anonymised examples from interviews conducted as part of the research for this report.

3.1 Advisor and auditor competences

The many similarities between Q-, E- and OSHMS, but also some important differences, are reviewed in Section 1. As noted there, accurately identifying hazards and implementing effective, efficient controls requires involvement of competent advisors in the relevant 'discipline'. The range and depth of advice needed can vary greatly, depending on the specific business and activities of the organisation - the chemical sector typically requires understanding of a broad range of hazards, each with a fairly complex hierarchy of controls. The advisor(s) used, who may be directly employed or contracted part-time, will need both knowledge (qualifications) and practical experience, and should be able to demonstrate how their resulting competences are kept current via personal Continuing Professional Development (CPD) records in addition to relevant original qualifications. As a consequence of the range of technology in use, the detail of local legislation and published guidance on good practices, it is often very difficult to find a single person capable of advising across the whole range of hazards and controls – certainly this would typically be the case for chemical manufacturing sites.

Some organisations do set up an integrated internal group to advise on quality, environment and health & safety standards and practices, but within that group have individual 'practitioners' (or external consultants) specialising in each discipline. Other organisations keep one or more of these areas separate, recognising that similar MS processes are needed, but also that cross-discipline competence is hard to achieve, except at the most basic level.

A global chemical company, based in Switzerland, uses global 'business processes' to manage production and sales operations, and audits these to ISO 9001:2000. The UK production site currently has an American EHS Manager, with wide MS experience but no formal qualifications in Q, E or H&S. There are also local Environmental and Health & Safety advisors, with appropriate UK qualifications and competences, supporting this generalist manager.
The site has separate internal ISO 9001 and Responsible Care audits and continual improvement plans, and the company uses an external certification body for ISO 9001 verification, but an internal global EHS audit process. The site has won repeated UK awards for health & safety excellence.

The same issue of cross-discipline competence applies to auditors. (Note: auditors may also be referred to as 'assessors', especially when they assess the evidence they collect against a certifiable standard). If one person is expected to cover quality, environment and health & safety management in a single audit, it is most unlikely any of the systems will be assessed or verified in much detail. Therefore the goal of continual improvement can easily be lost, and audits become a 'tick-box' check that processes are in place – rather than verification that these processes are effective and efficient.

UK RCMS auditors are individually approved by CIA, after an assessed training course. Pre-course requirements are chemical industry experience, plus accredited auditor competence to ISO 14001/ EMAS. The short RCMS auditor course then covers the 'more than compliance' and continual improvement ethos of RCMS. The breadth of technical awareness required by auditors is acknowledged, and RCMS external auditors almost always work in 'mixed-discipline' teams to ensure in-depth awareness of the full RCMS scope.

Auditors also require auditing competences, typically an auditing course involves 3-days training, but equally important are the personal qualities required for effective evidence-gathering, assessment and communication of audit findings. A summary of generic 'practitioner competencies' is given on the IIP website (ref. 21, note that IIP expect the same competences in both advisors and auditors) and reproduced as Annex 1 because such personal qualities are often not considered when selecting an auditor. Having received basic training, a new auditor needs to develop experience by participating in audits led by more experienced auditors.

An organisation with internal systems based on the EFQM model requested bids for Certification to ISO 9001. During bid evaluation they required to meet the proposed auditors, and awarded the contract to an organisation with limited experience in their business sector, but with an auditor clearly committed to continual improvement. When they later required Certification to ISO 14001, they rejected a bid from their current Certifier, as the proposed Environment auditor was judged to have a 'tick-box' approach, in contrast to the Quality auditor. This organisation won a European Quality Award in 2003.

The ISO Auditing Practices Group hosts a website (ref. 26) with a wealth of guidance about generic auditing issues and good practices. Most of the content applies to all MS, not just ISO 9001. This is a particularly valuable reference tool for auditors working in locations with little opportunity for face-to-face peer review and discussion of auditing practices.

FDA auditors were mentioned in two interviews as usually being very confrontational, requiring excessive detail in paper evidence, and having little concern for efficiency of their MS requirements. Most FDA audits are reported as 'competitive', with the auditees seeking to give no information other than what is specifically requested, and the auditors trying to identify 'stones to turn over' so as to find hidden faults – this type of auditor/auditee relationship is not good practice.

3.2 Internal and External Auditors

A key element in all formal MS is auditing – by definition the auditor(s) must be independent of the organisation they are auditing, otherwise the process is defined as management monitoring, not audit. However, there are degrees of independence and in all but the smallest organisations it should be possible to implement a system using auditors who are employed within the organisation, but in a different part and with different routine reporting relationships from the area they are auditing – this is defined as '1st party' auditing, whereas external audits are '3rd party' (client audits of suppliers are '2nd party').

Both types of auditor have advantages and disadvantages. The following table is taken from ref. 4.

Internal auditors	
Advantages	**Disadvantages**
• Know the organisation and where to look for evidence	• External stakeholders may have suspicions about their independence
• Reports have high internal credibility	• Take resources away from normal work – for both training and planned audits
• Excellent developmental experience because employees learn in detail about other parts of the organisation	• Can have a limited vision of improvement opportunities due to lack of external benchmarks
• Aid transfer of good practices across the organisation because they identify opportunities for sharing	
External auditors	
Advantages	**Disadvantages**
• High credibility with external stakeholders	• Must 'earn' respect for their findings within the organisation – initially they are often viewed negatively
• Provide strong benchmarking knowledge and give access to external Certification where this adds value	• Do not know the organisation, so may request much pre-audit documentation and take longer to complete their work
	• Can be expensive

Where external MS Certification is desired, external auditors are often employed early on and it can then be difficult to create an effective 'continual improvement' culture which also uses internal audit findings as a source of ideas for improvement. As can be seen from the table above, if there is no internal audit process some opportunities are lost which are not available from purely external audits.

In the most robust and effective systems, both external and internal MS auditors are used, just as they are for financial auditing – this arrangement is considered further in section 3.4.

3.3 Accreditation of External MS Audit services

Accreditation bodies are established in many countries, often by government or with the encouragement of government, with the primary purpose of ensuring that certification/registration bodies in the country are subject to oversight by an authoritative body, based on standards issued by the International Accreditation Forum (IAF, ref. 27). Accreditation reduces risk for government, business and customers by ensuring, through regular surveillance, that certification bodies are both independent and competent. Many organisations providing certification to ISO 9001, ISO 14001 and OHSAS 18001, and

also to some of the combined standards, have been assessed by an accreditation body, and therefore provide 'Accredited Certification', i.e. the processes they use to select, train and appoint competent auditors and to issue certificates are externally assessed as meeting IAF standards.

However there is no absolute requirement to obtain such accreditation before issuing certificates which verify that an organisation meets ISO, or any other, Standards. The market for certification services is often highly competitive, and one way to cut costs is to avoid paying for accreditation. An alternative view is that the checks carried out for accreditation are too limited to guarantee that all those accredited are of acceptable quality, so market forces are a better guide. Many clients who require suppliers to demonstrate that they "meet ISO 9001 standard", or an equivalent, are reported to never ask questions about whether the certificate has been issued by an accredited body.

At a seminar in March 2004 in Scotland, attended by organisations involved with ISO 9001, etc. in a range of business sectors, 160 attendees voted as follows:

1. Following ISO 9001 is a complete waste of time, our money and efforts would be better utilised in other ways – 24%
2. QMS based on ISO 9001 is good for business, but it can be adequately maintained by the business alone – 44%
3. As for 2, but to be effective it needs to be monitored by a competent 3rd party – 17%
4. Accredited Certification to ISO 9001 provides clear benefits for any business – 15%

In theory the use of an accredited certification supplier should provide more assurance that the MS assessment is effective than using a non-accredited supplier. However the experienced attendees at this particular seminar were evenly split on whether accreditation actually adds value in practice.

As noted in section 3.2, by definition auditors need to be independent of the systems they audit. However, if an organisation decides it needs certification to a particular standard as a pre-requisite for doing business, it is common to engage an experienced consultant to advise about what needs to be in place, and often then to assist with design and implementation of the changes needed. If the same consultant is later asked to certify that the organisation now meets the standard, they are no longer independent. Accredited bodies must have processes in place to prevent such conflicts of interest. Non-accredited bodies may have no concerns about the issue.

Because of the need to maintain independence, accredited auditors/assessors are expected to give written advice about MS improvements needed, but not about how to do this. If audit personnel rotate, as is typically the case for self-assessments and occasionally for external audit bodies, 'how to do it' advice about improvement opportunities can legitimately form part of their audit report.

Auditors should be willing to use their practical experience to support continual improvement, but may have concerns about prejudicing their independence for future audits. The format of their questions will often identify practical improvement steps which they have observed elsewhere. Also they can be asked for examples of how the desired improvements could be made. Informal verbal advice does not generally contravene the independence standard, and if sought at the end of the audit can be a valuable by-product for the auditee.

3.4 Certification and Self-Assessment

All the MS outlined in section 2 are based on a 'continual improvement' model, but there are challenges when linking this to award of a certificate which confirms that a recognised standard is achieved. The standard itself may require continual improvement, but what does this mean in practice?

An initial Certificate is not awarded until the specified standard is achieved, based on audit evidence. Re-certification is then normally every 3 years, with additional 6-monthly or annual 'surveillance visits' to check that the MS continues to function correctly. If there is evidence of a deficiency against the standard, there are several stages of reporting non-compliance, as judged by the Certification body. Terminology varies, but they can be summarised as:

- Observation
- Improvement opportunity
- Non-conformance
- Unaddressed non-conformance
- Suspension
- Certificate withdrawal.

Continual improvement issues that may arise during surveillance or re-certification include:

- If improvement goals are set, but not achieved, is that a non-conformance? – if so that would guarantee that all goals were set to be achievable, whereas in practice the use of 'stretch targets' seems to result in better business performance;
- If there is a single large failure, for example fatal accident, major release, product recall, is that a non-conformance?
- If improvement goals are not set, should the certificate be withdrawn? – if so many organisations should reportedly have lost ISO 9001 certificates after the 2-year transition period for ISO9001: 2000 in which improvement is required, compared to the 1994 version where it is not. In practice non-conformance reports were issued, but few certificates were withdrawn;
- If the certificate is for more than one site, how low can standards be on one site before the overall certificate is withdrawn? Must all sites be assessed for every renewal?

In practice, withdrawal of a certificate is very much a 'last resort', as it represents failure by the Certifier to convince their client that an improvement is needed. Whilst the great majority of organisations with Certificates take appropriate actions in response to audit Observations, Improvement opportunities and Non-conformances, a small minority may have quite serious MS deficiencies. Thus, having a MS certificate is not a guarantee of continual improvement.

The UK Investors in People (IIP) certification scheme (see section 2.5) now includes add-on modules to encourage continuous improvement, with 3 'improvement levels' above IIP certification at level 1. However this approach is too new to allow evaluation of its benefits.

If obtaining certification is not an issue, there is widespread evidence that a self-assessment approach works well in driving improvements – after all there is not much point in operating an internal self-assessment process unless the organisation is reasonably good at using the results to make improvements. Examples of MS based on self-assessment include EFQM, Responsible Care, HSG65, BS 8800, ILO (see section 2 for details). In some cases external assessment can be added after self-assessment has led to recognised improvements (notably Responsible Care and EFQM). Note also the box in section 3.3. where, for the participants in one recent UK seminar, self-assessment was seen as more useful overall than both types of external assessment.

A UK gas terminal obtained ISO 9002 certification for supply of products. As the globally-mandated corporate internal 'flawless operations' integrated MS became fully effective, the ISO 9002 systems were seen to have no added value and, after 6 years, the certificate was discontinued.

3.5 MS and Certificate Scopes

As noted in section 1.2, the 'targets' at risk if Q-, E- and OSHMS are ineffective are significantly different. In particular employees, those most at risk from OSH hazards, are also involved in managing those hazards. This contrasts with those 'at risk' if Q- or EMS are ineffective, who have no direct role in the management systems.

An organisation with internal processes based on EFQM is also externally assessed and certified to ISO 9001, ISO 14001, IIP and 3 sector-specific schemes. The main improvement drivers come from EFQM internal monitoring/audits and external audits, not the other external assessments. Every year the business benefits of each additional externally-obtained certificate are reviewed, and renewal is sought only if there is clear continued benefit.

When organisations are certified to a MS standard, both the standard and the 'scope' are always detailed on the certificate. For ISO 14001 and OHSAS 18001 the scope is usually each operational site, i.e. all operations on that site, or occasionally the whole organisation for all its sites. In contrast, ISO 9001 certificates typically cover only the delivery of specific products or services. The organisation may have other uncertified products or services, also organisational activities which do not contribute directly to product/service quality are excluded from the assessment. QMS external assessments with a typical product/service scope will seek evidence about the training and competence of employees to operate the product/service delivery process, but not about operational health & safety standards, or environmental standards, unless these directly affect the product/service. Nor will such QMS assessments cover non-operational aspects, such as hazards and working conditions in maintenance areas, offices, transport, etc.

When questioning individuals about current ISO 9001 certification to obtain evidence for this report, on more than one occasion they had to check the certificate to remind themselves of the exact scope, which was sometimes not for their full range of products/services. They reported that this is a question not often asked – most people, including senior staff and clients, are content with 'we are ISO 9001 certified'.

Similarly, some of the more 'people-based' MS, such as EFQM and IIP, are strong in assessing systems that ensure employees are encouraged to develop and contribute to the maximum extent possible, but weaker or non-existent in assessing OSH risks which may reduce or limit people's work capacity and thus their contribution.

In contrast with quality, no one would expect the scope of an EMS or an OSHMS to be less than the whole organisation. Indeed there is often pressure from external stakeholders (regulators, NGOs, investors) for both types of MS to extend up and down the supply chain, as part of a wider approach to sustainability and Corporate Social Responsibility (CSR).

In 2004 a UK chemical pigment supplier was asked by a UK paper mill for details of its site OSH results, as part of a mandatory supply-chain questionnaire. The paper mill is a subsidiary of a Finnish parent company, where social governance is particularly well developed – most customers are concerned about OSH issues in product use, but not about those where it is manufactured.

Largely because of these 'MS scope' issues, it would be wrong to expect any QMS automatically to improve internal SHE standards and results. However when a product QMS system is effectively linked with an EMS and an OSHMS, as for example in Responsible Care, there can be valuable synergistic effects.

3.6 Multiple Certificates

This is the most common approach – an organisation is independently assessed to each standard and separate certificates are issued. Depending on the global location, business sector and market pressures, either ISO 9001 or ISO 14001 may come first – sometimes aided by national or regional government support. From interviews carried out for this report, only relatively rarely is the main driver for certification internal, i.e. seeking recognition that high standards have been achieved, resulting from an internal continual improvement vision. In many more cases the need for certification is from national or international supply chain pressures.

Having been certified to one standard, it can be a natural step to add others. Many organisations will seek to use the same external assessment and certification body, believing there is bound to be some cost-saving. Only rarely is the quality of the assessment service a major consideration, as outlined in the box in section 3.1. Where certificates or awards are not provided via accredited bodies (e.g. IIP or EFQM), there will always be more than one external assessment body.

One concern with external assessments is that they almost never build from any internal self-assessment/audit processes, though this is permitted by IAF (ref. 28). Typically external audits are carried out by a single assessor (sometimes a team for the initial certificate), who will personally gather all the evidence judged necessary. However, given the way internal and external auditors can be complementary (see table, section 3.2), it should be possible to build from a strong internal audit process but still ensure the independence needed for a Certification assessment. No example was found of this being done by an external accredited auditor.

A UK-based oil and gas production affiliate of a global company developed a strong internal EHS-MS model, including an annual self-assessment audit plan covering the whole organisation, in response to major hazards legislation. The US-based parent had a pre-existing global EHS audit process which mandated an external 'compliance audit' of the UK subsidiary every three years. Initially the two systems operated independently and the external audits were viewed by the UK organisation as time-consuming and resulting in very few improvement ideas. It was suggested an experienced external auditor should join one internal audit, and this was agreed by all involved to give significant benefits, with the internal and external auditors complementing each other, providing value-adding findings and identifying several opportunities for good-practice transfer.

Effective audits use a balance of evidence from documents, interviews and workplace observations, and these latter two activities tend to disrupt normal work activities. Where organisations have multiple certificates, the combination of internal audits plus regular external reviews and re-assessments can give rise to a 'death by audit' culture. This may be exacerbated if key clients also require audits for supply chain assurance.

Typically auditees ask for audits not to coincide with busy periods. In contrast, one organisation with 7 different external annual audit/assessment processes required all the external bodies to plan these during its busiest month, on the basis that in that period auditors would be able to see every business system operating at its current maximum effectiveness and efficiency.

A global certification body reported when interviewed for this project that requests for 'combined audits' are much more common than audits of 'integrated systems', as few organisations have yet attempted to create an IMS (see 3.7). Combined audits are attractive to clients who judge there is less overall disruption to their normal work. The challenge for the certification body is to deploy an audit team

with the necessary range of competences, and to ensure appropriate time allocation to each of the separate MS being audited.

In Sweden it is common for organisations to be certified to both ISO 9001 and 14001, and to have combined audits. The national accreditation body is developing guidance to ensure such audits are balanced and the certification process remains robust.

3.7 IMS and Certification

As outlined in section 3.5, the process for obtaining and maintaining multiple certificates can be very resource intensive. An alternative is to adopt internally an Integrated MS (IMS), and to seek a single certificate covering the required standards.

An organisation which uses a 'business systems' or IMS model from start-up is relatively unusual, one example was found during the interviews for this report, in the hospitality industry. More commonly, organisations adopt an IMS approach when they observe the limitations of less sophisticated approaches to business management. If the organisation is still small, this may not be too difficult. If it is already large, the changeover from partially effective 'procedures-based' arrangements to a fully integrated business systems approach can require significant resources.

Two global oil companies merged, both had excellent OSH results. One used a global EHSMS model, the other a global IMS model, which became the overall model – neither were certified systems. One busy UK operational site was visited 4 years later, the local 'Compliance Co-ordinator' for the IMS systems and documentation reported that all local documents had not yet been fully revised and integrated, though to an outsider the systems in place appeared very comprehensive.

Four organisations with well-developed IMS were visited for this report. Two used EFQM as a basis (hospitality industry and integrity assurance to process industry), one used an internal model (upstream oil & gas) and one used ISO 9001 plus Responsible Care (chemicals – ISO 9001 for the main business systems, Responsible Care for operational systems). Each of these had at least one additional certificate, but there were no specific internal processes to support these, just the external assessments. The immediate impression when visiting each of these organisations to discuss their business is that the main IMS influences everything they do, provides strong drivers for continual improvement and that any external certification is a by-product.

One global supplier of accredited external assessments advertises an "Integrated Assessment Service (IAS)" on its website. Among the advantages claimed are: reduced assessment costs; less disruption on-site; less disruption to valuable senior management time. This seems to target organisations which view assessment to recognised standards as 'cost and disruption' rather than 'opportunity for improvement' and 'part of normal business'.

3.8 Impacts of non-OSH MS on OSH performance

It is likely that adoption of a MS approach for non-OSH business systems will have some effects on OSH management processes, systems and procedures. For example, smaller organisations systematically documenting procedures for the first time report that this often empowers junior employees, as they are clearer about their responsibilities and able to make decisions in line with these procedures in preference to referring all decisions upwards. It is also likely that employees will be consulted as the procedures are developed. Having clear responsibilities and consulting employees about work processes

are also recognised as important pre-requisites for effective OSH management, so there may be some synergistic OSH benefits.

In addition, a QMS or EMS should identify potential causes of product non-conformance, or environmental impacts, some of which present co-incidental risk of injury or illness for employees. Better management of these risks will also improve OSH results. However, QMS in general are weak on 'major hazards' to the business, their effects and contingency planning, whereas consideration of such hazards is an important feature in OSHMS. Also QMS typically do not consider the 'hierarchy of controls' (inherent safety, prevention, control, mitigation) which are an important feature of effective OSHMS risk assessment and management.

An organisation with very strong internal EFQM-based improvement processes and which won a European Quality Award in 2003 nevertheless had a more 'compliance approach' to general health & safety management. Some hazards were managed using exemplary continual improvement systems, but this was not consistent.

Most importantly, a robust OSHMS process is used to systematically identify hazards to people, define and implement effective and efficient controls and ensure residual risks are acceptably low. Other MS may identify some, but not all, OSH hazards.

After an accident investigation, a food industry manufacturer with a strong Hazard Analysis and Critical Control Point (HACCP) process and generally good OSH record was cited by the UK regulator for inconsistent risk assessment. The company strongly disagreed with this finding and sought advice from an experienced OSHMS consultant, who after further investigation concurred with the regulator. The HACCP process identified some, but not all, OSH hazards and the company eventually recognised this. Steps were taken to remedy this defect, and to ensure the resulting additional controls were regularly monitored and reviewed – these minor additions were readily added to the existing HACCP process.

4. CONCLUSIONS

It is clear from the evidence and examples presented in Section 3 that adoption by an organisation of a formal OSHMS or IMS does not in all cases result in long-term, continual improvement of OSH results that such systems are designed to generate (see also section 5.3 below, for a well-known example, from Australia). The overall determining factor is not the quality of the MS model, but how well all its detailed elements are implemented. Key elements in all MS models are planned monitoring (by those responsible) and audit (by others who are independent), leading to senior management review and targeted improvement plans. Effective processes for such regular monitoring, audit and review are vital, but not easy to implement or to maintain, let alone to continually improve.

Those who are implementing high-quality MS almost universally report that external auditors are less effective at identifying improvement opportunities than internal ones. Thus, counter-intuitively, independent Certification of OSHMS does not guarantee continual improvement of OSHMS practices and results – though it does identify organisations not in compliance with minimum standards, and thus not yet ready for Certification. If an enterprise has a real desire for continual OSH improvement, not just compliance with a standard, then external and internal auditors combined are a better option (see Section 3.2) and internal auditors alone are a better way to start (see Section 3.4).

Similarly, attempts to integrate Q-, E- and OSH- Management Systems may, or may not, be beneficial for OSH results, depending how the integration is managed (see examples in Sections 3.5-3.8).

The next Section summarises ten good practices which, if adopted, help to ensure that OSHMS or IMS do lead to continual improvement in OSH results.

5. RECOMMENDED MS PRACTICES

Below are described the ten recommended MS practices to aid continual improvement of OHS results.

When a Q-, OSH- or IMS is appropriately implemented, it can have very beneficial effects on OSH results. This section summarises key findings about what 'appropriate implementation' means, based on the author's experience and also on the survey of MS standards and practices undertaken for this report. Some of these key findings are also referred to in section 3.

5.1 Ensure continual improvement, not assessment to a standard, is the main deliverable

Many organisations, and the people they employ, are more comfortable with the idea of working to fixed standards than of continual changes to business processes so as to give better and better results. Perhaps partly for that reason, even standards such as ISO 9001:2000, which have the concept of continual improvement built-in to their structure, are often not regarded in that light. It is also clear from the survey that MS which start with self-assessment and add external assessment only after MS effectiveness and efficiency begin to improve, are more likely to generate a 'continual improvement culture' from the start (see section 3.4).

5.2 Ensure an effective internal audit process

Evidence from this survey is overwhelming that the reports from well-trained and motivated internal auditors provide more insights and opportunities for improvement than those from external assessors. These will include both effectiveness and efficiency improvements. However, many external stakeholders find it hard to believe that internal audit reports will be open and honest about deficiencies identified, so external audit/assessment may also be required to meet their expectations – external auditors are likely to concentrate on effectiveness, though the best external auditors will also appreciate opportunities for increased efficiency (see sections 3.2 and 3.4).

5.3 Ensure the adopted MS is not overly bureaucratic

Whilst there are many advantages in a systematic approach to OSH management, it is possible to place so much emphasis on the need for adherence to defined procedures that creativity, initiative and the ability to anticipate new or changed hazards and risks become stifled. The emphasis must be on the results, and how effective and efficient the OSHMS or IMS is for continually improving these, rather than on how comprehensive the MS is on paper.

An important area not easily managed via a formal MS is the 'organisational culture', which includes the issue of the extent to which non-compliant behaviour by individuals is, or is not, tolerated.

The explosion and fire at Longford, Australia in 1998 impacted not only people at the facility, but the whole state of Victoria (ref. 29), yet occurred in an organisation with a highly-developed and complex IMS/OSHMS (Operational Integrity Management System – OIMS). Findings of the subsequent Royal Commission included "… *there was a tendency for the administration of OIMS to take on a life of its own, divorced from operations in the field. Indeed, it seemed that in some respects, concentration upon the development and maintenance of the system diverted attention from what was actually happening in the practical functioning of the plants at Longford."* This significant disconnection between documented standards and the operations culture was apparently not high-lighted by the regular OIMS audits and reviews carried out prior to the explosion.

5.4 Use audit teams in preference to individuals

All audits require the use of judgement – about how much evidence to gather, in what form, and how to interpret the balance of that evidence (it will never be 100% consistent). Team audits allow: healthy challenge of individual judgements, thus guarding against undue bias – positive or negative; a broader range of technical and business competence than usually available from an individual; mentoring of less experienced auditors. Teams are particularly valuable for auditing: IMS; large and complex organisations; areas where the findings may have significant business impact, e.g. for high-business-value awards/recognition, including initial assessment against a recognised standard, or when significant non-conformances have been previously identified.

The market pressures on external assessment and Certification services are often such that lone auditors are used extensively. Except for very small organisations, this is not best practice when continual improvement is the primary requirement (see section 3.1).

5.5 Ensure sufficient OSH auditor competence for OSH-MS audits

This may seem obvious. Unfortunately some external assessment bodies do not require their auditors to have any recognised OSH qualifications, or experience. They may have excellent audit skills, but if they are not familiar with hazards and good practice controls in the sector being audited, their reports will have little value (see section 3.1).

When a team is used, it is usually sufficient if one member has these professional skills.

5.6 Ensure external audits build from the internal audit process

External audits typically include a review of the internal audit plan, and key findings. However, closer integration is possible, provided the internal audit process is of high quality. The ultimate goal should be to occasionally merge the audit teams and processes, in place of separate surveillance and re-certification visits (see sections 3.2 and 3.6).

5.7 Ensure value, rather than cost, is the main criteria when selecting external audit/assessment services

This is self-evident when audit is viewed as providing real opportunities for improvement, rather than being just a 'cost of doing business'. Note the experience of the European Quality Award Winner, detailed in the box in section 3.1, and the article on the LRQA website, ref. 32.

5.8 Do not rely on audits (self-assessment or external assessment) as the sole source for improvement ideas

Audit by its nature can take place only occasionally – typically no more than once per year for each part of an organisation. It gives a snapshot of conditions at that time, as judged by a few people, sometimes only one. In contrast, routine internal monitoring of business processes should be much more frequent, is carried out by many people at different levels in the organisation, and will typically result in more detailed information. In addition, there will be occasions when the controls in place fail to prevent a hazard being realised, and the consequences are injury, illness, damage, or a 'near-miss' event. These too are rich sources of data about the OSH-MS – was the hazard identified, if not, why? Were the specified controls in place, if not, why? Are additional controls required? How can they be made most effective and most efficient?

In the organisations interviewed for this report and with the most effective MS, regular management reviews were much more frequent than once per year, and improvement plans were updated perhaps quarterly. Audit results were fed into these reviews, but were not the major source of data.

5.9 Integrate business processes at high-level, not just via linked or common MS Certificates

A true IMS will include integration of: reporting lines for relevant discipline advisors; holistic business risk identification and controls assessment; aligned business processes to manage the various types of risk; internal and external reporting standards which cover all key risks. It is this type of integration which will reveal synergies between Q-, E-, and OSH processes, rather than more superficial integration via a common Certificate, or a single Certification body.

5.10 Chemical businesses should consider 'Responsible Care' as the preferred option when moving to an IMS

RCMS is a mature standard with many supporting tools and processes, operating internationally and likely to require increased international alignment of RC systems from late-2004. It is not a panacea, for example one study suggests that US-based RC participants improved their environmental performance more slowly than non-participants (ref. 33). However changes in safety performance were not studied and changes to the US RC system have since been made (see 2.4). The UK version of RCMS already fully incorporates points 5.1, 5.2, 5.4, 5.5, 5.7, 5.8 and 5.9 (partial) outlined above.

6. ACKNOWLEDGEMENTS

The willingness of organisations, in the chemical industry and beyond, to share their MS experiences is gratefully acknowledged. When interviewed all were guaranteed anonymity, so it is not appropriate to give more details.

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ANNEX

CORE AUDITOR COMPETENCIES

Source – Investors in People website (ref. 21)

Client focus

- Appreciates how an organisation operates in different client sectors
- Tailors approach to align with the client's goals and circumstances
- Respects the client's need for information, commitment and confidentiality
- Is fully aware of the impact of change on an organisation

Credibility/influencing

- Gains respect by operating in a professional and credible manner
- Engenders co-operation by considering the perspective of others
- Handles disagreements or resistance constructively and fairly
- Is confident about own knowledge and ability

Critical reasoning

- Thinks strategically, takes a holistic view of the way forward
- Seeks the right information to analyse a situation and draw sound conclusions
- Generates justifiable alternatives to solve a problem or reach an outcome
- Applies knowledge/experience effectively, yet is open to exploring new ideas

Communication

- Has a written style that is clear and has impact
- Delivers thoughts in straightforward terms, but maintains listener interest
- Listens and responds effectively, checks understanding
- Has a rigorous but impartial questioning style

Planning

- Effectively links objectives and actions to an overall strategy
- Prioritises and schedules to ensure optimum use of time and resource
- Is sufficiently organised and flexible to switch between several ongoing tasks
- Recognises when plans need to be adapted and acts accordingly

Managing relationships

- Adapts personal style to empathise with a whole range of people
- Builds and maintains rapport over sustained periods
- Invites a two-way exchange of information and feedback with others
- Is well received as a team member and as the leader of a team

Drive

- Strives to add value by achieving results in the best way
- Develops self to improve performance
- Remains positive and maintains effort despite setbacks, changes or ambiguities
- Can achieve results through the guided actions of others

Children's Environmental Health Indicators:

A Survey

CHILDREN'S ENVIRONMENTAL HEALTH INDICATORS: A SURVEY

by

Pascale Scapecchi, Environment Directorate, OECD

FOREWORD

In the context of the work undertaken on the economic valuation of children's environmental health, an overview of the current programmes designed to elaborate children's environmental health indicators has been done. The report was written by Pascale Scapecchi under the supervision of the OECD Working Party on National Environmental Policy (WPNEP). It benefited from comments from Nick Johnstone and Myriam Linster (OECD Secretariat), Fiona Gore and Eva Rehfuess (WHO) as well as delegates from WPNEP and from the Working Group on Environmental Information and Outlooks (WGEIO). This report is published under the responsibility of the Secretary-General of the OECD.

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EXECUTIVE SUMMARY

There is an increasing need and demand for environmental health indicators to support and monitor policy on environment and health.

Environmental health indicators can provide clear and concise information on the state of the environment and its potential effects on human health. They represent a useful tool to support policy, particularly environmental policies whose effects may only be detectable many years after their implementation due to their long time horizon.

Environmental health indicators can be of particular relevance to highlight the greater vulnerability of certain populations, such as children or the elderly, and to account for it in public policies related to health and the environment. In particular for children, an intervention in the early stages of life can have lifelong benefits for society as a whole. As such, the development of children's environmental health indicators appears to be essential.

The OECD has a long experience in developing, measuring and using environmental indicators to support public policies.

Given the increasing interest in the effects of the environment on children's health, an overview of existing projects and programmes elaborating children's environmental health indicators would allow for the examination of their consistency with OECD guidelines on the development and measurement of indicators, in order to determine their usefulness for OECD Member countries.

So far, only a few sets of children's environmental health indicators are available. This can be mainly explained by the lack of suitable data. Moreover, the lack of consensus about some key characteristics of indicator sets does not allow for comparability. Reliable environmental health indicators depend upon the existence of well established and definable relationships between environmental conditions and associated health outcomes. These relationships are particularly difficult to establish in the case of children, which does not facilitate the development of indicators.

The level of comparability and transferability of children's environmental health indicators is also currently limited, because of disparities in definitions, methodologies and standards in each country. Despite efforts to achieve a certain level of harmonisation, important gaps still remain with respect to methodological approaches. Further action is therefore needed in order to improve the comparability between these indicators over time and to identify the need for further research and co-operation on data collection and analysis.

Designing children's environmental health indicators is conceptually difficult.

When the "cause-effect" relationships are difficult to establish, as is the case for children, it is recommended to use a framework that allows for "many-to-many" relationships (*i.e.* an environmental pollutant may have several health impacts and a health impact may be generated or

aggravated by several environmental pollutants). In addition, the framework should be as flexible as possible in order to reflect the needs and interests of all stakeholders. The Multiple Exposures-Multiple Effects (MEME) model, developed by the World Health Organisation, has all these characteristics and thus appears to be the most appropriate, relevant and flexible model in the context of children's environmental health.

Specific criteria have to be used to select priority issues of environmental health. The criteria recommended by the OECD for the development of environmental indicators (*e.g.* policy relevance, usefulness, analytical soundness and measurability), seem also relevant for developing children's environmental health indicators. Given empirical evidence of heterogeneity among children populations, children's environmental health indicators should be defined over five broad stages: 0-1 year, 1-5 years, 5-10 years, 10-15 years, and 15-18 years.

According to the MEME framework, children's environmental health indicators should be divided into four categories: context, exposures, health outcomes, and actions. A list of priority areas should be established. The focus should be placed on priority concerns for children's environmental health rather than on actual indicators. For more efficient policy advice, strong links with concerned public health systems should be established.

As children's environmental health indicators constitute an essential tool to carry out comparative analyses and draw lessons from international comparisons, further developmental work is required.

For more information about **Children's environmental health indicators: a survey**, contact: **Pascale Scapecchi,** National Policies Division, Empirical Policy Analysis Unit**,** Environment Directorate, OECD.

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CHILDREN'S ENVIRONMENTAL HEALTH INDICATORS: A SURVEY

There is an increasing need and demand for environmental health indicators, from agencies to practitioners to help support and monitor policy on environment and health. Environmental effects occur on a long time horizon, on long latency times. As a result, the effects of a public intervention may only be detectable many years after undertaking actions. However, action requires clear, concise and reliable information. One way of providing information on the state of the environment and its potential effects on health is in the form of indicators. The development of a set of indicators may represent a useful tool to support policy.

In the case of environmental health, relevant indicators are those representing well-established links between health and the environment. The indicators may not be based on cause-effect relationships. In fact, there are a few established cause-effects relationships related to the health effects of environmental exposure because of the lag time between exposure and health outcome and the difficulty in identifying the dose or timing of exposures which may have occurred many years earlier.

The World Health Organisation (WHO) has identified five environmental health issues for indicator development at the global level, based on global burden of disease, such as respiratory diseases or physical injuries, for children under five at the global level. However, some of these issues may be more or less important in individual regions or countries, and some important regional or national issues may be missing. Moreover, certain populations may be at greater risk to poor health, such as children, those living in poverty, etc. Where, when and how to intervene and how policies aimed at reducing environmental health risks should better reflect the vulnerability of these sub-populations is a key consideration and an important dimension of public policy related to health and the environment. An intervention in the early stages of life can have lifelong benefits for the society as a whole. As such, the development of children's environmental health indicators appears as essential.

Several frameworks have been developed and used to derive environmental health indicators, more particularly for children. They include for example the DPSEEA framework (driving force-pressure-state-exposure-effect-action), the DPSIR framework (driving forces-Pressure-State-Impact-Resources) and the MEME model (Multiple Exposures-Multiple Effects) (Briggs, 2003).

The OECD uses indicators as a tool to support public policies. Together with its member countries it has established a common approach and framework for developing, measuring and using environmental indicators. The objective of this report is to provide an overview of the existing projects and programmes on children's environmental health indicators and examine their consistency with OECD guidelines on the development and measurement of indicators, in order to determine their usefulness to OECD Member countries.

1. Definition of an indicator

An indicator is defined as a parameter, or a value derived from parameters, which points to, provides information about and describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value.

The OECD terminology points to two major functions of indicators:

- They reduce the number of measurements and parameters that normally would be required to give an exact presentation of a situation. As a consequence, the size of an indicator set and the level of detail contained in the set need to be limited. A set with a large number of indicators will tend to clutter the overview it is meant to provide.
- They simplify the communication process by which the results of measurement are provided to the user. Due to this simplification and adaptation to user needs, indicators may not always meet strict scientific demands to demonstrate causal chains. Indicators should therefore be regarded as an expression of "the best knowledge available".

The use of indicators as policy support is commonly associated with economic analysis where economic indicators (such as the GDP or the GNP) have been used for a long time. A set of indicators, when appropriate, provides a simplified but nonetheless generally concise and precise picture of a system. Besides, when interpreted, indicators serve as "evidence" to highlight facts and identify emerging issues that need to be addressed.

Sets of indicators have been developed to evaluate the state of the environment. For instance, in the environmental context, indicators can either represent an issue in a broad sense (*e.g.* heavy metals in urban soils indicate the pattern of toxic pollution in general), or aggregate several pieces of information (*e.g.* a water quality index as a combination of several water quality parameters). The OECD has developed recommendations about design and measurement of environmental indicators, which are presented in what follows.

1.1 OECD's environmental indicators[1]

1.1.1 Background

Over the past 30 years, environmental policies and related activities adopted by OECD Member countries have evolved, largely driven by increased public awareness of environmental issues, their international aspect and their linkages with economic and social issues. Policy priorities have evolved as did the demand for reliable, harmonised and easily understandable information.

This has stimulated the production of environmental information that is more responsive to policy needs and public information requirements. The aim is to further strengthen countries' capacity to monitor and assess environmental conditions and trends so as to increase their accountability and to evaluate how well they are satisfying their domestic objectives and international commitments. In this context, environmental indicators are cost-effective and valuable tools.

Indicators can be used at international and national levels in state of the environment reporting, measurement of environmental performance and reporting on progress towards sustainable development. They can be used at national level in planning, clarifying policy objectives and setting priorities. The OECD work on environmental indicators is designed to:

- Contribute to the harmonisation of individual initiatives of OECD Member countries in the field of environmental indicators by developing a common approach and

[1] Based upon OECD (2003a).

conceptual framework; assist in further development and use of environmental indicators in OECD Member countries; and, promote the exchange of related experience with non-members and other international organisations;

- Support the OECD's policy analysis and evaluation work by developing core sets of reliable, measurable and policy-relevant environmental indicators to:
    - Measure environmental progress and performance,
    - Monitor policy integration, and
    - Allow effective international comparisons.

The OECD work focuses mainly on indicators to be used in national, international and global decision making, yet the approach may also be used to develop indicators at sub-national or ecosystem level. The actual measurement of indicators at these levels is encouraged and lies within the responsibility of individual countries.

The development of harmonised international environmental indicators is done in close co-operation with OECD Member countries. It uses a pragmatic approach, recognising that there is no universal set of indicators; rather, several sets exist, serving several purposes and audiences. OECD work led particular to:

- Agreement on a common conceptual framework, based on a common understanding of concepts and definitions and on the pressure-state-response (PSR) model (see Annex 1);
- Identification of criteria to help in selecting indicators and validating their choice: all indicators are reviewed according to their policy relevance, analytical soundness and measurability;
- Identification and definition of indicators;
- Provision and guidance for the use of indicators in connection with the evaluation of environmental performance, stressing that indicators are only one tool and have to be interpreted in context to acquire their full meaning;
- Agreement to use the OECD approach at national level by adapting it to national circumstances.

Those indicators are a way to monitor the integration of economic and environmental decision making, to analyse environmental policies and to gauge the results.

1.1.2 Functions of environmental indicators

As indicators are used for various purposes, it is necessary to define general criteria for selecting indicators and validating their choice. Three basic criteria are used in OECD work: policy relevance and utility for users, analytical soundness, and measurability.

A) Policy relevance and utility for users

An environmental indicator should:

- Provide a representative picture of environmental conditions, pressures on the environment and society's responses,
- Be simple, easy to interpret and able to show trends over time
- Be responsive to changes in the environment and related human activities,
- Provide a basis for international comparisons,
- Be either national in scope or applicable to regional environmental issues of national significance
- Have a threshold or reference value against which to compare it, so that users can assess the significance of the values associated with it.

B) Analytical soundness

An environmental indicator should:

- Be theoretically founded in technical and scientific terms,
- Be based on international standards and international consensus about its validity,
- Lend itself to being linked to economic models, forecasting and information systems.

C) Measurability

The data required to support the indicator should be:

- Readily available or made available at a reasonable cost/benefit ratio,
- Adequately documented and of known quality,
- Updated at regular intervals in accordance with reliable procedures.

1.1.3 Using environmental indicators

A) Guiding principles

When using environmental indicators in data analysis and evaluation, the OECD and its Member countries apply the following commonly agreed upon principles.

Indicators are not designed to provide a full picture of environmental issues, but rather to help reveal trends and draw attention to phenomena or changes that require further analyses and possible action. Indicators are thus only one tool for evaluation; scientific and policy-oriented interpretation is required for them to acquire their full meaning. They need to be supplemented by other qualitative and scientific information, particularly in explaining driving forces behind indicators changes which form the basis for an assessment. One should also note that some topics do not lend themselves to evaluation by quantitative measures or indicators.

Indicators' relevance varies by country and by context. They must be reported and interpreted in the appropriate context, taking into account countries' different ecological, geographical, social, economic and institutional features.

Most OECD indicators focus on the national level and are designed to be used in an international context. This implies not only nationally aggregated indicators, but also an appropriate level of comparability among countries. There is no single method of standardisation for the comparison of environmental indicators across countries. The outcome of the assessment depends on the chosen denominator (*e.g.* GDP, population, land area) as well as on national definitions and measurement methods. It is therefore appropriate for different denominators to be used in parallel to balance the message conveyed. In some cases, absolute values may be the appropriate measure, for example when international commitments are linked to absolute values. Moreover, the choice of the initial level of an environmental pressure and of the time period considered can affect the interpretation of results, because countries do proceed according to different timetables.

Within a country a greater level of detail or breakdown may be needed, particularly when indicators are to support sub-national or sectoral decision-making. This is important, for example, when dealing with river basin or ecosystem management, when using indicators describing drivers which are relevant at the local level, or when national indicators hide major regional differences. The actual measurement of indicators at these levels is encouraged and lies within the responsibility of individual countries. At these levels, however, comparability problems may be further exacerbated.

B) Measurability and data quality

Measurability issues such as the quality of underlying data are important in the use of environmental indicators, and must be taken into account to avoid misinterpretation. Measurability and data quality vary greatly among individual indicators. Some indicators are immediately measurable, others need additional efforts before they can be published and used. For example, most indicators of societal responses have a shorter history than indicators of environmental pressures and many indicators of environmental conditions, and some are still in development both conceptually and in terms of data availability.

An important criterion affecting the usefulness and relevance of an indicator is the timeless of the underlying data. The interval between the period to which data refer and the date when data are released should be as short as is practicable. Current timeless of environmental data often remains insufficient for policy evaluation or public communication purposes. Unlike some economic data, environmental data lag behind, referring to two or three years (or even more) prior to the current year.

The availability of coherent data over longer periods is essential to keep track of earlier policy measures and to monitor changes over time. To date, the consistency and completeness of time series data vary greatly by issue and by country, and do not often allow a systematic and meaningful presentation of trends over longer periods.

Coherence or comparability among countries and international harmonisation are essential to make data and indicators meaningful for decision making and performance evaluation and for allowing policy makers to make effective international comparisons. Despite significant progress over the past twenty years, differences remain among countries as well as within countries where different information sources often provide different figures on the same item.

Coherence between environmental and economic information systems is essential to establish links between environmental and economic variables, to analyse environmental pressures exerted by different economic sectors and distinguish government responses for those of the business sector or private households. To date, breaking environmental indicators down at sectoral level remains difficult because of different definitions and classifications used. Further

harmonisation work and closer links between accounting work and the development of indicators could help to overcome some of these difficulties.

1.2 OECD's health indicators[2]

The OECD has been publishing health statistics since the mid-1980s. The coverage of its health data files is very wide and for many indicators the series goes back as far as 1960 (OECD, 2003b). Criteria of selection of health indicators include:

- Relevance (to the description of the key aspects of health care systems);
- Sufficient consistency (to enable cross-national comparisons); and,
- Availability (in a significant number of countries).

Qualitative information gives the standard definition of the indicator and, where applicable, identifies any discrepancy between national data and the standard definitions.

The OECD health indicators are classified into ten parts:

1. Health status
2. Health care resources
3. Health care utilisation
4. Expenditures on health
5. Financing and remuneration
6. Social protection
7. Pharmaceutical market
8. Non-medical determinants of health
9. Demographic references
10. Economic references

Health indicators constitute a powerful tool for outcome-oriented policy making (Table 1). In this context, where health policy sets priorities to improve the global health status, health indicators can be used to describe the level of health and the disparities across countries and over time. Health status of a population depends on a great number of factors, often beyond the medical-care system, such as social and economic environment. However, it is not always obvious to determine the direct impact of medical-care system on changes in health status. To address this issue, health indicators should be designed in order to reflect more closely the performance and quality of health-care systems in maintaining or improving health outcomes.

Health indicators can also be used for monitoring population health status. In this context, where factors including social, environmental, and lifestyle factors are crucial, health indicators were usually based on mortality data, such as life expectancy, standardised mortality rates, infant

[2] Based upon OECD (1998).

mortality, and potential years of life lost. These mortality indicators provide useful information for describing the mortality patterns of the population.

Table 1 – Health indicators for outcome-oriented policy making [3]

Health status indicators	
Mortality	• Life Expectancy • Infant Mortality • Standardised Causes of Mortality Rates • Premature Mortality: Potential Years of Life Lost (PYLL)
Morbidity and Quality-of-life • **General Morbidity** • **Disease-Specific Morbidity**	• Perceived health status • Measures of impairment, disability, and handicap • Multi-dimensional health status measures (*e.g.* SF-36, EuroQol, and Health Utility Index) • Prevalence and incidence of diseases
Composite Health Measures (mortality + morbidity)	• Health expectancies (*e.g.* Disability-free life expectancy (DFLE) and Health-adjusted life expectancy (HALE)) • Disability-adjusted Life Years (DALYs)
Indicators of performance of the medical-care system	
Quality of medical care	• Rates of avoidable mortality and morbidity • Survival rates • Rates of effective health-care interventions which play important role in health gain • Rates of adverse events following treatment • Rates of satisfaction with health-care system

However, given the continuing increases of life expectancy and chronic diseases, more information on the non-fatal consequences of diseases is required. To this end, indicators on morbidity and quality of life have been developed. Increased emphasis has been placed on health goals, such as preventing disability, improving physical and mental functioning, and reducing the pain and distress caused by disease. In turn, these emerging concerns have created a demand for better data on the nature, causes, and distribution of diseases in the population and their impact on the well-being and quality of life.

National health surveys provide reliable information on general morbidity (such as perceived health status, disability, physical and mental functioning, and multi-dimensional concepts of health) to measure variations in health status among individuals and populations. However, there is a significant lack of international consensus on the concepts of health and morbidity to be measured, on the methodology and administration of these surveys, making any international comparison extremely difficult, if feasible.

[3] Source: OECD (1998).

At the same time, the role of medical care in determining health outcomes is not easily assessed since many factors outside the medical-care system have a significant impact on health status. Clear and robust links between health status and a specific medical-care intervention could not be determined without conducting multi-variable modelling or randomised controlled trials.

As such, the OECD has undertaken some parallel work to develop a group of indicators where the links between medical-care interventions and health are better established. These measures would prove valuable for monitoring what is being achieved in the medical-care system and health-care policies across OECD Member countries. As presented in OECD (1998), examples of commonly-used performance indicators could include the following:

- Rates of avoidable mortality and morbidity, where there is clear evidence that timely and appropriate medical interventions would either prevent the condition or treat the disease at an early stage.

- Rates of effective health-care interventions which have been proven to have an undisputed and important role in health gain, such as immunisation or breast cancer screening. In these cases, measurement of process – intervention or uptake rates – could be used as a proxy for outcomes.

- Survival rates at a given point in time after an intervention or treatment.

- Rates of adverse health events which can only be a result of health-care interventions, such as hospital-acquired infections or complications in routine surgery.

- Rates of satisfaction with health-care systems.

To proceed with the development of these indicators, a set of selection criteria could include the following characteristics:

- Policy relevance, *i.e.* indicators reflect health problems that are a major concern in most OECD Member countries;

- Consistency, *i.e.* the relationship between medical care intervention and health status is well established;

- Utility, *i.e.* indicators clearly relate to areas involving substantial resources or burden of disease;

- Sensitivity, *i.e.* indicators should be sensitive to quality of care differences.

Applying these criteria could help design a set of health indicators for outcome-oriented policymaking.

While a universal composite health measure could constitute an attractive goal for many, an indicator addressing various types of health problems for any population group is not feasible. Each indicator serves its own purpose and together, they provide a more comprehensive picture of health status in the population than relying on one summary measure. As suggested by Briggs (2003), linked sets of indicators are usually better than single indicators since they can provide a fuller and more robust picture of what is being analysed.

Harmonisation of national indicators of health outcomes is in its infancy. However, there is broad agreement, in particular across OECD countries, on the necessity for a key set of relevant and coherent health indicators to assess and compare country performances and establish sustainable targets for health policy. International co-ordinated efforts need to be made to increase the comparability of health indicators. Mortality and morbidity data provide inputs to develop health indicators to monitor health status and appreciate the effectiveness of health policies and programmes. As such, the development of relevant and comparable mortality and morbidity statistics should be encouraged by collaborating with existing international projects.

In order to construct accurate, relevant and internationally comparable indicators of health, the development of a common and standardised information base of mortality and morbidity data is essential, as outlined in Table 2. Improvement of this core information is the first step to move towards more outcome-oriented policy making.

Table 2 – A framework for data development of selected health indicators[4]

Selected health indicator	Data requirement	Main data sources	Areas to improve
Life expectancy	• No. of deaths by age • Population counts	Death registries	
Potential years of life lost (PYLL)	No. of deaths by age and by causes	Death registries	Ascertainment and classification of the causes of death needs to be improved.
Perceived health status	Self report on one's health	Survey	Survey question needs to be standardised
Prevalence of impairment, disability or handicap	Self report on one's impairment, disability, or handicap	Survey	• Definition of disability and handicap needs to be clarified; • Objective scales need to be developed for measurement; • Survey questions need to be standardised.
Disease prevalence	No. of existing cases of specific diseases	• Hospital and other medical records; • Survey; • Estimates based on incidence.	Methods used in data gathering need to be standardised.
Disease incidence	No. of new cases of specific diseases	Hospital, other medical and administrative records	Methods used in data gathering need to be standardised.
Health expectancies	• No. of deaths by age	• Death registries • Survey	• Definitions of disability, handicap, etc. need to be

[4] Source: OECD (1998).

	• Population counts • Prevalence of disease, disability, handicap, perceived health or multi-dimensional health status. .		clarified. • Methods and questions used in data gathering need to be standardised
Disability-adjusted life expectancy	• No. of deaths by age and cause, • Incidence and duration of specific diseases, • Severity weights	• Death registries • Hospital and other medical records • Survey of preferences of health states using person trade-off method	• Ascertainment and classification of causes of death needs to be improved. • Methods used to gather incidence data needs to be improved. • Weights and discount rates used in calculation need approval

2. Environmental health indicators

2.1 Definitions

As proposed by Corvalán *et al.* (1997), an environmental health indicator may be defined as "*An expression of the link between the environment and human health, targeted at an issue of specific policy or management concern and presented in a form which facilitates interpretation for effective decision-making".*

An environment and health indicator has two major characteristics. Firstly, it should embody a link between environment and health. As such, it is more than either a health indicator or an environmental indicator. The element that turns a simple environmental or health indicator into an environmental health indicator is the knowledge of the relationship between exposure to environmental factors and health effects. Any environment and health indicator must therefore be based on a clear and firm relationship between the environmental hazard and the health effect. The further removed the indicator is from the health effect, the weaker this link is liable to be.

Secondly, an environment and health indicator should be associated with policy. To be effective and useful to decision makers, an environment and health indicator should relate to aspects of environment-related health which are of high relevance to decision makers, understandable by concerned people and amenable to control. As suggested by Corvalán *et al.* (1997), an environmental health indicator should be expressed in terms of the health risk associated with a specific environmental hazard. Indicators should tend to provide a better early warning, both of impending environmental problems and of the effects of intervention.

The main objective of environmental health indicators is to support the decision-making process in environmental health. They are useful for highlighting problems, identifying trends and tracking of policy progress. Information on the local and national health impacts of environmental hazards are made available to decision-makers, environmental health professionals and the community. Data is analysed and converted into valid information presented in a form which facilitates interpretation for effective decision-making, interpreted and acted upon by those responsible for environmental health protection.

The main objective is to gain knowledge about the structure of interdependency between environmental degradation and health risks and to identify vulnerable groups and individuals.

This will offer the possibility to develop strategies for the increasing health impacts associated with environmental degradation and to understand how to promote awareness of these risks. In the end, this would allow to formulate prevention and mitigation strategies for policy makers – to develop and implement an action plan.

Indicators are neither neutral nor non-contextual items. They are targeted at specific policy concern. Like all other forms of information, they depend on the way in which they are designed and the purpose for which they were built. Up to now, only few indicators in existing national sets are directly related to children. Few attempts to develop environmental health indicators have considered children case. As such, they do not serve children well. New indicators are therefore needed that explicitly focus on children's environmental health.

2.2 Frameworks for environmental health indicators

Frameworks are a methodology to describe the relationships between the causes and the impact on a system. In the environmental health context, frameworks are used to describe the linkages between health effects and pollutant concentrations.

Frameworks have been developed to emphasize the level of specificity or desired focus of a specific monitoring programme, and thus the adaptation of the framework is dictated by the goals and objectives of the monitoring exercise. Whether the interest of the monitoring programme is to look at the factors involved in greater detail leading to the pressures (or driving forces in Corvalán *et al.* (1996)) on a system, at the states or responses within the system (*e.g.* external dose, internal dose and effect at different levels), or at actions aimed at reducing negative impacts (*e.g.* government emission control legislation) is determined by the programme goals and its ultimate purpose. The terminology and degree of detail (number of compartments explicitly identified within the phenomenon being studied) developed in the framework also depends upon the programme objectives. The terminology must explicitly be defined in order for the framework to provide helpful tools (specified indicators) in identifying and selecting indicators to retain in a monitoring program.

Identifying vulnerable groups and individuals and gaining knowledge about the collective and individual risk perception and/or risk awareness will form a basis for effective action planning and taking. To this end, frameworks have been designed to develop and derive environmental and health indicators. The choice of a framework constitutes one of the most fundamental questions in developing environment and health indicators.

A conceptual framework for the development and use of environmental health indicators, the so-called DPSEEA-framework was developed. Other frameworks have then been developed to derived children's environmental health indicators, namely the DPSIR framework, and the MEME model. In what follows, we briefly present the frameworks most commonly used for the development of environment-related health indicators.

2.2.1 DPSEEA Framework[5]

The DPSEEA model, endorsed by the WHO to organise its own environmental health indicators, took a broader approach to include macro driving forces in the pressures on health and the environment. DPSEEA stands for Driving forces, Pressures, State, Exposures, Effects, and

[5] Source : WHO (2004a)

Actions. Inspired from the PSR model[6] successfully used for environmental indicators, it has been designed for setting a system of environmental health indicators within the decision making context.

The DPSEEA framework helps understand the interrelationships between the elements of Driving force-Pressure-State-Exposure-Effect-Action and provides a simple way of presenting the indicators themselves. The DPSEAA model (Figure 1) is useful as it covers the full spectrum of potential forces and resulting actions and brings together professionals, practitioners, and managers from both environmental and public health fields to help orient them in the larger scheme of the problem.

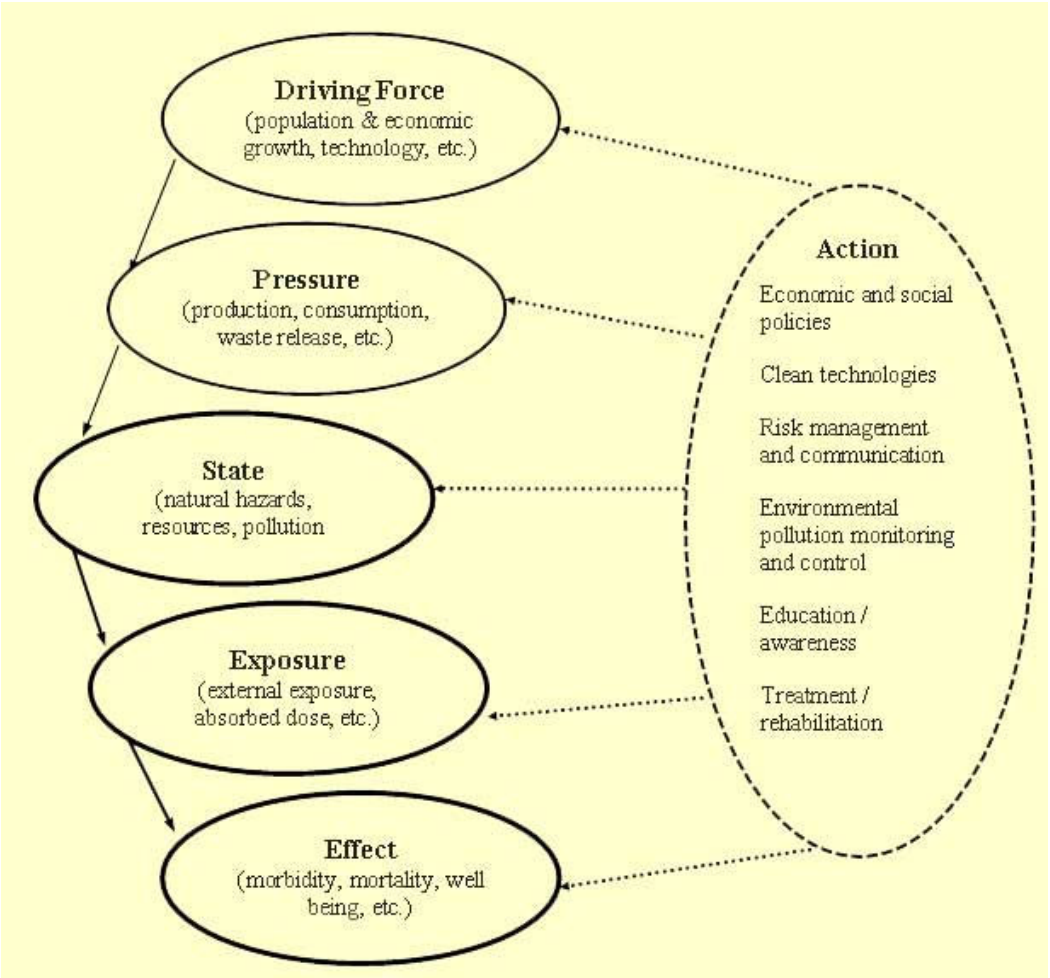
The driving forces (D) component refers to the factors that motivate and push the environmental processes involved. These result in the generation of pressures on the environment (P). In response to the pressures, the state of the environment (S) is often modified. Deterioration in the state of the environment, however, poses risks to human well-being only when there is interplay between people and the hazards in the environment. Exposure (E) is therefore rarely an automatic consequence of the existence of a hazard: it requires that people are present both at the place and at the time that the hazard occurs. Exposure to environmental hazards, in turn, leads to a wide spectrum of health effects (E), which may be acute (associated with short-term exposure) or chronic (associated with long-term exposure). Some hazards may have a rapid effect following exposure, whereas others may require a long time to produce their adverse health effect. The concept of exposure is best developed in relation to pollutants from environmental sources. The amount of the pollutant absorbed, *i.e.* the "dose", depends upon the duration and intensity of the exposure.

In the face of environmental problems and consequent health effects, society may attempt to adopt and implement a range of actions (A). These may take many forms and be targeted at different points within the environment–health continuum. Actions may be taken to reduce or control the hazards concerned, such as by limiting emissions of pollutants or introducing flood control measures. The most effective long-term actions, however, are those that are preventive in approach, aiming at eliminating or reducing the driving forces.

The further down this causal pathway, the more difficult it gets to acquire relevant data. It means that often proxy indicators have to be used (Corvalán, 1998).

[6] For further details on the PSR model, see Annex 1.

Figure 1 – The DPSEEA framework[7]



2.2.2. DPSIR Framework

The DPSIR (Driving forces, Pressure, State, Impact, Response) model is a general framework for organising information about state of the environment. Adopted by the European Environment Agency, in particular for the Environmental Information Systems in Europe, this framework is similar to the DPSEEA model and set environmental health indicators within policy making. Built upon the PSR model (OECD, 1993)[8], the DPSIR framework has also inspired the United-Nations' DSR model (UNCSD, 1996).

[7] Source of the figure: http://www.fep.paho.org/english/env/Indicadores/Page10.asp?Valida=ok

[8] The DPSIR model is a more disaggregated version of the PSR model. For more details on the PSR model, see Annex 1.

The purpose of this framework is to structure data and information on different environmental problems. This conceptual model was originally derived from social studies and then widely applied for organising systems of indicators in the context of environment and, later, sustainable development.

The framework (see Figure 2) assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which are:

- Driving forces of environmental change (*e.g.* industrial production)
- Pressures on the environment (*e.g.* discharges of waste water)
- State of the environment (*e.g.* water quality in rivers and lakes)
- Impacts on population, economy, ecosystems (*e.g.* water unsuitable for drinking)
- Response of the society (*e.g.* watershed protection)

The driving forces (D) are underlying sectoral factors, which lay behind pressures and influence a variety of relevant variables. Examples could include the GDP, the number of cars per inhabitant, and, the total industrial production.

The pressure indicators (P) describe the variables which directly cause (or may cause) environmental problems, such as toxic emissions, CO_2 emissions, noise caused by road traffic, and, the amount of waste produced by scrap cars.

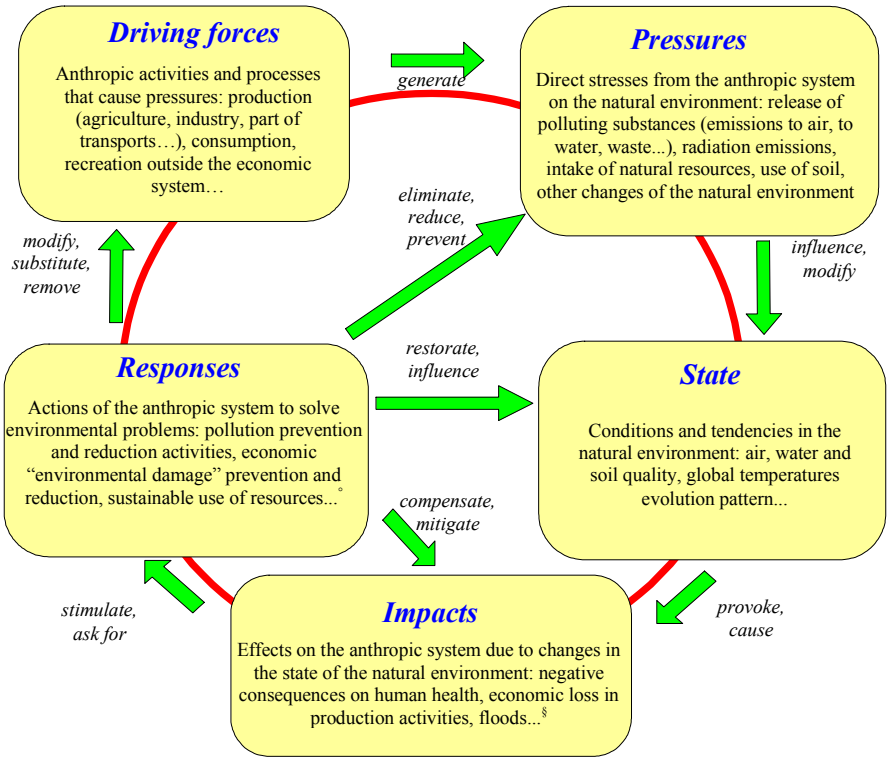
The state indicators (S) provide an indication of the current condition of the environment. Examples could include the concentration of lead in urban areas, the noise levels near main roads, and, the global mean temperature.

The impact indicators (I) describe the ultimate effects of environmental pressures on the state of the environment. The percentage of children suffering from lead-induced health problems, the mortality due to respiratory diseases, and the morbidity cases resulting from lack of sanitation and hygiene constitute good examples of impact indicators.

The response indicators (R) represent the efforts decision-makers undertake to solve – or at least to mitigate – these problems. Examples could include the implementation of cars with catalytic converters, maximum allowed lead level in paints, the pesticide standard rate contained in baby food, and, the revenue coming from pollution levies.

This framework accounts for the fact that increased pressures do not necessarily lead to increased impacts and on the other hand, reduced pressures do not always lead to an enhanced state of the environment. In this sense, the DPSIR model is more analytical than the PSR model.

Figure 2 – The DPSIR model[9]



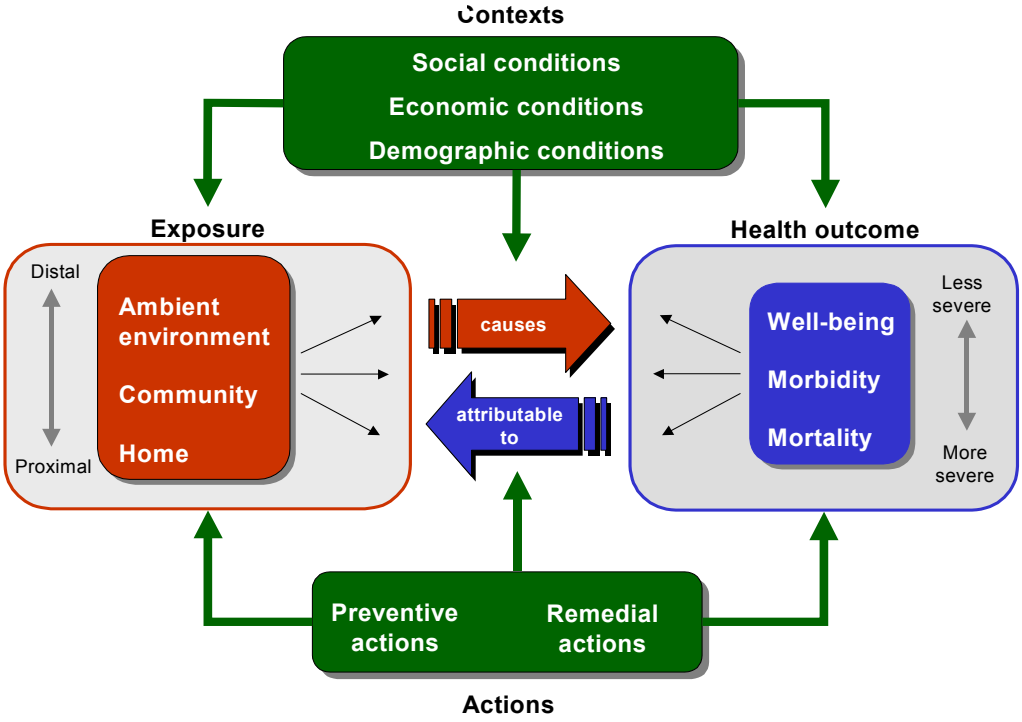
2.2.3 MEME Framework[10]

The Multiple Exposures-Multiple Effects (MEME) model has been developed by the WHO. This framework provides the conceptual and theoretical basis for the development, collection and use of children's environmental health indicators. The model emphasises the complex relationships between environmental exposures and human health outcomes. Individual exposures can lead to many various health outcomes; specific health outcomes can be attributed to many different exposures. Both exposure and health outcomes – as well as associations between them – are affected by contextual conditions, such as social, economic or demographic factors. Beyond identifying these underlying driving forces for children's environmental health problems, information on socio-economic status is important for disaggregating exposure and health information to identify vulnerable groups. Actions can be aimed at reducing exposures or at reducing the severity of health outcomes. The MEME model (see Figure 3) thus describes the four elements required for monitoring children's environmental health: exposure indicators, health outcomes indicators, contextual indicators and action indicators.

[9] Source of the figure: Costantino *et al.* (2003).

[10] Source: Briggs (2003).

Figure 3 – The MEME model[11]



As the model illustrates, one can identify indicators for environmental contaminants, such as pesticide residues, drinking water contaminants, and indoor or outdoor air pollution. Information on specific indicators that monitor the presence of these contaminants, for example in blood, can also be collected. Finally childhood diseases that result from various exposures can also be included in the model.

The MEME model is compatible with the DPSEEA framework, as the MEME model represents both a simplification and an extension of the DPSEEA framework. The main difference between the two methodologies comes from the definition of the state and pressure components. In the DPSEEA framework, it is – in practice – difficult to distinguish from state and pressure components. To avoid this practical difficulty, state, pressure and exposure components have been combined in the MEME model under the general heading of "exposure".

2.3 Limits of these frameworks

The PSR, DPSIR and DPSEEA frameworks are widely used to structure and select environmental health indicators. However, as all models, they do not embrace perfection and are subject to limitations[12].

[11] Source of the figure: http://www.who.int/ceh/indicators/indiconcept/en/

[12] It should be reminded that these models, in particular the PSR and the DPSIR models, have been designed for more general purpose than analysing health and environment relationships. They have been

The first limitation that is common to these models is their unconformity to reality. Models constitute a simplification of reality, a tool serving specific needs. For many of them, in their attempt to simplify the complex associations existing between environment and health, they neglect the "many-to-many" relationship: a single health outcome may derive from many different exposure causes, while several individual hazards lead to a wide range of adverse health impacts. The DPSEEA, the PSR and the DPSIR models are *"too linear"* (Briggs, 2003). In addition, traditional frameworks do not reflect changes and flows occurring in real life, they are *static*. However, it is obvious that each link in the framework is itself dynamic and uncertain. Each step is subject to a wide range of influences and controls. As a consequence, frameworks do not provide basis for an in-depth understanding and analysis of the phenomenon, feedback interactions, and cumulative impacts.

Another major limitation of these three frameworks is that exogenous factors referring to the social and the economic dimensions, such as the policy context, social attitudes and the pre-existing economic infrastructure of the area concerned, are not taken into account in these frameworks. As such, important factors may be omitted in the conceptual model, though they may have a large influence on individuals' susceptibility to environmental risk factors. Neglecting these factors may be seriously misleading and may result in inefficient policy advice. In addition, the DPSEEA, the DPSIR and the PSR models are "partial" models, as they only refer and cover environmental issues

A third limit common to the DPSEEA, the PSR and the DPSIR models is their focus on the anthropogenic causes of environmental degradation and on environmental issues. As such, they may be more relevant for analysing environmental hazards such as air/water/soil pollution, than to establish indicators associated with natural hazards, such as floods, or social/occupational risks.

The weight given to indicators within policy advice is more and more important. Therefore, other representations of the links between environment and health are required, as realistic and as flexible as possible. A reasonable suggestion could be the MEME model. Unlike the traditional models (PSR, DPSIR and DPSEEA), this approach does not try to separate proximal causes of disease (exposures) from distal causes (the state and the pressure components): all these are combined under the general heading of exposures. In the MEME framework, exposures may be measured either more or less directly. In the same way, health effects may be expressed either in mortality or in morbidity terms. It recognises that both exposures and health outcomes may be affected by contextual factors, such as social conditions, demographics or economic development, which may influence the susceptibility of the population to environmental health effects. The MEME model also takes account for the many-to-many relationships between environment and health, meaning that neither environmental nor health indicators can be interpreted in terms of simple and direct relationships.

Based upon these arguments, the MEME framework appears as the most appropriate, relevant and flexible model for developing environmental health indicators even though it shows similarities with the traditional frameworks.

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developed so as to be as simple as possible, to be easily understandable by the users. Therefore, they are not perfectly suited for in-depth analyses of the relationships between health and the environment.

3. Overview of empirical projects

The aforementioned frameworks provide a convenient tool to develop health indicators. They have been applied in various empirical projects for a couple of years to derive children's environmental health indicators. In what follows, we present the main projects undertaken to evaluate children's environmental health indicators. We then discuss how these projects help improve knowledge and promote better practices with respect to the development of children's environmental health indicators.

3.1 Environmental Health Indicators

The HEADLAMP Project[13]

Description: The HEADLAMP (Health and Environment Analysis for Decision-Making) project is a joint UNEP, USEPA and WHO project, which in 1994-1995 proposed methodologies for health risk assessment of environmental health hazards and indicators.

Participating countries: Field studies were conducted in selected developing countries: India, South Africa, Benin, Nicaragua, the Philippines and Chile.

Objectives: The project aims at improving information support for environmental health policies and at bringing valid and useful information on the local and national health impacts of environmental hazards to decision-makers. Based on these characteristics, a framework is proposed for the application of HEADLAMP for managing specific environmental health problems.

Methodology: Following the DPSEEA framework, the project combines methodologies in environmental epidemiology, human exposure assessment and other health and environment sciences to produce and analyse data, to convert these data into valuable and understandable information that can be interpreted and used by those responsible for environmental health protection. Its main tools are linkage methods of health and environment data, the use of environmental health indicators to quantify and monitor the local situation, and the interpretation and translation of resulting information into the decision-making process. The project has three main characteristics which differentiate it from *ad hoc* epidemiological studies: (1) it is based on scientifically established relationships between environmental exposures and health impacts; (2) it uses routinely-collected data, or where necessary, new data collected using low-cost techniques; and (3) it aims at providing information on which to base preventive action against environmental health problems.

Outcomes: The project stimulated the identification and use of local environmental and health indicators for priority setting and decision-making[14].

[13] Indicators derived from this project are not focused on children. However, as it constitutes one of the first projects attempting to develop environment and health indicators, it provides useful insights and should therefore be mentioned. In particular, some indicators developed in this project might have been of particular relevance for other projects directly dealing with children's environmental health indicators.

[14] Further information is available in the publication "Linkage methods for environment and health analysis – General guidelines", document WHO/EHG/95.26 available from the WHO.

The EHIS Project[15]

Description: The environmental health indicator system (EHIS) was developed by the WHO. The indicators and related tools have been developed by an internationally co-ordinated network of experts. 15 WHO Member states, the EEA and EC DG SANCO participate in the WHO-EHIS project.

Participating countries: Albania, Armenia, Bulgaria, Czech Republic, Estonia, Finland, Germany, Hungary, Lithuania, Netherlands, Romania, Slovakia, Spain, Sweden and Switzerland.

Objectives: the EHIS was undertaken to provide a harmonised methodology of integrating environmental and health information.

Methodology: indicators are constructed as interlinked in terms of upstream determinants, environmental risks and health effects, actions according to the DPSEEA framework. A feasibility study was carried out to test data availability, to reach a consensus on a set of "core" indicators. An extended set was also developed with indicators which need further development.

Tools mainly consist of specialised software for uniform collection, processing and exchange of environment and health data.

Specific age groups are not analysed. Indicators are not focused on children. However, some may be of particular relevance (*e.g.* indoor/outdoor air pollution, water pollution).

Selection criteria of indicators were based on:

- Evidence for health-environment links
- Scale and severity of the problem
- Policy relevance
- Evidence for effective interventions
- Possibilities for actions

Outcomes: 10 health-relevant environmental issues were selected in the indicator set[16]:

- Air quality (ambient and indoor)
- Housing
- Traffic
- Noise
- Radiation
- Waste and contaminated lands
- Water and sanitation
- Food safety
- Chemical emergencies
- Workplace conditions

[15] Source: WHO (2004a).

[16] See Annex 2, table A for an overview of EHIS recommended indicators.

The ECOEHIS Project[17]

Description: the ECOEHIS ("Development of Environment and Health Indicators for European Union Countries") was undertaken by the WHO to contribute to the EC health monitoring system. The project is developed in the context of the ECHI project (see below).

It allows for monitoring public health and environmental policies, supporting national and multinational analyses, and facilitating effective decision making related to environmental health risks in the Member States. The project is developed in the context of a broader WHO/Euro project on the establishment of Environmental Health indicator system in Europe. EC DG SANCO also participates in this project.

Participating countries: Austria, Belgium, Denmark, France, Finland, Germany, Italy, Netherlands, Portugal, Spain and Sweden.

Objectives: the main objective of the ECOEHIS project is to develop indicators on environmental health to serve the EC health monitoring system. The project will provide input to the ECHI process of selecting core set of indicators.

Methodology: The ECOEHIS project is based on the previous work undertaken by the WHO on environmental and health indicators. As ECOEHIS is part of the ECHI project, harmonisation of operational definition of selected environment and health diseases with the ECHI set will be realised.

Substantial part of the ECOEHIS project deals with the verification of the environment and health indicators compatibility with the EC legislation (WHO, 2003), to assess applicability and therefore support national policies and actions to reduce adverse health effects in the European Union.

The ECOEHIS scope covers the following areas of public health:

- Housing conditions
- Home and leisure activities
- Transport (road accidents)
- External environment (air pollution, water pollution, radiation and other types of pollution, including noise but excluding food safety)

Some of the topics covered by the ECOEHIS project are relevant for children, such as air pollution (indoor and outdoor) and water pollution. However, specific age groups are not analysed.

Selection criteria for indicators include:

- Policy relevance
- Availability/Feasibility, accessibility and quality of the data
- Evidence for health-environment links

Outcomes: 7 health-relevant environmental issues were selected in the indicator set:

- Air quality

[17] Source: WHO (2004c).

- Noise
- Housing
- Traffic accidents
- Water, sanitation and health
- Chemical emergencies
- Radiation

The ECHI project[18]

Description: The European Community Health Indicator (ECHI) project was undertaken under the European Union Health Monitoring Programme (HMP) aiming at establishing a framework for data collection, exchange and reporting in the field of public health, in order to facilitate the monitoring of trends, differences and policy impact throughout the EU. The OECD and WHO-Europe also participate in this project.

Participating countries: Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain, Sweden and United-Kingdom.

Objectives: the ECHI project has been developed in an attempt to provide a common frame for the construction, selection and classification of EU health indicators, for use at the Community and Member states level.

Methodology: The ECHI framework (Figure 4) defines the areas of data and indicators, following a set of explicit criteria, define generic indicators in these areas and subsets of indicators, only focusing on the medical/physical domain. It is based upon the traditional bio-medical/epidemiological/individual risk factor approach.

As suggested by Figure 4, "Health improvement" is the public objective to be achieved. To this end, "Health Determinants" represent the factors that can be influenced to improve health, and "Health services" constitute the means to achieve this goal.

The choice of these categories has been based on considerations of conceptual coherence, on an optimal consensus among the classification used by other international organisations, as well as on new developments in public health monitoring (Kramers, 2003).

The project also provides guidance on the stratification of data by age, gender and, when data are available, socio-economic status and region. In particular, specific age groups are considered, and more particularly children, such as the specific entries on health and services for both mother and child, which provide indicators on children's health, family structure, etc.

The ECHI project does not rely on clear foundations/theoretical model for its indicator selection. The selection criteria applied in the design of the indicator set included the following characteristics:

- Comprehensiveness and conceptual consistency;
- Taking account of previous work; and,

[18] Source: Kramers (2003), ECHI (2001).

- Coverage of Member States and Community interests.

The proposed indicators are "generic" indicators, what means that their actual operational definitions have not yet been tested. As availability and operationalisation of indicators were not the main focus of the project, indicators do not meet these criteria.

The flexibility appears as the main important characteristic. To this end, the ECHI framework has been emphasised around the definition of "user-windows". These are subsets of the overall indicator list, each of which reflecting a specific user's requirement or interest. This concept allows working with interested-oriented subsets of indicators (e.g. environment and health indicators). For different purposes, different sets of indicators can be examined (health indicators, environment and health indicators). The focus has been placed on ways of building user-windows for the different needs of the EC.

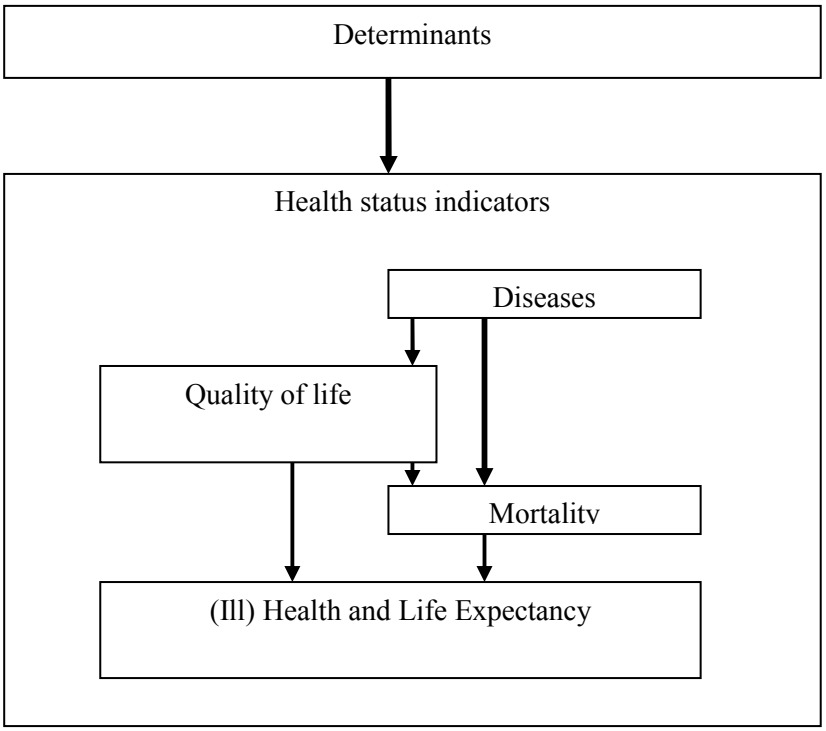
Outcomes[19]: The indicators cover all relevant domains within the field of public health, in particular those defined as priority for the EU Member states. The indicator set underlies on previous work, undertaken by WHO Europe, the OECD and EUROSTAT in this area, and consider the priority areas currently pursued in the Member States and through the Community health policies. This project is being carried out to a large part by other projects within the HMP, which cover specific areas of public health or areas of data collection.

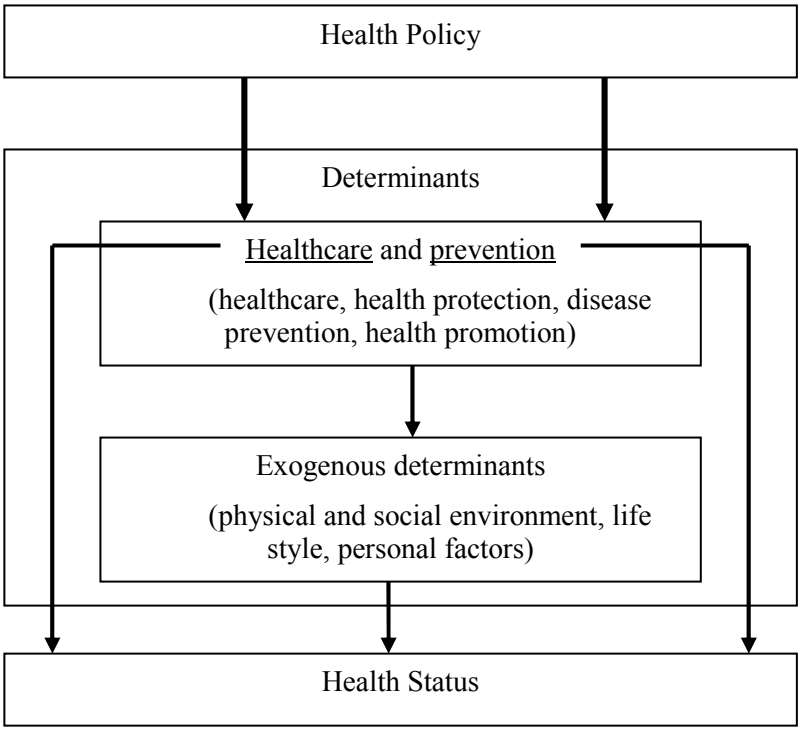
The main categories of the health indicator set are the following:

- Demographic and socio-economic factors
- Health status
- Determinants of health
- Health services and health promotion

[19] See Annex 2, table B for an overview of ECHI recommended indicators.

Figure 4 – The ECHI conceptual scheme





3.2 Children's environmental health indicators

The Child Health Indicators of Life and Development project [20]

Description: The Child Health Indicators of Life and Development (CHILD) project is a third-wave project within the European Community Health Monitoring Programme (HMP) undertaken by the European Commission.

Participating countries: Austria, Belgium, Denmark, France, Finland, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, and the United-Kingdom.

Objectives: The objective of the CHILD project was to examine the issues affecting children's health and development, as well as the preventive and therapeutic services in order to measure and recommend indicators of children's health. In addition, adjustment of current services and policies became another important input of the project.

Methodology: The CHILD project is based on the framework adopted in the ECHI project. The project addresses all aspects of child's health and its determinants. A review of relevant literature was undertaken so as to identify and validate CH indicators. A systematic approach was adopted to identify appropriate indicators and to assemble a composite list.

As exposed in Rigby *et al.* (2003), childhood can be decomposed into different stages, traditionally into age bands of five-year. Each of these stages of childhood has its own health issues, determinants and needs. Therefore, indicators of children's health need to be designed over age groups. Children are defined over five broad stages: 0-1 year, 1-5 years, 5-10 years, 10-15 years, and 15-18 years.

Given empirical evidence that there is a gender differentiation in many aspects of child health, the CHILD project includes analysis of gender, in order to identify whether or not gender bias exists in regard to many health aspects.

A list of intrinsic characteristics required to select relevant indicators includes the following:

- Validity: face validity (ability to measure what is said to be measured), content validity (accounts for the qualities that the definition implies), and construct validity (demonstrates an expected empirical relationship with other related indicators);
- Consistency: reliability in the measurement;
- Sensitivity: can register possible changes;
- Feasibility: available and reliable source data; and,
- Definition: unambiguous in the data construct.

Outcomes[21]: The project has identified 38 core indicators, providing purpose and evidence for each of these. It also identified 17 key health child topics on which further work is required to harmonise indicators across different national settings.

[20] The presentation of the CHILD Project is based upon Rigby et al. (2003).

[21] See Annex 2, table C for an overview of CHILD recommended indicators.

The recommended set of CH indicators covers the following four categories:

- Demographic and socio-economic situation;
- Health status and well-being;
- Determinants of health, risk and protective factors; and,
- Health systems and policy.

The CHILD project allows for the identification of tracer indicators (indicators related to tracer health conditions which will be indicative of other health aspects too, or related to tracer services). One of the most important additional benefits of the CHILD project is the extension of work to adjustment of policies and services related to child health.

Children's health and the environment indicators in North America[22]

Description: The Children's Health and the Environment Indicators in North America (CHEINA) project is the result of an initiative undertaken by the Commission for Environmental Co-operation (CEC) in order to develop children's environmental health indicators for North America.

Participating countries: Canada, Mexico and the United-States.

Objectives: Through the development of children's environmental health indicators, the objectives of CHEINA are three-fold:

- Provide a basis to help policy makers prioritise interventions at national and global level,
- Provide a basis to monitor and evaluate effectiveness of initiatives aimed at reducing environmental health risks to children,
- Provide a template for developing other indicators.

Methodology: The MEME was selected as the model and approach in creating a list of indicators into three topic areas:

- Asthma and respiratory diseases;
- Effects of lead and other toxic substances; and,
- Waterborne diseases.

The recommendations reflect the environment and health indicator model developed by the WHO (Briggs, 2003). The MEME model is recognized as best capturing the complex interactions between the environment and children's health and the flexibility required for preparing the North American children's environmental health indicators set[23].

The following criteria have been applied in selecting indicators:

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[22] Source: CEC (2003).

[23] The priorities of this project are not derived in terms of analysis of the global burden of disease.

- Useful and relevant: each indicator must be related to a specific question or condition of interest that highlights a trend or caution regarding children's health and the environment.
- Scientifically sound and credible: each indicator must be unbiased, reliable, valid, and based upon high-quality data. The methodology for collecting the data should be robust and repeatable. There must be a credible link between the environmental condition that the indicator addresses and the health outcome.
- Appropriateness and availability: as not all countries will be able to report on all selected indicators, countries will choose indicators from the list that are most appropriate and available from their national perspective and based on information that already exists.
- Applicable and understandable: the indicator must be useful for policy-makers and non-expert audience.

Indicators are organised into four categories:

- Context,
- Exposure,
- Health outcome, and,
- Action indicators.

Outcomes[24]: A set of 12 indicators is recommended for children's health and the environment indicators in North America. It covers the four priority areas identified by the CEC Council, which are: asthma and respiratory diseases, effects of lead, effects of exposure to other toxics substances, and water-borne diseases.

The SCALE Project[25]

Description: The SCALE initiative, launched by the European Commission, presents a systematic approach to the development of a European Environment and Health Strategy. It is based on Scientific evidence, focused on Children, meant to raise Awareness, improve the situation by use of Legal instruments and ensure a continual Evaluation of the progress made, hence the name SCALE.

Participating countries: the SCALE project involves Governments of Austria, Belgium, France, Germany, Hungary, Italy, Sweden, The Netherlands, Portugal and Slovenia. International organisations: the WHO, the EEA, European Public Health Association (EUPHA), the European Network for smoking Prevention (ENSP). It also includes EUROFER, the European Confederation of Iron and Steel Industries.

Objectives: The SCALE project aims at assessing the adverse environment-related health impacts in order to provide harmonised methodology and dataset which would serve country needs and would enable international comparisons.

[24] See Annex 2, table D for an overview of recommended indicators.

[25] Source: SCALE (2004).

Methodology: To this end, the project adopts a flexible, country-specific approach allowing for differences and changes in user needs and data availability.

It comprises the build-up of information systems as well as the compilation of adequate political measures. Feasibility studies and data collection will be implemented in accession countries and Member states. Co-operation with other organisations (WHO, EEA, EU) is envisioned, in particular during the data collection.

Indicators are developed for adults and children, at the European scale. The focus is placed on links between physical/chemical/biological factors living environment and health priority diseases (respiratory diseases, neuro-developmental diseases and childhood cancer).

The criteria for selection of indicators are the following:

- relevant: fitness to a purpose
- useful: highlight temporal/spatial trends or provide a warning
- scientifically credible: clear E&H relationship, good quality data
- data-availability & comparability
- understandable

Outcomes: a set of environment and health indicators will be proposed on the following categories:

- Childhood cancer
- Endocrine disruptors
- Respiratory health
- Neurodevelopment

Global Initiative on Children's Environmental Health Indicators[26]

Description: a Global Initiative on children's environmental health indicators (CEHI) was launched at the WSSD in 2002. It represents a global effort (see Partners below) to improve environmental conditions to children. The implementation of this Initiative is lead by the WHO.

Participating countries/Partners: the Global initiative involves Governments of Canada, Italy, Mexico, South Africa, and the United-States. International organisation: the CEC, the OECD, UNICEF, UNEP, and WHO. It also includes non-governmental organisations: the international network on children's health, environment and safety (INCHES); the international society of doctors for the environment (ISDE); and, the physicians for social responsibility (PSR).

Objectives: the objectives of the CEHI Global Initiative are to develop and promote the use of children's environmental health indicators in informing policy makers on the effectiveness of public interventions aiming at improving children's health. This should encourage the assessment of children's environmental health.

[26] Source: WHO (2004b).

Methodology: the MEME model provides the conceptual and theoretical basis for the development, collection and use of children's environmental health. The project builds on previous work undertaken in the area to initiate a series of regional pilot studies on each continent to develop, collect and report children's environmental health indicators. Regional pilots have already started (in 2004) in North America, Latin America and the Caribbean, Europe, the Middle East and Africa.

The selection criteria used for environmental health indicator include the following:

- Scientific validity
  - Credible - i.e. base on a known linkage between environment and health
  - Sensitive to changes in the conditions of interest
  - Consistent and comparable over space and time
  - Robust - i.e. unaffected by minor changes in methodology, scale or data
  - Representative of the conditions and area of concern
  - Accurate - i.e. based on reliable data
  - Scalable - i.e. capable of being used at different scales

- Utility and practicability
  - Relevant to an issue of policy or practical concern
  - Actionable - i.e. related to a condition which is amenable to influence or control
  - Understandable by and acceptable to those at whom it is addressed
  - Timely - i.e. up-to-date
  - Specific - i.e. targeted at an explicit phenomenon or issue
  - Measurable - i.e. base on available data and manageable methods
  - Cost-effective - i.e. capable of being constructed and used at acceptable cost

Outcomes: This project has pre-selected indicators representing the five major causes of illness and death in children under 5, which are[27]:

- Perinatal diseases;
- Respiratory diseases;
- Diarrhoeal diseases;
- Insect-borne diseases; and,
- Physical injuries.

[27] See Annex 2, table E for an overview of CEHI recommended indicators.

Limitations of these projects

All these projects provide considerable and valuable inputs to the development of indicators on children's environmental health. However, many of them present some limitations that should be examined in order to improve the quality of resulting indicators. Two broad categories can be identified: construction issues and measurement issues.

Construction issues

The main deficit common to past and current programmes developing environmental health indicators is related to the differences in indicator definitions and construction, which includes geographical scale, age groups, diagnosis, time periods and selection criteria. This issue increases the difficulty of comparing indicators. Indicators are tools that serve specific needs, what means that each project will provide different indicators according to its own objectives and interests. However, the lack of harmonisation in the definition of indicators and the variation in their national interpretation may be seriously problematic. Further developments are required in order to obtain comparable and reliable information.

The selection criteria used to determine which indicator is appropriate or not are another source of definition/construction disparity. The definition of an indicator contains some criteria for the selection of an indicator in the final set or its reject. However, the selection criteria have not been fully standardised yet. In the literature, a wide array of selection criteria are referred to as a precondition for including an indicator into an indicator set. In the end, all studies seem to use the same criteria, defined differently but basically identical. The criteria most commonly used for the selection of indicators apply OECD recommendations for environmental indicators, meaning that indicator's characteristics include policy relevance, utility, analytical soundness and measurability, as presented in Section 1.

Measurement issues

The differences in the system of data collection between the different countries – and therefore between the various projects – are another major problem. The lack of harmonisation in the methodological approaches does not facilitate the comparison. Further development is required in order to provide comparable information.

Another common result is the lack of data: when data are missing or difficult to collect, inappropriate data may be used instead. There is an obvious lack of socio-demographic data in the data analysis, though lots of data sources are available. Diet, lifestyle, education data are also missing though they could contribute a lot to indicators construction. Appropriate indicators for housing, long-term exposure chemicals, indicators of early effects would also be extremely useful to better understanding these issues and to find efficient way to reduce or mitigate them.

The scarcity of data may also cause problems of reliability and compliance to quality control in using not appropriate or irrelevant environment and health data. Feasibility studies for new indicators would help improve reliance and quality of the data.

The division of information source may also cause problems of technical comparability[28]. It implies data exchange with many holders, which is time consuming and uses more resources than

[28] This issue is not specific to environmental health data but is common to environmental data more generally.

necessary. Centralisation of data could facilitate the development of relevant indicators for environment-related health problems.

Harmonisation of definitions, selection criteria and methodological approaches would constitute an important step forward and would help providing more efficient policy advice. A harmonised set of environment and health indicators would help better understand the health risk associated with specific environmental hazard, and this is even more important when considering indicators on children's health. By enhancing data comparability, it would enable international comparisons and would result in a better use of existing data, taking into account different user needs at different levels (i.e. by developing different subsets or user-windows as in the ECHI project). As a consequence, it will save resources.

In order to avoid duplication of work, future projects (or projects just about to be launched) should account for previous work undertaken in the WHO, the EEA, the EU and the OECD. Even though the associated projects are not perfect and some are not specifically focused on children or on other specific age groups, they provide guidance on the various aspects of the development process of an environment and health indicators set, and highlight difficulties that may be encountered when considering children as well. Mechanisms for co-operation between international agencies should thus be encouraged in order to develop sound children's environmental health indicators.

Concluding remarks

The valuation of the environmental health risks to children requires a better understanding of the relationship between environment and health. To evaluate the state of children's environmental health, sets of indicators are being developed to inform and help policy makers appreciate the effectiveness of current environment and health policies aiming at reducing adverse health effects, thus facilitating priorities setting.

So far, only a few sets of children's environmental health indicators are available. This can be mainly explained by the lack of suitable data. In the meantime, this scarcity may encourage second-best solutions, such as using/transferring available data even though they may not be appropriate. However, developing children's environmental health indicators cannot be based on these sources alone, making new data collection urgently needed.

Moreover, the lack of consensus about some key characteristics of indicator sets does not enable any comparability. Reliable environmental health indicators highly depend upon the existence of well established and definable relationships between environmental conditions and associated health outcomes. Difficulties in establishing these relationships are particularly true for children, which may make the assessment of indicators set difficult.

The range of environmental threats to children's health is quite broad and differences exist among various regions of the world. The level of comparability/transferability of children's environmental health indicators is currently limited, because of disparities in definitions, methodologies and standards in each country. Despite efforts made to achieve a certain level of harmonisation, important gaps still remain with respect to methodological approaches. Efforts need therefore to be made in order to improve the comparability between these indicators over time and to identify the need for further research and co-operation on the data collection and analysis.

Designing children's environmental health indicators: a way forward

The main aspect of the design of children's environmental health indicators is the choice of the **underlying framework**. In the case of environmental health, and more particularly children's

environmental health, the cause-effect relationships are particularly complex to establish, mainly because of the confounding factors and other sources of complex interactions. Unlike traditional frameworks used to elaborate environmental health indicators, the MEME model accounts for the many-to-many relationships between environment and health, thus appearing as the most appropriate, relevant and flexible model in this context.

As the framework is supposed to reflect the needs and interests of involved parties, a flexible approach should be recommended. For example, adjustments should be possible in order to fit country own interests and applied collection data methodology.

Selection criteria are another source of concern. In order to facilitate the "mapping" of policy questions over the indicator set, the issues must relate to aspects of environment and health which are of both relevance to the decision-makers and – directly or indirectly – amenable to control. A number of criteria and evaluations have been used to select priority issues of environmental health concern. However, they are more or less equivalent to those recommended by the OECD (1993) for its work on environmental indicators, namely:

- Policy relevant: fits to a specific purpose
- Usable: highlights temporal/spatial trends or provides a warning
- Analytically sound: clear E&H relationship, good quality data
- Measurable: available and comparable

Empirical evidence suggests existence of heterogeneity among **children populations** (Tamburlini, 2003). As exposed in Rigby *et al.* (2003), childhood can be decomposed into different stages, traditionally into age bands of five-year. Each of these stages of childhood has its own health issues, determinants and needs. Therefore, indicators of children's health need to be designed over age groups, as done in the CEHI Project. Children's environmental health indicators should then be defined over five broad stages: 0-1 year, 1-5 years, 5-10 years, 10-15 years, and 15-18 years.

Given the recommended use of the MEME framework, **children's environmental health indicators should be categorised** as the following:

- Context
- Exposures
- Health outcomes
- Actions

Harmonised agreement on a list of **priority areas** should be pursued. As suggested in SCALE (2004), priority areas could include noise, water, food, housing, air pollution, allergy and asthma, and traffic, since they represent new policy issues in most OECD countries. The focus should be placed on priority children's environmental health concerns rather than on the actual indicators, such as is done in the CHEINA project (in the short term). And, for a more efficient policy advice, strong links with concerned public health systems should be established.

Concerning the lack of suitable data, a good compromise would consist in using existing data and indicators, and further promote data collection to achieve a more harmonised and complete assessment of the state of children's environmental health in the long term, as undertaken in the Global Initiative (INCHES *et al.*, 2002). To this end, the CEHI core set of children's environmental health indicators should constitute the best starting point (see Annex 2 Table E for an overview of CEHI core set of children's environmental health indicators).

Environment and health indicators, and more particularly children's environmental health indicators, constitute an essential tool for related-field researchers and policy advisors in governments, the private sector and the academic community, to carry out comparative analyses and draw lessons from international comparisons. Reliable children's environmental health indicators would help policymakers identify and prioritise the environmental health issues that need to be addressed, evaluate the effectiveness of past and current environment and health policies focused on children, and respond to emerging policy issues (Corvalàn *et al.*, 1997). The development and use of children's environmental health indicators requires further work and remains a priority.

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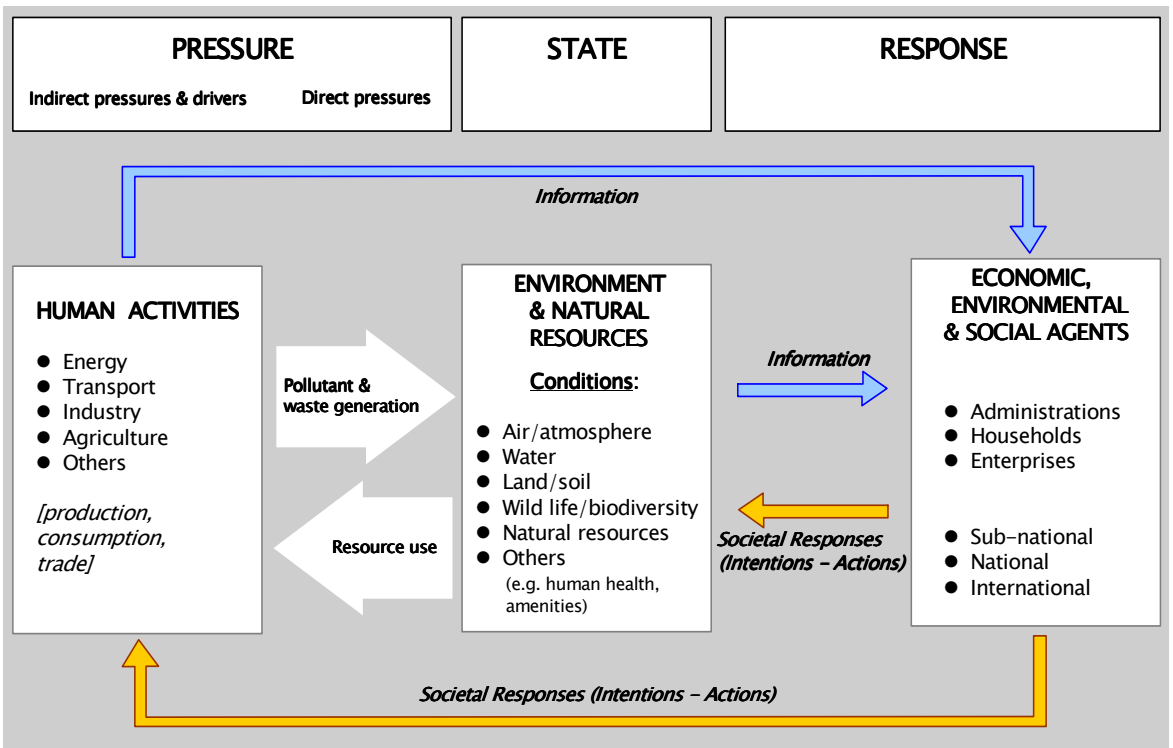
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Annex 1 – The Pressure-State-Response Model

The PSR model has initially been developed by the OECD to structure its work on environmental policies and reporting (e.g. OECD, 1985). It considers that: human activities exert pressures on the environment and affect its quality and the quantity of natural resources ("state"); society responds to these changes through environmental, general economic and sectoral policies and through changes in awareness and behaviour ("societal response").

- The PSR model highlights these cause-effect relationships, and helps decision makers and the public see environmental, economic, and other issues as interconnected. It thus provides a means of selecting and organising indicators (or state of the environment reports) in a way useful for decision-makers and the public, and of ensuring that nothing important has been overlooked.
- The PSR model has the advantage of being one of the easiest frameworks to understand and use, and of being neutral in the sense that it just says which linkages exist, and not whether these have negative or positive impacts. This should however not obscure the view of more complex relationships in ecosystems, and in environment-economy and environment-social interactions.
- Depending on the purpose for which the PSR model is to be used, it can easily be adjusted to account for greater details or for specific features. Examples of adjusted versions are the Driving force - State - Response (DSR) model formerly used by the UNCSD in its work on sustainable development indicators, the framework used for OECD sectoral environmental indicators and the Driving force-Pressure-State-Impact-Response (DPSIR) model used by the EEA.



Environmental pressures describe pressures from human activities exerted on the environment, including natural resources. “Pressures” here cover underlying or indirect pressures (i.e. human activities themselves and trends and patterns of environmental significance) as well as proximate or direct pressures (i.e. the use of resources and the discharge of pollutants and waste materials). Indicators of environmental pressures are closely related to production and consumption patterns; they often reflect emission or resource use intensities, along with related trends and changes over a given period. They can be used to show progress in decoupling economic activities from related environmental pressures, or in meeting national objectives and international commitments (e.g. emission reduction targets).

Environmental conditions relate to the quality of the environment and the quality and quantity of natural resources. As such they reflect the ultimate objective of environmental policies. Indicators of environmental conditions are designed to give an overview of the situation (the state) concerning the environment and its development over time. Examples of indicators of environmental conditions are: concentration of pollutants in environmental media, exceedance of critical loads, population exposure to certain levels of pollution or degraded environmental quality and related effects on health, the status of wildlife and ecosystems and of natural resource stocks. In practice, measuring environmental conditions can be difficult or very costly. Therefore, environmental pressures are often measured instead as a substitute.

Societal responses show the extent to which society responds to environmental concerns. They refer to individual and collective actions and reactions, intended to:

- mitigate, adapt to or prevent human-induced negative effects on the environment;
- halt or reverse environmental damage already inflicted; and,
- preserve and conserve nature and natural resources.

Examples of indicators of societal responses are environmental expenditure, environment-related taxes and subsidies, price structures, market shares of environmentally friendly goods and services, pollution abatement rates, waste recycling rates, enforcement and compliance activities. In practice, indicators mostly relate to abatement and control measures; those showing preventive and integrative measures and actions are more difficult to obtain.

Annex 2 – Overview of recommended environment and health indicators.

Table A – The EHIS project[29]

	Driving Forces	Pressures	State	Exposure	Effects	Actions
Air quality	Road transport fuel Tonne-kilometres Passenger-kilometres	Pollutant emissions to air		Population-weighted urban annual average concentration of: NO_2, PM_{10}, $PM_{2.5}$, SO_2 Distribution of daily O_3	Years of Expected Life Lost (YLL) attributed to long-term exposure to fine particles	Policies on ETS exposure
Noise				Population exposed to noise by sources	Attributable risk for cardiovascular morbidity, mortality Self-reported annoyance and sleep disturbance	National regulations for leisure events Urban/ national action plans EU Noise Directive country enforcement
Housing				Affordability Accessibility Crowding Dampness and mould Radon in dwellings Household hygiene Crime and fear of crime	Extremes of indoor temperature Domestic accidents: injuries and fatalities	
Traffic Accidents			Renewal rate of passenger cars Road accident rates Speed limit exceedences	Time spent on the road Use of vehicle safety devices	Mortality due to transport accidents Potential YLL attributable to traffic accidents Injury rates DALY lost due to traffic	

[29] Source : http://www.who.dk/EHindicators/Indicators/20030528_1

					accidents Mortality due to driving drinking	
Water and Sanitation		Wastewater treatment	Recreational water compliance Drinking water compliance	Safe drinking waters: access to piped regulated water supply	Outbreaks of water-borne diseases	Bathing waters management systems Water safety management
Chemical Emergencies		Industrial facilities under EU 'Seveso II' directive				Government preparedness Land-use planning Active register of chemical incidents
Radiation					Skin cancer incidence	Effective monitoring of radiation activity

Table B – The ECHI project

Source: http://europa.eu.int/comm/health/ph_projects/1998/monitoring/monitoring_project_1998_full_en.htm#8

Class 1: Demography and socioeconomic situation	• Population • Socio-economic factors		
Class 2: **Health Status**	• Mortality	• Life expectancy and related indicators • General mortality • Cause specific mortality	
	• Morbidity	• Morbidity, disease-specific	• Diseases/disorders of large impact • Diseases selected for other reasons
	• Generic health status		
	• Composite measures of health status		
Class 3: **Determinants**	• Personal and biological factors	• Biological risk factors • Personal conditions	
	• Health behaviours	• Substance use • Nutrition • Other health related behaviours	
	• Living and working conditions	• Physical environment	• Outdoor air • Housing • Drinking water supply • Sewage system • Ionising radiation • Noise
		• Working conditions	• Physical workplace exposure • Mental workplace exposure • Accidents related to work • Occupational diseases
		• Social and cultural environment	• Social support • Social isolation/networks

			• Live events
Class 4: **Health systems**	• Prevention, health protection and promotion	• Disease prevention • Health promotion • Health protection	
	• Health care resources	• Facilities • Manpower • Education • Technology	
	• Health care utilisation	• In-patient care utilisation • Out-patient care utilisation • Surgical operations • Medicine use/medical aids	
	• Health expenditures /financing	• Health care system • National expenditures on health • Expenditures on medical services • Medical goods dispended to outpatients • Total health expenditure by age group • Health expenditure by fund source	
	• Health care	• Subjective indicators • Health care process indicators • Health outcomes	

Table C – The CHILD project

Source: http://europa.eu.int/comm/health/ph_projects/2000/monitoring/fp_monitoring_2000_exs_08_en.pdf

Class 1: **Demography and socioeconomic situation** **(upstream health determinants**	• **E**conomic circumstances • Poverty • Parental education • Education attainment • Single parent household • Asylum seeking		
Class 2: **Health status and well-being**	• Mortality	• Total mortality • Selected cause- specific child mortality rates	• Infectious diseases • Congenital malformations • Malignant neoplasm (cancer) • Unintentional injuries (burns, poisoning, transport, drowning, suicide, assault and homicide, perinatal).
	• Morbidity	• Incidence of childhood caner • Incidence of childhood diabetes • Prevalence of asthma • Incidence of specific childhood infectious diseases • Child dental morbidity	
	• Injuries	• Burns • Poisoning • Fractures	
	• Mental health	• Attempted suicide	
	• Mental health (indicators to be developed)	• Child abuse	
	• Mental health (indicators to be developed)	• Behavioural disorders	• Hyperactivity • Conduct disorders • Adolescence depression • Adolescence anxiety • Learning disorders • Educational

			development • Perceived well-being • Permanent or severe disability
Class 3: **Determinants of health, risk and protective factors**	• Parental determinants	• Breastfeeding • Exposure to household environmental tobacco smoke • Parental support	
	• Lifestyle determinants	• Physical activity • Tobacco smoking • Alcohol abuse • Substance misuse	
	• Other health determinant factors	• Overweight/obesity • Children in care • Early school leavers • Pre-primary education enrolment • Air pollution exposure of children	
Class 4: **Health systems and policy**	• Health systems policy		
	• Health systems quality		
	• Social policy indicators		
	• Physical protection policy	• Transportation safety • Protection from exposure to lead • Protection from exposure to potentially hazardous noise • Reduction of exposure to environmental tobacco smoke	
		• Play and leisure (to be developed)	• Access to safe facilities
		• Healthy parenting (to be developed)	• Percentage of children whose parents have attended educational programmes

Table D – The CHEINA project

Source: CEC (2003).

Priority Area	Indicator Name	Type of Measure	Description/Comment
Asthma and Respiratory Disease	Percent of children living in urban areas where air pollution levels exceed relevant air quality standards	Exposure surrogate	Obtainable by cross-referencing air quality data with census data for urban areas. Either national or WHO air quality standards can be used.
	Indoor Air Quality	Exposure surrogate	Measure of children exposed to second-hand smoke in Canada and the US, and biomass fuels in Mexico.
	Prevalence of asthma cases	Effect	Can be the number of children under 18, 14, 5, or a combination of ages. In Canada and US, information is obtained by household surveys. In Mexico, doctors report cases on a diagnosis form.
Effects of Lead and Other Toxic Substances on Children's Health	Blood lead levels (presented by range, e.g., below detectable level; detection limit - 2.5 ug/dl; > 2.5-10 ug/dl; > 10 ug/dl)	Exposure	Although lead may have health effects at lower levels, 10 ug/dl is considered a trigger for medical intervention.
	Children living in homes with a source of lead	Exposure	Sources of lead reflected in the indicators may vary by country, depending on the major sources of concern and data availability.
	Pesticides (body burden, residue levels on food, use or sales)	Exposure	Best measure is body burden, followed by residue levels on food and use data. Sales data is not desirable.
	Pollutant Release and Transfer Register (PRTR) data	Exposure	PRTR data exist in all three countries. These data can highlight releases of a range of chemicals.
Water-borne Diseases and Children's Health	Percent of children (households) served with treated water	Exposure	Counts how many children/ homes/people have access in their home to water piped from a centrally treated system. Alternative indicator could be children (households) without access to treated water.
	Percent of children (households) served with sanitary sewers	Exposure	The percentage of children (households) who have sewage removed from their immediate surroundings will require further discussion and refinement.
	Morbidity (number of childhood illnesses attributed to waterborne disease)	Effect	
	Mortality (number of child deaths attributed to waterborne disease)	Effect	
	Percentage of children served by drinking water systems in violation of local standards	Action	Consider additional criteria, such as systems with <x violations per year, number of days in violation, etc.

Table E – The CEHI Project

Source: Briggs (2003)

	Contexts	Exposures	Health Outcomes	Actions
Perinatal diseases	Children aged 0-14 years being in poverty	Famine risk People living in informal settlements Women of childbearing age who are malnourished Women of childbearing age working in unregulated workplaces Births to mothers living in unsafe or hazardous housing	Perinatal mortality rate Intrauterine growth retardation in newborn children Congenital malformations requiring surgical correction in children under one year of age	Women of childbearing age within one hour's travel of specialist maternity and perinatal care Attributable change in number of households lacking basic services Prevalence of stunting in children aged 0-4 years
Respiratory Diseases	Children aged 0-14 years living in poverty	Children aged 0-14 living in unsafe, unhealthy or hazardous housing Overcrowding Children aged 0-14 years living in proximity to heavily trafficked roads Mean annual exposure of children aged 0-4 years to atmospheric particulate pollution Children aged 0-4 years living in households using biomass fuels or coal as the main source of heating and cooking Children aged 0-14 years living in households in which at least one adult smokes on a regular basis Intrauterine growth retardation in newborn children	Mortality rate for children aged 0-4 years due to acute respiratory illness Morbidity rate for children aged 0-4 years due to acute respiratory illness Prevalence of chronic respiratory illnesses in children aged 0-14 years	Attributable change in tobacco consumption Attributable change in atmospheric pollutant concentrations Attributable change in numbers of households relying on biomass fuels or coal as the main source of heating or cooking
Diarrhoeal diseases	Children aged 0-14 years living in poverty	Drinking water supplies failing national microbiological water quality standards People living in informal settlements Children aged 0-14 years living in disaster-affected	Diarrhoea mortality rate in children aged 0-14 years Diarrhoea morbidity rate in children aged 0-4 years Recurrence rate of outbreaks of diarrhoeal disease among children	Attributable change in the number of households lacking basic services Attributable change in the number of food outlets failing food hygiene standards Children aged 0-4 tears

	Contexts	Exposures	Health Outcomes	Actions
		areas Children aged 0-14 years living households without basic services for water supply, sanitation, and hygiene	aged 0-4 years	able to obtain rehydration therapy within 24 hours of need
Insect-borne diseases	Population growth rate in areas endemic for insect-borne diseases	Total area of insect vector habitats Children aged 0-14 years living in households providing suitable conditions for insect-borne disease transmission Children aged 0-14 years living in areas endemic for insect-borne diseases	Mortality rate of children aged 0-4 years due to insect-borne diseases Prevalence of insect-borne diseases in children aged 0-14 years	At-risk children aged 0-14 years covered by effective, integrated vector control and management systems.
Physical injuries	Children aged 0-14 years living in poverty	Children aged 0-14 years living in disaster-affected areas Children aged 0-14 years living in proximity to heavily trafficked roads Children aged 0-14 years involved in routing employment Children aged 0-14 years living in unsafe, unhealthy or hazardous housing Children aged 0-14 years living in homes lacking access to a piped water supply	Mortality rate of children aged 0-14 years due to physical injuries Incidence of physical injuries to children aged 0-14 years	Children aged 0-14 years living within reach of specialist emergency medical services Attributable change in physical injuries to children aged 0-14 years requiring treatment