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Sustainable chemical regulation in a global environment

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Abstract

The globalisation and unintended impacts of chemicals sets substantial challenges for sustainable development and the protection of natural resources such as land and water. Currently, there are three key chemical Conventions, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal which came into force in 1992, the 1993 Rotterdam Convention on Trade in Dangerous Chemicals and the Stockholm Convention on Persistent Organic Pollutants (POPs) (2004). These Conventions have as common features a mechanism for assessment of chemical safety, a process for the addition of new chemicals to a list of controlled substances and capacity building in developed countries. However, they only cover a small fraction of the chemicals manufactured and traded across the world. Defining effective regulation of chemicals is an on-going debate that has the potential to have a significant impact on vested commercial and political interests. A sustainable chemical industry should take account of evidence-based standards and through legal mechanisms adopt long-term precautionary evaluations rather than short-term market driven decisions. It is argued in this paper that effective international chemical regulation in the future will come from the adoption of sound chemical management and corporate social responsibility, but it recognised that this will face the challenge of economic disparity between countries and the potential export of regulatory risk from big chemical conglomerates to poorly regulated jurisdictions.

Introduction: The Challenge of Regulating Chemicals

This paper considers current international conventions dealing with the trade in chemicals and their limitations; and second suggests possible developments in the international governance of chemicals to support sustainable development and natural resource protection. The role of law in settling the parameters of safety sets challenges for chemical regulation and the effective application of sound chemical management. Effective regulation and sound chemical management have to be at the forefront of creating trust between the citizen and the state an essential component in creating a culture of safety in the chemical industry (Dunleavy, 1985). Chemical regulation requires flexibility in the design, application and enforcement of legal rules, and must engage across jurisdictions and international law. The economic significance of the chemical industry means regulation is likely to be hotly contested and raises the possibility of chemical conglomerates exporting risk to countries with poor regulatory structures and enforcement.

Background: Chemicals in our world

Rachel Carson's landmark book *Silent Spring*, published in 1962, was among the first to raise concerns about the impacts of unregulated chemicals on the environment and humans. Since then the chemicals industry worldwide has evolved rapidly, accounting for a significant proportion of manufacturing and trade with an estimated value of £2 to 2.5 trillion in 2010. The global production of chemicals has reached volumes of over 400 million tonnes annually (Eklund & Karlsson, 2010). Chemical production can be critical to the economic growth of many countries and provides a realistic guide to economic activity. It, also, may be a barometer of a country's development potential.

There has been a shift in the geographical distribution of key chemical manufacturing countries from their 1970's concentration in the industrialised countries of Europe, North America and Japan to newly developed economies. China is amongst the largest producers of chemicals in the world and together with Brazil, India, Indonesia and South Africa accounts for 28% of global chemical production (Tuncak & Ditz, 2013; Broeren, 2014). The diversity of chemicals also has increased over the same period with nearly 8 million substances, which fulfil an array of roles in agricultural, industrial and domestic settings, now available in the market place (Egeghy *et. al.* 2012), Approximately 30,000 of these are widely used with sale volumes at or above 1 tonne per year (Muir & Howard, 2006).

Both manufactured organic and inorganic chemicals find their basis in natural resources. Organic chemicals are often synthesised from raw materials such as crude oil, natural gas and liquefied petroleum gas i.e. butane or propane. These are the starting point for approximately 50% of chemical synthesis with products including polymers e.g. polyethylene and polyvinyl chloride; dyes and pigments; and synthetic rubber. Inorganic chemicals synthesised from natural resources, for example soda ash manufactured from salt brine extracted from inland sources or seawater and limestone which is mined. Other inorganic chemicals, such as titanium dioxide and phosphates are present in mineral ores and mined. The chemical industry undoubtedly acts as an important driver for the extraction of a variety of natural resources found in developing countries and adds to pressures that may result in over-exploitation of limited resources.

Each part of a chemicals life-cycle from production, to commercial use and final disposal can result in environmental exposure and unintended consequences (McEldowney, 2004). The events and costs of the chemical accident at Bhopal in India (Varma & Varma, 2005) are all too familiar. The extent of chemical hazard (an intrinsic feature of the chemical) and the risk of environmental and human exposure (Tarazone *et. al.*, 2014; Egeghy *et.al.*, 2012) vary with chemical. They may be highly toxic and ecotoxic, or they may have chronic exposure effects at low concentrations over prolonged periods of time e.g. endocrine disrupting chemicals (WHO/UNEP, 2013). Manufactured chemicals can be extremely persistent in the environment, may bioaccumulate or biomagnify (Xu *et. al.*, 2013) and may have both short-range and long-range transboundary effects (Smaranda & Gavrilescu, 2008; Wöhmschimmel *et. al.,* 2013). Hazardous chemicals all too commonly affect natural resources. Water bodies, including both freshwater and coastal marine systems are vulnerable from point source pollution arising from waste streams or from diffuse pollution arising from urban and agricultural land (European Environment Agency, 2011; Peters *et. al.*, 2013). In the developing world there is ample evidence of exposure to chemicals in diverse countries and regions including India (Sharma *et. al.*, 2014) and South Asia (Ali *et.al.*, 2014). In China, many chemicals banned in western countries are manufactured and marketed.

Determining the fate, transport and impacts of chemicals often pushes science to the limits of knowledge and unforeseen consequences are not altogether unusual. The relatively recent concern over endocrine disrupting chemicals (EDCs), the so-called hormone mimics, and indeed the number of chemicals that appear to have endocrine disrupting capacity (WHO/UNEP, 2013; Matthiessen & Johnson, 2007) is a good example of the unexpected. Add to this the potential impacts of climate change on chemicals in the environment (Wöhrnschimmel *et.al.*, 2013; Manciocco *et.al.*, 2014) then the desirability of and need for precautionary action to manage chemicals should be high on the international agenda. The trade in chemicals and its control needs to be addressed as a key component of sustainable development and as a fundamental part of protecting scarce natural resources.

Part 1: Chemicals and International Conventions

There are three key chemicals Conventions. The Basel Convention that regulates the export of hazardous chemical waste, the Rotterdam Convention which regulates trade in industrial chemicals and pesticides, and finally the Stockholm Convention that is intended to restrict and ultimately eliminate the production and use of certain organic chemicals based on their persistence and impacts. Both the Basel Convention and the Rotterdam Convention have prior informed consent procedures intended to provide developing countries with sufficient data to make informed decisions about the hazardous waste or the chemical intended for trade. The Rotterdam Convention and the Stockholm Convention have scientific committee procedures for adding chemicals to the list of compounds that fall under the auspices of each Convention. All the Conventions regard technical assistance and capacity building as a key part of their work and put emphasis on training and technology transfer.

Basel Convention

In the 1980's there was growing concern about export of hazardous waste from the industrialised West to Africa, where disposal was poorly regulated (Cobbling, 1992). As a specific response to this the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in 1989 and came into force in 1992 (Basel Convention, 2011). This regulates the transboundary movement and subsequent disposal of hazardous waste, including chemicals if they fall under the Convention's definition of hazardous waste. The Convention covers hazardous waste throughout its life-cycle, from waste generation to transport and final disposal or re-use. This was the first legally binding, international global instrument on hazardous waste (Hackett, 1990; Peiry, 2010; Basel Convention, 2011). There are currently 53 signatories and 180 Parties to the Convention.

A prior informed consent procedure under the Basel Convention ensures the provision of sufficient data to developing countries for informed decisions on the import of chemicals in hazardous waste. This is administratively quite complex and its success relies on the developing country having the economic resources and appropriate infrastructure to implement the procedures of the Convention. The receiving party must also monitor transboundary waste movement and ensure implementation of its decisions. These requirements set substantial challenges for developing countries in terms of cost and human resources (Krueger, 1998). Article 14 of the Basel Convention has established regional and sub-regional centres for training and technology transfer on the management and minimization of hazardous waste. The importance of and necessity for capacity building in developing countries is recognised and there is a growing emphasis of training and technology transfer (Krueger, 2001), in line with other significant chemical conventions (see below). Currently there are 14 autonomous Regional and Coordinating Centres for Capacity Building and Technology Transfer funded by the host country and designed to address specific sub-regional or regional problems and needs. The Convention has also brought a focus on sound chemical management embracing the life-cycle of the waste from waste prevention and minimization to recycling, recovery and final disposal (Krueger, 2001).

The Rotterdam and Stockholm Conventions

The two further key chemical conventions regulate trade in hazardous chemicals and find their basis in the Earth Summit of 1992 (Selin, 2010). Agenda 21 includes two chapters on the management of chemicals and chemical waste (Chapter 19 and 20) for the first time bringing chemicals management together with sustainable development (Tuncak & Ditz, 2013). This laid the basis for two key Conventions involving chemicals (Selin, 2010). The first was the 1993 Rotterdam Convention. This Convention regulates trade in pesticides and industrial chemicals (Rotterdam Convention, 2014) using a prior informed consent scheme. An exporting party is required to receive prior consent from an importing party for substances listed in Annex III to the Convention. The procedure is complex and inevitably sets a challenge for successful implementation and enforcement (McDorman, 2004). The secretariat to the Rotterdam Convention is divided between UNEP Chemicals (industrial chemicals) and FAO (pesticides). Parties to the Convention must inform the Secretariat when they ban or severely restrict a chemical.

The Rotterdam Convention has a mechanism for evaluating and adding chemicals to Annex III through the work of a chemical review committee. The embedding of such a scientific advisory committee at the heart of a multilateral environmental agreement such as the Rotterdam Convention is an inevitable consequence of attempting to manage chemicals internationally. Achieving a suitable make-up in the membership of the Chemical Review Committee is fairly complex and sets a challenge for policy makers, especially when you consider the current 72 signatories and 153 parties to the Convention. Kohler (2006) argues that the membership of scientific advisory committee has to fulfil a number of functions as well as be representative. He notes how policy makers have attempted to ensure that the committee members have at the one time institutional diversity; have relevant expertise while allowing for the input of more indirect know-how; and adequately represent the diversity of stakeholders in terms of the economics, societal influences and geography that defines nations. Given that the membership of the chemicals review committee is limited, negotiating a suitable balance in membership is demanding but pivotal to the operation of the Convention (Kohler, 2006). The scientific advisory committee is crucial in providing a platform for the application of the precautionary principle within the Convention, and a suitably balanced membership is likely to avoid a narrow a techno-scientific approach. Giddings *et. al.* (2002) emphasise the risk of marginalising the social and economic drivers that support sustainable communities through an approach based solely on 'hard' science.

Originally the Convention controlled 27 substances, the list contains 43 hazardous chemicals (or groups of related chemicals) today, 32 of which are pesticides. Four new chemicals (1 pesticide and 3 industrial) were added to Annex III at a Conference of the Parties (COP6) in 2013 and a further 6 are under review by the Chemical Review Committee (Rotterdam Convention, 2014). Under the Rotterdam Convention programmes of work are adopted by the Conference of the Parties, these include a variety of activities that provide technical assistance for specific needs identified by the Parties for sound chemical management. Capacity building is recognised as crucial for the effective implementation of the Convention, however there remains debate about the most effective mechanisms to achieve it. Building effective capacity in international chemicals management is a thorny problem and there are many questions around how best to enhance state, local and NGO ability to implement Convention requirements (VanDeveer & Dabelko, 2001). There undoubtedly has been an increase in regional participation and delivery over recent years particularly through the use of the regional and sub-regional centres established under the Basel and Stockholm Conventions (see below).

The second Convention that finds its basis in the 1992 Earth Summit is the Stockholm Convention on Persistent Organic Pollutants (POPs), which entered into force in 2004. The chemical substances under this Convention are included on the basis of a particular set of environmental characteristics rather than because of their trade or disposal as in the Rotterdam and Basel Conventions. As for industrial chemicals under the Rotterdam Convention, the Secretariat is provided by UNEP Chemicals. The objective of the Stockholm Convention is to restrict or ultimately eliminate the production, use, trade, release and storage of POPs (Stockholm Convention, 2014). This Convention goes beyond the rather limited chemical management underpinning trade in chemicals. It regulates the production, use, trade and ultimate disposal of pesticides and industrial chemicals listed as POPs under the Convention. Essentially this is the first convention to extend controls over the life-cycle of a chemical (Tuncak & Ditz, 2013; Selin, 2010). POP management under the Convention includes establishing technical standards for the control of by-product POPs.

Article 12 of the Convention requires developed countries to provide both technical assistance and also financial resources to aid developing countries to fulfil their obligations under the Convention. There is a focus on training and technology transfer with regional and sub-regional centres intended to support capacity building and the implementation of the Convention. Four of these Centres are in Africa, 5 in Asia and the Pacific, 2 in Central and Eastern Europe, 4 in Latin America and the Caribbean and 1 in Western Europe (Stockholm Convention, 2014). Given that there are currently 152 States as signatories and 179 Parties to the Convention the number of centres dedicated to capacity building is not reassuring. Chemical management is highly technical and relies on the successful interaction of diverse expertise both science and non-science. There are valuable lessons from past and present EU experience. The EU essentially failed in chemical management for many years and even with the development of a new regulatory structure for chemicals across the EU, achieving sustainable and precautionary management of chemicals may still prove to be elusive (McEldowney, 2004; Stokes & Vaughan, 2013). Nevertheless the EU has had some 50 years of experience in chemical regulation and has a well-developed technical, scientific and regulatory expertise as a consequence. Many countries lack this and have little institutional knowledge and technical ability for effective engagement with the Treaty organisations and requirements (Klánová *et. al.,* 2011). Recent chemical regulation in the EU has required substantial capacity building in chemical management at corporate levels and this is likely to be absolutely fundamental to the success of chemical conventions on the international stage and should attract considerably more attention and suppoty.

As with the Rotterdam Convention there is a mechanism for evaluating and including additional chemicals for regulation, with a POPs Review Committee considering evidence on individual chemicals. The concerns over achieving a balanced review committee with appropriate expertise are similar to that of the Rotterdam Convention as are the arguments for its pivotal role in the operation of the Convention (Kohler, 2006). The techno-scientific work of the POPs Review Committee is complicated by the undoubted problems in reaching consistent evaluations of risk and persistence associated with chemicals (Boethling *et. al.*, 2009; Arnot *et. al.*, 2011). Nevertheless the POPs Review Committee, in 2013, recommended that the use of a further 2 chemicals be phased out. Today there are 17 chemicals (or groups of chemicals e.g. PCBs) listed under Annex A for elimination; 2 chemicals (or groups of related chemicals) for restriction under Annex B and 5 chemicals (or groups of related chemicals) for reduction of unintentional releases with the ultimate goal of minimization and if possible elimination under Annex C to the Convention.

The Synergies Process

Science-based standard setting in the regulation of chemicals raises fundamental challenges for implementation that require careful consideration. In recognition of this international chemical management and implementation of the Conventions has been strengthened by the Synergies decisions beginning at the 2008/9 Conference of the Parties to the Basel Convention, Rotterdam Convention and Stockholm Convention. Further decisions strengthening coordination and cooperation were agreed in 2011 and 2013. The overall objective of the ‘synergies process’ is to strengthen coherence in implementation of the three Conventions through providing policy guidance and effective support (Synergies, 2014). The synergies process stretches across the secretariats to the regional and sub-regional centres and focuses on decision-making, organisational and technical issues as well as improving public awareness and information management (Peiry, 2010). The inclusion of regional and sub-regional centres in the process can only help address the knotty problem of capacity building in chemical management.

This more integrated and coherent approach to the institutional arrangements for international management of hazardous chemicals and chemical waste is likely to be beneficial, avoiding replication of effort and strengthening cross-fertilisation of success. The synergies process is undoubtedly a pioneering development in international chemical management (Peiry, 2010). Fundamentally though, international chemical management has a history of development that is reactive e.g. the international response to the export of hazardous waste through the development of the Basel Convention, rather than proactive and forward looking. It is time to examine if the Conventions really fulfil the needs for sound chemical management that should be one of the foundation stones in sustainable economies.

Why is the current framework insufficiently proactive?

Important as the chemical Conventions are they cover only a small fraction of the chemicals manufactured and traded across the world given the estimated 30,000 chemicals sold at volumes of over a tonne (Muir & Howard, 2006) or the 105,000 chemical substances marketed in the EU alone (Stokes & Vaughan, 2013). The objectives are laudable focusing on “protection of human health and the environment” but in a limited form i.e. to specified chemicals or chemical waste. The international application of the precautionary principle is by the nature of the Conventions limited to a few substances and doesn’t appropriately reflect the extent of global production and trade in chemicals. The Conventions were never designed to address all the issues, concerns or impacts raised by chemical production, trade, use and disposal (Tuncak & Ditz, 2013). The introduction of new chemicals under the Rotterdam and Stockholm Conventions is inevitably a slow process and limited in the case of the Stockholm Convention to one group of hazardous chemicals, the POPs. The existing Conventions are not flexible and in reality cannot respond appropriately or sufficiently to new developments in chemical technology or newly identified hazards from chemicals. They do not offer control over the bulk of chemicals as an important part of the jigsaw that makes up sustainable economies based on adequate local, regional and global protection of the environment and human health. Given the all-pervasive nature of chemicals in modern life, a strategic and forward-looking international response to chemicals that is both reflexive and targeted at the corporate culture governing chemicals is overdue. It is in the nature of conventions that they may be too restrictive and insufficiently responsive to changing circumstances.

Part 2: An Improved Regulatory Framework for Sound Chemical Management

The momentum towards adopting a substantive precautionary and sustainable response to chemicals on the international stage is beginning to grow. The World Summit on Sustainable Development in Johannesburg agreed a goal to achieve sound chemical management by 2020 (Tuncak and Ditz, 2013). This has had a disappointing outcome resulting only in the development of a policy framework, the ‘Strategic Approach to International Chemicals Management’ (SAICM). There are five themes to this framework with reducing chemical risk foremost. The remainder of the themes are intended to enable this goal through appropriate governance structures, knowledge and information exchange linked to capacity-building and technical cooperation. All these are recognizable components of existing chemical Conventions and are illustrative of the highly demanding and technical nature of chemical management for regulators and at the corporate level and the need for substantial capacity building in many countries. The establishment of SAICM, however, falls well short of providing acceptable international standards of protection from risks inherent in the life-cycle of traded chemicals. The SAICM (2014), itself, also raises concerns that the absence of a robust system of regulation may encourage illegal international traffic in chemicals.

The existing chemical Conventions essentially are reactive rather than proactive and precuationary. A more precautionary stance in international chemical management would have a number of advantages. It is likely that the environment and communities would have greater protection. Furthermore, avoiding the degeneration of valuable natural resources by chemical exposure would have undoubted economic benefits. There may be other, less obvious advantages. It has been argued that the true application of the precautionary principle on the international stage shifts the burden of scientific uncertainty towards the state. This encourages better co-ordination of policy-making and reinforces multilateral processes such as the chemical Conventions. Precaution tends to underline the importance of international organisations in facilitating and coordinating responses to challenge (Maguire

& Ellis, 2005). It may be that a full application of the precautionary principle strengthens the institutions of the chemical Conventions.

Precaution, prevention and assessment of harm in chemical management

There are a number of international agreements that specifically call for precaution linked to chemicals. The precautionary approach to chemical management is called for in the Stockholm Convention (Preamble, Article 1, Article 8 and Annex C). Agenda 21 of the Earth Summit also calls for a precautionary approach in Chapter 19 on chemicals (and many other chapters). Axiomatic to precaution is preventative action even in the face of scientific uncertainty as stated in Principle 15 of the Rio Declaration. Preventative action linked to chemicals is, of course, multifaceted and should be applied throughout the life-cycle management of chemicals. There are a number of techniques that have been adopted in national and regional e.g. EU, regulation of chemicals that would move international control over chemicals to a more proactive and preventative stance.

The European Union has developed an innovative chemical regulation called REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals), which entered into force in 2007, and is intended to manage risks to humans and the environment posed by manufactured chemicals (European Chemicals Agency, 2006). Under REACH chemicals produced or imported in quantities of 1 tonne or more have to be registered by companies. This registration process for marketing substances in the EU requires the producer or importer to submit a dossier on the chemical considering hazards, potential exposure, uses, downstream users, and risk management measures throughout the life of the substance i.e. from production or import to final disposal. After registration the evaluation of the data is carried out by the European Chemicals Agency established under the REACH. More data can be requested by ECHA or there may be a time-limited authorization of the chemical to be marketed. It is also possible for a chemical to be banned if the risks associated with its use are considered unacceptable (McEldowney, 2004; Hansen *et.al.*, 2007; Fisher, 2008).

A life-cycle approach is familiar territory under REACH and in many national jurisdictions (Hansen *et. al.*, 2007; Fisher, 2008) as well as on the International stage through the Stockholm Convention. This is essentially a cradle-to-grave (i.e. research and development, raw material extraction and processing, manufacturing, transportation and distribution, use, reuse, maintenance, recycling and final disposal) approach to chemical management. Life-cycle chemical management is included in Agenda 21 (Chapter 19 on chemicals and Chapter 20 on hazardous waste). Each stage of the chemicals life-cycle should be assessed for possible hazards and risks to the environment and humans, and management techniques should be put in place to eliminate these or at least minimise risks. This is fundamental to the application of the precautionary principle in sound chemical management.

Another facet of chemical management linked to precaution is that those responsible for production of potentially harmful substances should take on the burden of identifying chemical hazards and risks (Hansen *et. al.*, 2007). This places considerable pressure on company managers and requires appropriate responses throughout the corporate structure. If applied at an international level a transfer of the burden of chemical assessment from State to company has substantial implications. The costs of assessing risks can be significant and would be transferred from States to the producers and downstream users of chemicals. Such a transfer of responsibility and costs formed part of REACH, which shifted information collection and assessment of chemical hazard and risk, previously a responsibility of the State, to producers and importers (Article 5). In the EU it is now for companies to examine the potential for adverse effects throughout a chemicals life on the environment and human health and to provide this information within the technical dossier for registration of the chemical (Articles 10 and 14), which is evaluated by the European Chemicals Agency (McEldowney, 2004; Hansen *et.al.*, 2007; Fisher, 2008).The economic burden of chemical risk assessment was in a sense privatised (Fisher, 2008) moving from the State to companies.

This change in the EU was contentious and highlighted the conflict between applying the precautionary principle and maintaining the competitiveness of the chemical industry that was to take on the burden of costs (Fisher, 2008). The chemical industry is diverse, from large multinationals to small enterprises often involved in producing chemical formulations. In this business environment the problems of transferring costs and potential economic consequences multiply (McEldowney, 2004). The small producer may be particularly vulnerable to cost implications of such a transfer and may lack an appropriate knowledge base to assess chemical hazard and risk. Even more susceptible to these problems are likely to be producers and exporters in developing countries. The key point here, however, is that chemicals marketed in small volumes i.e. under 1 tonne, where human and environmental exposures are likely to be limited do not have the same extensive assessment requirements as large volume chemicals under REACH. This appears to be a key reason why the original fears that REACH would have a disadvantageous economic impact on developing countries exporting to the EU have not been realised (Ackerman *et. al.*,2008). In any case, identifying small volume producers and downstream users is likely to be a considerable challenge. Shifting the burden of assessment down to this level will be a technically and economically significant problem. Transferring assessment to industry for large volume chemicals, however, is currently possible since it involves easily identifiable large manufacturers. Moreover, multinational and large volume producers and exporters of chemicals already bear the costs of REACH if they want access to the large EU market. Once achieved, global control of large volume chemicals will, in itself, be a major innovation and considerable cultural shift for the industry. Success in achieving this is likely to grow regulatory expertise and confidence in individual countries including developing countries, both empowering and facilitating control over smaller producers.

Passing the cost of assessment to large manufacturers may have unintended consequences, however. Companies in highly regulated developed economies may export the regulatory burden to jurisdictions where regulation and enforcement is poor. They may be tempted to transfer their chemical manufacturing to developing economies in order to reduce costs. The trade for such chemicals would be restricted to countries where the regulatory capacity was limited, but this could still be highly profitable. There may even be continued production of chemicals banned in developed economies; there is evidence for this in China at present. The concern about the export of regulatory risk has historical foundation for chemicals. Chemical waste was exported from the highly regulated West, where substantial controls over the safe disposal of hazardous waste were effectively enforced, to African countries with poor implementation and enforcement of environmental regulations (Cobbling, 1992). The Basle Convention came into existence for this reason.

Chemical regulation and innovation in a global market

One of the consequences of successful chemical regulation is to internalise the costs of chemical risks to manufacturers. It has been argued that this is an important driver for innovation in the chemical industry towards safer chemicals (Tuncak, 2013). Further pressure for innovation might come for the need to consider substitution by safer chemical alternatives in risk assessments. Substitution of a chemical may involve two responses the first is the obvious replacement of a hazardous chemical by another that is less hazardous. The second is the adoption of a different technology or product process that may avoid the use of the hazardous chemical entirely (UK Chemicals Stakeholder Forum, 2010; Tuncak & Ditz, 2013).

REACH includes, in the evaluation of chemicals for elimination or risk reduction, consideration of the availability and accessibility of alternatives (along with technical feasibility, economic and environmental/health costs, risk, and efficacy of elimination) (McEldowney, 2004; Fisher, 2008; Tuncak & Ditz, 2013). This has been criticised as insufficiently robust and lacking a truly precautionary stance since substitution is not required if a company can show an overriding socio-economic need for a product (Hansen *et. al.*, 2007; Maxim & Spangenberg, 2009). Substitution is a significant route forward in improving the safety of chemicals (Ahrens *et. al.*, 2006) and a robust requirement for consideration of alternative safer chemicals at the heart of chemical assessments should be a key component of any international control of chemicals. Indeed, it is arguable that interrogating chemical design itself as part of an assessment process might encourage movement towards green chemical design i.e. chemicals and manufacturing processes designed specifically to reduce or ideally eliminate hazards (Tuncak & Ditz, 2013).

There are, however, recognisable barriers to substitution. The ultimate limit to applying a substitution requirement is that there may simply be no alternatives, or limited raw material as a feed stock. There may also be an affect on the competitiveness of a company through higher costs of substitutes arising from a mixture of research and development costs, perhaps costs from new infrastructure requirements and potentially higher production costs (UK Chemicals Stakeholder Forum, 2010). There are, however, a number of factors that favour industry adopting substitution and environment friendly chemical design. Not least are regulatory pressures. The American Chemical Society (2013) underlined the importance of a strong regulatory regime to encourage technological innovation towards safer chemical design. Such regulatory drivers also open market opportunities for companies for innovative products (Ahrens *et. al.* 2006). New products may actually have a competitive advantage through being more efficient or having a better technical performance, they may lower material and production costs and they may simply be more competitive because of public choice (see below). Undoubtedly choosing the right substitution will be a difficult decision making process for a company but the barriers should not be insurmountable and it should be viewed as an opportunity for improving products and business models (UK Chemicals Stakeholder Forum, 2010).

The importance of regulatory pressure to support substitution is clear and should be at the heart of any international chemical regulation. Substitution forms an element of the Stockholm Convention and the Montreal Protocol on ozone depleting compounds. It is not, therefore, unfamiliar territory on the international stage. Agenda 21 in the chemicals chapter 19, recommends both substitution i.e. reducing risk by using safer and non-chemical technologies, and also strengthening research for safe(r) chemicals. Significantly, the international consensus at the basis of the SAICM (2014) also recognises chemical substitution as a key facet in sound chemical management.

Regulatory pressure has an important role in the choices of chemical companies but equally pressure from an informed market place and a concerned public is a substantial driver towards sustainable chemical production and techniques such as chemical substitution (Ahrens *et. al.* 2006; UK Chemicals Stakeholder Forum, 2010). Full access to information on risks and hazards of chemicals and their alternatives for regulators, industry, investors and the public is likely to be highly influential in the future of chemical production across the world (Tuncak, 2013). The availability of information for policy-makers and regulators is, of course, a fundamental part of capacity building, a well-recognised need in the existing chemical Conventions. Another important element is the public availability of information on the safety, management and risks of chemicals (Hilson, 2005; Fisher, 2008). Access to information is also a major component of the precautionary principle (Hansen *et. al.*, 2007). The Synergies process of the three key chemicals Conventions (see above) recognises the fundamental need for public awareness and the availability of information (Peiry, 2010). International chemical classification and labelling criteria were first adopted at the Johannesburg World Summit on Sustainable Development in 2002 (UNECE, 2014a). Harmonization of labelling and safety data sheets was recognised at the summit both as an important mechanism to support the safe use of chemicals and as method to facilitate chemical trade.

Such public availability of information, although crucial, has to be managed carefully. Stokes and Vaughan (2013) point out that the availability of risk assessments on chemicals to the public is of questionable use since they are unlikely to be understandable to the majority. Safety Data Sheets, supplied with chemicals to inform users, have a tendency to become overlong, as more and more precautionary information is included. As a consequence the safety information becomes less user friendly and largely ignored (Stokes & Vaughan, 2013). This actually curtails the use of supplying advice on how to use products safely as part of risk management strategy. Complex data from detailed risk analysis are difficult but not impossible to successfully translate into a usable form for stakeholders and the public. Part of a robust regulatory system should require sufficient, but not overpowering, provision of public information on chemicals. This would ensure proper use of the chemicals and consequent risk mitigation, but would also provide an understandable information set for the public to make informed choices on purchasing products. Consumer pressure, supported by a robust regulatory regime, may be highly influential in driving industry to embrace chemical substitution.

It has been proposed that precautionary and sustainable chemical governance on the global stage is likely to be strengthened not just by public access to information, but also by an active dynamic dialogue between industry, the public and regulators founded on this information (Klinke & Renn, 2010; Stokes & Vaughan, 2013). There is contradictory evidence on whether this is an effective tool that can have a major influence on regulation. A study in 1982 assessing the impact of public participation on control sulphur emissions found that there was no relationship between countries with substantial participation and the stringency of regulation (Knoepfel & Weidne, 1983). It is possible that the influence of dialogue is more subtle and longer term. Public participation may change the nature of the discourse between policy makers and industry influencing the evolution of regulation rather than current regulation. In the context of sound chemical management, availability of information is fundamental to safe chemical use and public dialogue on safety is likely to influence the attitudes of producers and policy makers. It may well also influence regulatory enforcement where this is weak. Such discourse will be most effective if devolved to local regions and based on engagement. Stakeholder and public engagement is an important pillar in environmental matters, clearly reflected in the UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (the Aarhus Convention). The Aarhus Convention has a Protocol on Pollutant Release and Transfer Registers intended to " enhance public access to information through the establishment of coherent, nationwide pollutant release and transfer registers (PRTRs)" (UNECE, 2014b). This is intended to provide publicly available inventories on pollutants, many of which are chemical substances, from industrial sites as well as other sources. Taken together the Convention and its Protocol provide a framework for public engagement supporting sustainable development goals. Such provision of information exposes companies to public scrutiny and puts them under pressure to reduce pollution. The marginalisation of communities because of narrow techno-scientific approaches to precaution and sustainable development (Giddings *et. al.*, 2002) may in part be mitigated by such transparency.

Conclusion

Standard setting in the chemical industry illustrates the regulatory challenges and opportunities in our contemporary globalised world. Regulation of chemicals is necessarily a matter of international concern as its reach transcends national boundaries. The chemical industry has significant economic value for many countries with large numbers and volumes of chemicals traded internationally. In effect regulation has to reach beyond the boundaries of individual countries. Setting standards for chemicals through application of risk assessment and the precautionary principle establishes the parameters of the regulatory discourse. One of the lessons, however, of chemical regulation is that science led, evidence based regulation can be adopted despite vested interest and political lobbying. Sceptics, however, may complain that the outcome is to set unrealistic standards that are almost impossible to enforce and are largely unattainable, especially in many developing countries. Ultimately becoming exploitative of the weaker bargaining position of poorer countries. There is no doubt that the technical complexity of chemical regulation has left developing countries particularly vulnerable to exploitation. The Basel Convention was designed specifically to address this vulnerability in hazardous waste disposal and together with the Rotterdam Convention and the Stockholm Convention works to deliver capacity building in chemical management in developing regions. Much more should be done in this regard with continued investment in the knowledge and technical capacity of developing economies.

Weak regulatory governance structures with poor infrastructures will inevitably struggle to meet the challenges involved. The outcomes may well disappoint with apparently little achieved (Stokes & Vaughan, 2013). Yet, there is growing international recognition that it is important to adopt a comprehensive strategy for sound chemical management (SAICM, 2014) and an acknowledgement that the current international governance of chemicals is insufficiently robust (Krueger & Selin, 2002; Tuncak & Ditz, 2013). Developed economies such as the EU have pioneered this regulatory area and despite shortcomings there is considerable potential for their regulatory stance to influence the global chemical market and feed into international chemical initiatives e.g. OECD's chemical safety and biosafety programmes (OECD, 2013).

The current Conventions undoubtedly have brought significant improvement in international chemical regulation. The use of the prior informed consent procedures by the Rotterdam and Basel Conventions allow a country receiving a chemical waste or involved in chemical trade to make informed choices based on data. The Stockholm Convention has introduced whole life-cycle chemical management to international regulation, albeit for one specific group of compounds. All the Conventions work, increasingly together, on capacity building in developing countries through training and technology transfer. However, even taken together the three Conventions are insufficiently precautionary, they are limited to regulating a small part of a chemical life-cycle and they do not cover the vast majority of chemicals currently on the market place. Sound chemical management has not attracted the priority it deserves on the international stage, and has still to enter the normative discourse of many countries especially in the developing economies. This is because of the lobbying by vested interests as much as the complexity of the problem. The argument, however, that sound chemical management through the application of the precautionary principle is an important pillar of sustainable development remains unanswerable. A new legally binding treaty for sound chemical management, or the adaptation of an existing Convention, that incorporates cradle to grave management of chemicals has much to recommend it. In tandem with an inevitably techno-scientific approach of chemical regulation, an emphasis on stakeholder and public engagement would promote and strengthen sustainability in chemical management by opening industry and indeed the regulators to public scrutiny and pressure.

The climate change negotiations, finalised in Paris in 2015, set the scene for future policy making. There is ample evidence of the conflicts and attempts to obfuscate that come from the different normative positions of states. The politics of values, regulation, and perceived commercial interest make a heady mix for debate (Fisher, 2008), but ultimately the economic interest of states must be to protect scarce resources. Chemical manufacture has the potential for profound and long-term impacts on natural resources through over exploitation or pollution, which has consequences for the environment, humans and on future generations. Their regulation should form a significant part of sustainable development across the world.

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