Inherently Safer Production, a natural complement to cleaner production

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Summary
Inherent Safety – an approach involving the use of processes and materials with little or no toxicity, flammability or instability – is generally recognized as an important concept in the design of chemical plants. Inspired by the successful development of cleaner production, a feasibility study was conducted for a similar development towards Inherently Safer Production. In four pilot cases carried out in 1997–98, a methodology to generate Inherently Safer technological options was developed and tested. The study indicated that the majority of options had payback times of less than two years, and that Inherently Safer Production was a feasible concept with great potential for simultaneous improvement of safety and economic performance and for integration into cleaner production programmes.

Résumé
La sûreté intrinsèque (qui consiste à utiliser des procédés et matériaux peu ou pas toxiques, inflammables ou instables) est généralement considérée comme un concept important pour la conception des usines de produits chimiques. Devant le succès de la production plus propre, une étude de faisabilité a été menée sur une évolution semblable vers une production intrinsèquement plus sûre. Une méthodologie pour produire des options technologiques intrinsèquement plus sûres a été élaborée et testée dans quatre expérimentations pilotes effectuées en 1997–1998. L’étude montre que la majorité des options étaient amorties en moins de deux ans et que la production intrinsèquement plus sûre était un concept faisable, qui offre un fort potentiel d’amélioration simultanée de la sûreté et des performances économiques, mais aussi d’intégration dans les programmes de production plus propre.

Resumen
La seguridad intrínseca – un concepto que se refiere al uso de procesos y materiales de baja toxicidad, no inflamables o inestables – generalmente es un elemento importante en el diseño de plantas químicas. Alentados por la evolución exitosa del concepto de producción más limpia, se realizó un estudio de factibilidad para desarrollar de manera similar el concepto de Producción Inherentemente más Segura. En 1997–98 se efectuaron cuatro experiencias piloto donde se desarrolló y evaluó una metodología para generar opciones tecnológicas Inherentemente más Seguras. El estudio demostró que la mayoría de las opciones tenía periodos de retorno de inversión de menos de dos años, y que Producción Inherentemente más Segura era un concepto factible con gran potencial para mejorar simultáneamente la seguridad y el rendimiento económico y para la integración con programas de producción más limpia.

Most chemical production involves "transformation" processes, which are inherently complex and tightly coupled. "Normal accidents" are an unavoidable risk of systems with these characteristics (Perrow, 1984). Alternative chemical processes exist that almost completely eliminate the use of highly toxic, volatile, or flammable chemicals. Accidents in these systems result in significantly less harmful chemical reactions or releases. Inherent Safety makes chemical plants also less vulnerable to sabotage and terrorism.

The concept of Inherent Safety is now well known among chemical engineers as a sound set of principles for the design of new facilities and is developed into a vital part of the curricula of engineering schools in several parts of the world. But Inherent Safety is only seldom used to improve existing plants and plays a minor role (if any) in the dominant approaches to safety management. Inherent Safety can and should be used in existing facilities. However, implementation is limited since it is perceived as an engineering function and due to conceptual and institutional barriers of Inherently Safer Technologies (Kletz, 1998). Stimulated by the successful development and dissemination of the concept of cleaner production, a feasibility study has been conducted for a similar development towards Inherently Safer Production.

Inherently Safer Production departs from the conventional notion of safety management. The traditional approach entails identification of hazards of the existing situation in existing production processes, assessment of the associated risks and minimization of these risks. By contrast, the
Inherently Safer Production approach involves the identification of hazards and risks, the search for and evaluation of alternative technological options, and elimination or reduction of hazards by implementing Inherently Safer Technological Options. In both safety management approaches, organizational and human aspects are just as important as technological factors. The Inherently Safer Production approach is, however, more future-oriented and deals more proactively with technological options, while traditional safety management tends to focus on management of the present technology.

**Inspiration from cleaner production approaches**

While replacement of existing production systems with benign chemical or non-chemical processes has conventionally focused on cleaner production, the focus can be expanded to include Inherent Safety.

Inherent Safety is similar to-or a natural extension of--cleaner production. Both address technological aspects and organizational and human factors and attempt to prevent the possibility of harm from accidents or pollution by eliminating the problem at its source. Both typically involve fundamental changes in production technology: substitution of inputs, process redesign and re-engineering, and/or final product reformulation. In order to investigate whether similar approaches used in cleaner production programmes can help identify Inherently Safer Technological Options and whether such options would be economically attractive, a feasibility study has been undertaken.

**The approach**

The methodology comprises a safety analogue of the methodologies in cleaner production demonstration projects and knowledge of Inherent Safety principles. The underlying concept was to encourage firms to prevent accidents and accidental releases by identifying: 1) what changes in the production process to inherently safer inputs, processes, final products and equipment could be made, i.e. Inherent Safety Opportunity Audits (ISOAs), and 2) the specific inherently safer technologies that could be used, i.e. Technology Options Analysis (TOAs). Unlike a hazard, risk, or technology assessment, these techniques seek to identify which Inherently Safer Technologies could be implemented.

The basic design principles to generate Inherently Safer Technological Options can be clustered in several ways (e.g. Bellinger et al., 1996; Klerk, 1998). The four categories adopted from the American Center for Chemical Process Safety (Bellinger et al., 1996) are: Minimize, Substitute, Moderate, and Simplify. A fifth principle of Optimal Plant Layout has been added for the Inherent Safety of logistical activities.

The present approach consists of three phases, each comprising several steps and the use of some specific tools. The present aim is not to prove the value of a blueprint methodology, but rather to develop a methodology that enables a change towards Inherently Safer Production while meeting the needs of industry. Thus, the approach can be customized to suit the needs of the respective pilot companies. Two phases that have been added for evaluation purposes are described briefly below.

The first phase consists of the following: 1) initiating and obtaining commitment from the firm; 2) initial design and preparation; 3) conducting a safety audit; and 4) selecting specific candidate processes or operations within the firm.

The second phase consists of the following: 1) conducting a functional review; 2) developing a specific set of search questions; 3) brainstorming for Inherently Safer Options; 4) constructing an information search process on Inherently Safer Options; 5) identifying prospective Inherently Safer Options; 6) designing a consistent set of systematic changes; 7) carrying out a feasibility study; 8) obtaining commitment from the project team; and 9) providing recommendations to management.

The possibility of introducing new hazards (by the adoption of an alternative technology) has been explicitly considered and evaluated in 6).

Stage three aims at implementation and consists of three steps: facilitating decision-making, preparing implementation, and carrying out the implementation.

The two additional stages (solely for research purposes) are: monitoring and evaluating implementation (monitoring actual design changes and progress in implementation), and case evaluation.

Inherent Safety is broadly defined as comprising the hazards relevant for Process Safety (fire, explosion, runaway reaction, etc.), Occupational Safety, Environmental Safety, Product Safety, Accidents on Occupational Health, Acute Effects on Community Health or Nuisance, and various types of sudden and accidental releases.

**Table 1** Summary of results in terms of (technological) options

<table>
<thead>
<tr>
<th>Locations</th>
<th>Netherlands and Greece</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of options identified</td>
<td>35</td>
</tr>
<tr>
<td>Options implemented during the project (number, percentage)</td>
<td>9 26%</td>
</tr>
<tr>
<td>Options implemented in the Dutch cases (number, percentage, n = 21)</td>
<td>8 38%</td>
</tr>
<tr>
<td>Options implemented in the Greek cases (number, percentage, n = 14)</td>
<td>1 7%</td>
</tr>
<tr>
<td>Average number of options identified per pilot</td>
<td>9</td>
</tr>
<tr>
<td>Economically feasible options (number, percentage)</td>
<td>26 72%</td>
</tr>
<tr>
<td>Options where feasibility was not (yet) fully assessed (number, percentage)</td>
<td>7 19%</td>
</tr>
<tr>
<td>Options that were not economically feasible (number, percentage)</td>
<td>3 8%</td>
</tr>
</tbody>
</table>

**Overall findings**

Does the approach lead to the identification of inherently safer (technological) options that are economically feasible?

Several Inherently Safer Technological Options were identified in all four cases, as well as more traditional safety options (Table 1). The expert role of technologically oriented consultants and an extensive external data search were important in the identification of (especially the more fundamental) options. Three factors seem to have a positive influence: 1) being early in the life cycle (i.e. at the design stage); 2) an on-site cross-functional workshop on the principles of Inherent Safety; and 3) consultations with stakeholders. Many Inherently Safer Options are shown to have short payback periods. In a time of ever-increasing competition, potential economic incentives for Inherent Safety are evident: greater reliability of production, and economic optimization of operability and maintenance of existing installations.

**What are the strengths and weaknesses of the approach?**

Although the method has been useful in all four cases, specific considerations required some changes in the approach, which depended mainly on the life cycle stage of the installation. The enormous effort involved in (re)engineering and construction of a plant is repaid over the course of the project. While commitment of all parties involved is essential for project success, the commitment of the plant operation "owner" is especially crucial. In current installations, the management is primarily interested in improvements that give a return on investment within one to two years.

The company’s capacity for generating, adopting and implementing Inherently Safer Options varied considerably in the four cases. Capacity improvement during the course of the researchers’ intervention was even more varied. In the Dutch cases, capacity was increased by the intensive cooperation between the company’s personnel.
and the consultants/researchers in the pilot processes, especially during the workshops held on Inherently Safer Production and Inherently Safer Technology Options. Several initiatives of the respective action plans specifically addressed the plant's capacity to identify, adopt, and implement (future) Inherently Safer Options, although the options generated in workshops with the firm's personnel were not dramatic examples of Inherently Safer Technologies. Many useful secondary prevention options were also identified. In the Greek cases, the consultants played an important role, which had a very positive influence on the creation of far-reaching inherently safer options. However, the consultants were not able to influence the firm to adopt and implement these options or to involve the firm's personnel. External expertise contributes most to the methodology for the initial audit, brainstorming for improvement options and providing external data for more inherently safer technological options.

Are demonstration projects to stimulate inherently safer production feasible?

This study demonstrates in all four cases that, through application of the approach, substantial progress towards inherent safety and a better safety performance can be realized in economically attractive ways, as shown by the numerous inherently safer technological options identified.

Many options identified were not only economically feasible; the majority had payback times of about one or two years.

Participation of the management and personnel is important in implementing the approach in existing plants. However, a company unaccustomed to analysis and process-related problems solving on inherent safety needs a two-step approach. First, the problem-solving methods are raised so that employees have an opportunity to discuss previous concerns. As participants better understand the framework, a group is formed that can start working on inherently safer options. When the improvement projects are defined and the action plan is approved, the employees engaged in brainstorming options should also be involved in the implementation process. This facilitates understanding of the approach and upsloping of the commitment to inherently safer production. Overall, it may be concluded that demonstration projects to stimulate inherently safer production are feasible in existing plants.

Unexpected early improvements in safety and environmental performance

In the HSSP case, the company struggled prior to the project with several persistent issues of safety, environmental, and quality, which made improvements in these performances easily identifiable. The greatest progress was realized before the identified options were implemented.

Thirteen of the 14 environmental incidents in 1997 happened in the first half of the year before the plant personnel became involved in the project. One accidental release took place in the half year directly thereafter. In the same period similar progress was made in related areas such as product quality.

What accounted for the dramatic improvement in safety soon after the project began, and before the implementation of the identified inherently safer options? Although there is no scientific evidence, it was apparent to the plant's personnel and managers that the first two phases of the methodology were beneficial. This helped them to better understand the process control and related safety problems and to set clear maintenance priorities and to guide investments for incremental technological improvements. Without additional help from the researchers, they adapted several steps from the first phases of the methodology and used them — successfully — to better understand other process control, environmental, and quality problems.

These findings indicate that the interdisciplinary and participatory components in the approach, as developed in the Dutch cases, strengthened the commitment to safety of those involved. It also indicates that the first two phases of our methodology can lead to better communication, cooperation and more fruitful decision-making.

Norway's Environmental Home Guard

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MILJÖHEMVERNERET, or the Environmental Home Guard, was launched in Norway in October 1991. It is a network of individuals (over 100,000 to date), groups, organizations and institutions committed to changing their daily activities in ways that reduce use of natural resources, energy and environmentally harmful substances, minimize waste generation, and protect biodiversity.

EHG activities, targeted towards people aged 25 to 50, concentrate on four main areas:

- providing simple, precise and easily understood information on how to make more environmentally friendly choices in everyday situations as individuals, groups and organizations;
- producing tools for voluntary organizations so as to assist them in involving their members and local clubs in environmental protection;
- recruiting individuals and families in a network made up of people who pledge to start changing their habits;
- helping voluntary associations, institutions, schools, companies, kindergartens and housing cooperatives improve their environmental profile.

The movement aims to mobilize those who have the will to contribute to a better environment but do not feel they have the knowledge or skills to become activists.

Tools for change

The key tool is the Action Plan, a list of suggestions that individuals can follow in everyday life. Prospective participants are asked to choose points for their own personal or family Action Plan. Beginners may start with a few simpler tasks; not everyone wants or has the time to hunt down barrels of toxic waste or study local waste disposal plans in depth.

Other EHG materials and activities that help individuals and collectives change to more environmentally friendly consumption patterns include:

- Green Living, a comprehensive programme for households and consumers that identifies a broad spectrum of practical tasks that can be carried out, with factors such as extent of involvement and method of information access established individually;
- MOREBIBL, a quarterly magazine providing up-to-date information on green alternatives, product analyses, activity reports, and innovative ideas and challenges;
- Greenback, an environmental profile test for households (available online at www.gronguide.no), based on questions relating to nine different areas and resulting in a green score, with brief comments on the household's profile;
- the Action Team, a support network of households that meet frequently to examine their everyday habits and to motivate each other towards a greener life;
- Action at Home, an alternative for households that wish to explore greener solutions without joining groups;
- The Green Guide (www.gronguide.no), a web site with basic information on typical environmental issues and over 500 green solutions (in Norwegian) for households and consumers;
- The Green Line, a national hotline for consumers who seek information about green solutions.

One-off publications are also produced. Examples include The Green Office (published with the Norwegian Society for the Conservation of Nature); Think Locally!, on how organizations can influence local authorities to improve planning and zoning (published with the Norwegian Association of Local Welfare Societies); and Leaving No Trace Behind, a guide for fishing, hunting and hiking (published with the Norwegian Association of Hunters and Anglers).

Around half the municipalities in Norway have used EHG materials and programmes to mobilize citizens for greener living. Businesses also use mate-
For the researchers, the successes in these early stages were somewhat unexpected. This indicates that the first two phases of our methodology can be used as a tool for safety management, and can have considerable value separately, apart from the implementation of the (technological) options identified.

**Combining cleaner production with Inherently Safer Production activities**

The Inherently Safer Production approach presented here is closely related to cleaner production approaches and may be considered the preventative complement of UNEP IE's Emergency Preparedness and Response Programme. For National Cleaner Production Centres it seems a logical extension of their activities, as the methodology for ISP is similar to that of cleaner production.

While National Cleaner Production Centres already have many capabilities that are useful for stimulating Inherently Safer Production, some additional competences and tools are required. Representatives of the Cleaner Production Centres should undergo training in Inherent Safety principles, safety management and the evaluation of the safety impact of technological options. As the latter may require specialized know-how, networking with some relevant information centres is crucial.

Finally, Inherent Safety is not only relevant in improving environmental safety and preventing sudden and accidental releases, but also in improving occupational safety. In this way ISP may be a direct link between environmental activities and a specific set of social preventive activities. This could be regarded as a step further towards sustainable development as it is increasingly acknowledged that policies for sustainable development should integrate environmental, social and economic aspects.

**Recommendations**

Based on the results of this research, we would like to take the opportunity to make the following recommendations to UNEP DTIE and the National Cleaner Production Centres:

- In the present era of rapid technological innovations, safety can no longer be guaranteed only through risk management in existing installations. Especially with a view towards sustainable growth, it is vital that more proactive and future-oriented safety approaches are developed.
- The Inherently Safer Production approach provides new perspectives for more innovative safety initiatives. It opens the way for stimulation programmes to help companies or sectors to voluntarily direct Safety Management towards the identification and implementation of Inherently Safer technological options. Such stimulation programmes could be set up separately, but also as an extension of or integrated with stimulation programmes for cleaner production.
- In major accident hazards policies, e.g. the post-Seveso guidance on the preparation of the safety report, associated with the Post Seveso II Directive (EU 1996a), it is often suggested that firms should adopt Inherent Safety approaches as the preferred strategy over traditional safety measures. This study underlines the need to evaluate whether such policies are successful in developing Inherently Safer industries. The research demonstrates that the Inherently Safer Production approach can be useful in this respect. For UNEP DTIE, the approach presented may form the bridge between its activities to stimulate cleaner production, and its policies to promote emergency preparedness and response. Today UNEP DTIE has no policy to promote preventive approaches to safety, and Inherently Safer Production seems a logical way to do so. In terms of company practice, the approach presented offers a practical and economically attractive tool that may be integrated in the company's SHE (Safety Health and Environment) Management system.
- From the perspective of environmental policies (such as the EU IPPC directive, EU1996b), the present study is relevant in two ways. First, Inherent Safety includes environmental Inherent Safety. We see Inherent Safety as directly complementary to the traditional cleaner production/pollution prevention approaches, which usually neglect sudden and accidental releases. Secondly, the solutions databases that are available or are presently being developed to support the implementation of cleaner production should preferentially promote technological and procedural solutions, and not only administrative and organisational ones.

The EHGs does not mean to imply that all environmental problems can be solved by "shopping green". Many issues require politicians and industry to make the right decisions on behalf of the community, e.g. via legislation, taxation and development of better products.

In Norwegian the activities of the EHGs are called a diagnost - a concept with roots going back many centuries. It means a collective effort, a working activity in which people contribute as volunteers. The EHGs has no local branches, annual meetings, minutes or any of the usual trappings of organizations. The focus is on ad hoc activities and local action.

The EHGs is an attempt to combine the know-how of the environmental movement with the vast networks of traditional voluntary organizations involved in humanitarian, social and cultural issues, of which Norway has many. The country consists largely of many small communities, spread over a large geographical area with low population density. Voluntary work in clubs and associations is an integral cultural factor in such communities.

In general, the EHGs information and activities are characterized by:

- an optimistic approach, pointing towards solutions and better alternatives;
- a touch of humour;
- simple, direct language;
- use of cultural activities and modes of expression (theatre, music, etc.);
- establishment of personal relations with the target population; when people contact the EHGs, they should be met by individuals, not impersonal bureaucrats.

To achieve sustainable consumption through consumer power, the EHGs has outlined a strategy based on six co-ordinated principles:

1. Facilitate greener choices for consumers by providing simple, practical information related to consumption; demand better labelling of products, both general information on contents as well as more specific, independent eco-labelling; and work for a larger choice of greener products at reasonable prices and of acceptable quality.
2. Organize consumers by making them feel they are many individuals thinking and choosing in similar ways; give them the opportunity to commit themselves to start changing their habits and consumption patterns; and ensure that measures are put in place to ensure joint action is chosen so as to maximize campaigns effectiveness.
3. Exert pressure from below and from above. For example, large supermarket chains dominate the market for groceries in most western countries. This means a few individuals decide what choice of products is offered in stores and define desirable product qualities for producers and wholesalers. In such a situation, it is most effective to apply pressure to supermarkets from two different directions: from "below" through individual customers and citizens groups, and from "above" through political pressure and lobbying.
4. Open several fronts. Do not rely only on individuals and families to generate pressure for sustainable consumption. The impact on the market is much greater when many different types of institutions (schools, companies, etc.) make similar demands.
5. Build alliances. Environmental organizations have high levels of expertise on ecological issues, while other voluntary organizations have broad networks and contacts with individuals who may not yet be involved in environmental activities. Through alliances between the green movement and other types of voluntary organizations, many more individuals and families can be mobilized for a greener lifestyle.
6. Follow up with political action (campaigns, lobbying, etc.) to improve the collective systems that can facilitate changes in consumption patterns. Examples are taxation, legislation, bans on toxic products, waste sorting systems, improved recycling systems and new recycling industries, and better public transport. Appeals and information to individuals can be counterproductive if poor collective systems prevent people from effecting change.
nologies that both prevent gradual pollution and are inherently safer. As a second best strategy, similar databases of Inherently Safer Technologies could be developed.

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