Chapter 2
The Nature and Extent of Site Contamination

2.1 Introduction

During the 1970s and 1980s, a number of serious site contamination cases brought the issue to the attention of the public and lawmakers in a handful of countries, such as the United States, Japan and the Netherlands (see, e.g., Okubo and Yagi 1998). Interim regulations were promptly enacted in response to these politically sensitive incidents, followed a few years later by more detailed legislation on site contamination and liability for remediation. The international reporting of such high profile incidents, and an increase in general public concern about site contamination on the domestic scene, motivated other countries to introduce legislation of their own.

Developed countries have begun collating and analysing national data on site contamination, with some also compiling publicly accessible site registers. Whilst site contamination was at first perceived in terms of relatively rare incidents (Nathanail and Bardos 2004:1), it is now recognised as a problem capable of affecting large sections of the population in a range of different ways. A wealth of practical experience is being gained and exchanged in all aspects of site management around the developed world, and scientific research is contributing to a far greater understanding of the issue.

By contrast, there is little or no understanding of the issue in many developing countries (Fowler 2007: 3; United States International Trade Commission 2004: 2–6). This generally reflects a domestic situation where the issues of poverty and poor health understandably take priority over less visible and direct problems, such as environmental harm. The subordination of environmental concerns to economic and health priorities was evident in economies in transition in the late 1990s (Boyd 1999: 3–5). However, an effort began in 2009 to compile a global inventory of contaminated sites, with an emphasis on developing countries (Blacksmith Institute 2012a), to help overcome the lack of public awareness of the issue.

There are also other possible explanations for the failure to address site contamination in some countries: a lack of recognition of soil as a vital natural element and resource for human survival and development (European Environment Agency

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2007a: 115); the fact that site contamination often occurs on privately owned land, out of the public eye and beyond the reach of regulations; the absence of reliable, detailed information on the scale and severity of potentially contaminated sites; the lack of scientific knowledge regarding the processes and effects of site contamination; and the complex nature and political sensitivity of the issue (Boyd 1999).

Even where a major incident of site contamination affects public health on a large scale in a developing country, the need for national regulation of the issue may not be recognised. It may be perceived as a 'one-off' or local problem rather than one which could be repeated in other locations around the country. While some developing countries are now becoming aware of wide-scale contamination within their borders, they are struggling to formulate an effective response to it.

Developing countries could potentially be assisted in their efforts to address contaminated sites by the broad experience of developed countries, in particular through technology transfer and the availability of a model framework for managing site contamination. Such a model framework should distil all the lessons learned by developed countries over the past 30 years and comprise the key elements for effective site contamination management.

In whatever form it takes, an international instrument on site contamination is needed in the near future because it is clear that this complex issue is not being addressed comprehensively or at all in some countries. Developing countries in particular remain ill-equipped to deal with the challenges of responding to site contamination as it emerges as a significant threat to human and environmental health.

An awareness of site contamination as a valid and important environmental issue is lacking at the highest domestic and international levels, resulting in an absence of political pressure to act. An international instrument would help to raise awareness of site contamination and provide a fundamental framework for individual countries to take regulatory action. The justifications for an international instrument on site contamination are explored in more detail in Chap. 7 below.

2.2 Sources and Effects of Site Contamination

2.2.1 Common Types of Contaminating Activities

The types of activities which commonly cause site contamination vary between countries, primarily depending on the industries and contamination levels permitted in each country. However, in most developed countries the main cause of site contamination is industrial activities. In North America, such activities include the operation of factories, mines, smelters, electrical power plants and other production facilities, and harbours. Other common sources of contamination are above-ground and underground fuel storage tanks, fuel pipelines, dry-cleaning facilities, military bases, airports, laboratories, landfills, municipal and medical waste incineration plants, and use of contaminated soil for residential development.

Industrial causes of site contamination also predominate in Australia and New Zealand, with additional causes (both past and present) including cattle and sheep dipping, manufacture and use of fertilisers and pesticides, and timber treatment (Rae 2006; New Zealand Ministry of Environment 2007). As for other developed countries, the main sources of contamination in Japan and Korea are the chemical and electroplating industries, together with mines, refineries, and agricultural fertilisers (United Nations Environment Programme 2002).

In the more industrialised countries of the Caucasus and Central Asia, large-scale contamination has been caused through a combination of agricultural practices, mining (uranium and metal ore), oil and gas extraction, nuclear power generation and waste disposal (European Environment Agency 2007a: 118). In many of these industries and sectors, accidents and poor management have compounded the problem.

Europe reflects a similar trend to North America and Australasia, with typical contaminating activities including industrial production and commercial services (chemicals and heavy metals), town gas manufacturing, oil processing, municipal waste treatment and disposal, industrial waste treatment and disposal, power plants, storage, transport spills on land, mining (such as disposal of tailings, acid mine drainage and use of catalytic reagents) and military sites (ammunition, fuel and chemical usage and storage) (European Environment Agency 2007a, b). In Eastern Europe, major sources of site contamination have been military installations, nuclear reactors and storage of hazardous chemicals, resulting in a legacy of contamination which will take decades or longer to remediate, at great cost to taxpayers (United States International Trade Commission 2004: 2–11).

The predominant sources of contamination in developing countries are also industrial activities, particularly in the form of untreated industrial or chemical waste disposal. Groundwater contamination is particularly widespread in developing countries (Kao 2004). The United Nations Environment Programme (UNEP) identifies discharges of untreated urban and industrial effluents, chemical leaks from storage facilities, and solid waste disposal as among the most serious problems (UNEP/ADEME 2005: 3). However, some of the other activities commonly causing site contamination are similar to those in developed countries: mines and smelters, tanneries, battery processors, chemical manufacturers and other industries (Blacksmith Institute 2007).

On the African continent, contaminating activities include mining operations, pesticide and fertiliser use, oil exploration and transport, waste disposal and untreated sewage discharges (Coles 2008). Waste disposal and wastewater discharges are also common causes of contamination throughout South and Southeast Asia, where lead contamination presents particular problems (UNEP 2002). Groundwater contamination may be caused by accidental spills from surface waste ponds, underground and aboveground storage tanks, pipelines, landfills, injection wells, septic tanks, radioactive waste disposal sites, land application of wastes and pesticides, saltwater intrusion, and acid-mine drainage (Kao 2004: 66).

In Latin America, industrialisation of some regions after World War II led to the intensive mining and processing of raw products such as crude oil and wood, together with the growth of the metal-working and chemical industries in the 1960s and 1970s (Marker et al. 2007: 2). Rapid urban expansion in the large cities of the region also resulted in many waste disposal problems, and an increasing reliance on landfills. These activities have resulted in significant contamination in Latin American countries, particularly in the major metropolitan areas of São Paulo, Rio de Janiero and Buenos Aires (Marker et al. 2007).

Even in Antarctica and the Arctic, site contamination presents a problem. Petroleum and diesel spills are the leading sources of contamination in polar regions, with the already harmful effects exacerbated by the extremely cold conditions (Snape et al. 2008: 1). Land-based crude oil spills in the Arctic are generally attributable to broken pipelines, and shoreline spills are caused by tankers. Snape et al. (2008: 3) note that spills are usually caused 'by infrastructure failure, human error during fuel transfer, "third party actions" (e.g. sabotage), or natural hazards.' Remediation can also be a lengthier and more challenging process in cold regions, due to rapid migration of contaminants off-site, slow natural attenuation rates and the prohibitive costs of excavation and removal (Snape et al. 2008: 1–2).

Naturally occurring site contamination is an additional issue in some countries, and has a particularly deep impact on developing countries because of their reliance on untreated groundwater for consumption, irrigation and other uses. Since the 1980s, naturally occurring arsenic has been found in Bangladesh, India, Cambodia, China, Mongolia, Taiwan, Laos, Burma, Nepal, Pakistan and Vietnam (World Bank 2005; Singh 2004). Some 60 million people live in the affected areas. According to the World Bank (2005), much research has been carried out into the causes and effects of natural arsenic contamination and possible mitigation measures, but significant uncertainties remain, so the issue will continue to present a challenge.

Naturally occurring contamination can also present potential health problems in some developed countries. For example, in California, natural deposits of selenium pose a high risk to the health of humans and animals (e.g., Orange County Nitrogen and Selenium Management Program). Selenium in small amounts is necessary to sustain life, but it can be toxic at high levels, and it is bio-accumulative. Groundwater containing selenium can be discharged into surface water when it is disturbed by activities such as urban development, thus causing further contamination and affecting humans and animals more directly.

2.2.2 Common Contaminants

Contaminants may be either organic or inorganic elements or compounds. Organic compounds are derived from plant or animal sources and contain carbon. As contaminants, they include pesticides and herbicides (such as dioxins, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)) and volatile organic compounds, such as benzene. Inorganic contaminants are of mineral origin and include, among others, lead, mercury, chromium, cadmium, arsenic, copper, nitrates, cyanide, asbestos and sulphuric acid.

Given the similarity between contaminating industrial activities in developed countries, it follows that they also have the most prevalent contaminants in common. In Europe, the main contaminants are heavy metals (37%) and mineral oil (33%), together with polycyclic aromatic hydrocarbons, aromatic hydrocarbons, phenols, chlorinated hydrocarbons and cyanides (European Environment Agency 2007a, b). Common contaminants in the United States and Canada include dioxins, furans, lead, mercury, asbestos, arsenic, PCBs, benzene, cadmium, PAHs and benzene by-products. Similarly, in Australasia, common contaminants include hydrocarbons (from petroleum storage), hexavalent chromium, lead, arsenic, trichloroethylene, tetrachloroethylene, dioxin concentrates and cadmium (from fertilisers) (UNEP 2002).

The Blacksmith Institute has compiled a list of contaminants that are typically found in developing countries, which includes mercury, arsenic, chromium, lead, cadmium, cyanide, PCBs, pesticides, persistent organic pollutants, coal, volatile organic compounds, asbestos, dioxins, PAHs, petrochemicals, fluorides, abandoned chemical weapons and radionuclides (Ericson 2011: 24).

Early results of the Blacksmith Institute's Toxic Sites Identification Program indicate that some contaminants are particularly prevalent in certain areas: for example, cadmium (India and Asia), pesticides (India, Central and South America) chromium (Eastern Africa, India, China and South America), arsenic (South America, India and China) and radionuclides (Asia and the Caucasus). Lead is considered a global threat (Ericson 2011: 29).

2.2.3 Effects of Contamination

The physical effects of contamination are diverse, and can be both direct and indirect. As Layard (2006: 133–134, citing McEldowney and McEldowney 1996: 170–171) observes,

> contaminated land can [. . .] prevent or inhibit the growth of plants and have toxic effects on invertebrates and vertebrates, it can contaminate water, enter the food chain, be ingested, inhaled or make skin contact, it can cause the chemical degradation of building materials or cause fire or explosion.

The release of contaminants into the soil may also result in damage to, or loss of soil functions, which are essential to sustaining life. Indirect contamination occurs when the contaminant is transferred to its final destination via the environment or an organism.

Concern regarding the health effects of contaminants on humans, in particular, is usually the factor generating wider awareness of, and motivating political responses to, the site contamination issue (Blacksmith Institute 2007: 2). Health effects can be long-lasting, and depending on the nature of the contaminant, the vulnerability of the individual affected, and the level of exposure, may include an increased risk of cancer, respiratory illness (possibly including asthma), disease, reproductive problems, impairment of neurological functions and hormone disruption (European Environment Agency 2007b: 68–71). In addition, an individual's exposure to a contaminant may have delayed effects, by either remaining dormant in that individual until some later date, or being passed down to the next generation, where it then manifests itself in an illness (European Environment Agency 2007b: 70).

There are also serious socio-economic impacts of site contamination. The confirmed or suspected existence of contamination on a site can result in high investigation and remediation costs (Ericson 2011: 38). It can also affect property value and marketability, as prospective purchasers or developers may not want to take on the financial and legal burden of remediation. This is particularly so where there is uncertainty as to the degree of contamination, the level of cleanup required or the allocation of responsibility for such cleanup.

In addition, property stigma (or 'blight') can occur where a contaminated site has already been remediated, but its previously contaminated status causes the market value of the property to remain depressed (Wolf and Stanley 2003: 308). Property blight was a major concern when a national register of potentially contaminated land was proposed in the United Kingdom, such that the relevant provision (sect. 143) in the Environmental Protection Act 1990 was promptly withdrawn before it entered into force.

The stigma of a contaminated site, particularly in urban areas, may also affect the morale of the people living and working nearby. The presence of a suspected or known contaminated site can undermine the confidence of local residents and businesses, resulting in avoidance of the area and increased use of cars for commuting (Royal Commission on Environmental Pollution 2004: 1). Investment in the area may be discouraged, leading to further abandonment and dereliction. Meanwhile, vandalism, graffiti and other antisocial behaviour may increase on or near the relevant site because of a perception that it is useless and worthless. In rural areas, the identification of a contaminated site in or near a village can even result in the entire village being stigmatised and parts of it subsequently abandoned (Barnes et al. 2005: 277).

The consequences of site contamination can extend well into the future where the contaminants involved are particularly long-lasting, the chosen remediation method is not completely effective, or where liability for remediation is disputed and the relevant public authorities have insufficient funding to carry it out themselves. 'Orphan' sites—those which have been abandoned by owners or operators, and for which no party can be made liable for remediation—continue to pose a problem for governments in many countries, even decades after their closure. Although new environmental protection laws in some countries may eradicate the problem of prospective orphan sites, historical orphan sites must still be addressed using other methods.

2.3 Extent of Site Contamination

2.3.1 Geographical Locations and Trends

As a general rule, site contamination occurs as a result of industrialisation processes, which means that it is a problem mainly experienced in developed countries, or those countries currently undergoing economic transition or rapid urbanisation. In Europe, the largest and most affected areas are the heavily industrialised regions of north-western Europe (European Commission 2002). However, as mentioned above, the former Communist countries of Eastern Europe have extensive site contamination problems caused by decades of intensive industrial activity (United States Environmental Protection Agency 2008a), military operations, uranium mining and mismanagement of nuclear reactors (Blacksmith Institute 2009a, b).

North America has extensive historical site contamination problems, particularly in its urban centres. Likewise, serious site contamination problems are characteristic of the populous areas of Australia and New Zealand (UNEP 2002: ch 2). Site contamination is now emerging as an issue for countries in Eastern Europe, the New Independent States of the former USSR, Central and South America, Africa and Asia. The Blacksmith Institute (Ericson 2011: 23, 41) estimates that up to 100 million people may be affected globally by point-source contaminated sites that involve industrial chemicals or other similarly harmful contaminants.

As the 2007 Bellagio Principles note (Blacksmith Institute 2007), with particular emphasis on developing countries,

> efforts continue [in] every country to rein in ongoing sources of toxic discharges. However, some of the most significant sources of pollution are legacy or "orphan" sites. [. . .] Often, legacy pollution is intermingled with toxins from active polluters, and both must be addressed together.

Despite the clear correlation with industrialisation and urbanisation, contaminated land can also be found in rural areas, particularly where fertilisers have been applied to the soil for agricultural purposes, contaminated water has been used for irrigation of crops (e.g., China: see Xu 2007), or chemicals have been used to treat farm animals (e.g., Australia and New Zealand: see Craig 2003: 109). Contaminated sites in rural areas—especially in developed countries, but increasingly also in developing countries—typically result from mining operations, timber processing facilities, railways, petrol stations, septic tanks, landfills and farming. Generally, these contaminating activities receive less public attention because of their location and subsequent lack of visibility. In addition, a smaller population may be affected by the contamination in rural areas, and there are not the same pressures as are felt in urban areas to remediate and redevelop contaminated sites.

2.3.2 Number of Contaminated Sites and Proportion of Land Mass Affected

The total number of contaminated sites that have been identified and require remediation worldwide has been estimated to be in the hundreds of thousands (e.g., Industry Canada 2005: 1). However, this is likely a conservative estimate, because the individual figures given for each country are also in the high hundreds of thousands. A handful of studies and surveys have been undertaken into the global market for remediation services over the past decade. One survey by Industry Canada (2005: 4) estimates the annual global remediation market to be worth between US$12 billion and US$35 billion. However, as the survey notes, it is difficult to accurately quantify both the actual number of contaminated sites and the value of their remediation, because many countries have not completed the identification and assessment of sites (Industry Canada 2005: 4).

A UNEP-funded project, GLASOD, produced a world map in 1990 showing the global extent of several different types of human-induced soil degradation, of which pollution was one. Almost 20 years later, the Blacksmith Institute announced that it would develop a inventory of 'polluted places' around the world, called the 'Global Inventory Project' (Blacksmith Institute 2009a, b). The Project is supported by other international actors, including the European Commission and the World Bank.

The Global Inventory Project has since been renamed the 'Toxic Sites Identification Program' (TSI Program), and represents an international effort to "identify and assess contaminated sites with an impact on human health in low and medium income countries" (Ericson 2011: 19). Countries with no or minimal industrial activity, those subject to civil conflict, and those with oppressive or uncooperative political regimes were excluded from the TSI Program. While it is not intended to provide a comprehensive inventory of all contaminated sites, the aim of the TSI Program is to promote an understanding of the global scale of the contamination problem (Blacksmith Institute 2012b).

The Blacksmith Institute originally estimated that around 500 sites would be identified and assessed over the duration of the TSI Program (Blacksmith Institute 2009b). However, more than 2,095 sites have now been identified, and more than 1,500 of these have also been assessed (Ericson et al. 2012; Ericson 2011: 28). Although 80 countries were prioritised on a 'final list' for inventory purposes, a lack of funding has meant that work is only being carried out in just over half of those (Ericson 2011: 22). Following the compilation of a national site inventory for each country, the TSI Program encourages the relevant government to prioritise sites and commit funding for intervention purposes (Blacksmith Institute 2012b).

Many countries have not yet carried out a comprehensive and systematic national survey, so it is difficult to assess the proportion of the global land mass that is likely to be currently affected. As Layard (2006: 136) points out in the context of Europe, there are several problems in estimating the number of potentially and actually contaminated sites. First, even though much data exists at the local level, little of it is of direct use and there are data gaps at the regional level. Second, monitoring and data collection procedures at the national and regional levels are not harmonised, so they remain inconsistent. Third, data flows between data collectors and the organisations responsible for reporting have not been established at the national and regional levels (European Environment Agency 2000: 26, cited in Layard 2006: 136).

These factors are also relevant to other developed regions of the world, particularly in countries with federal systems, where individual states or provinces may have developed their own methods of identifying contaminated sites and there is minimal coordination of data at the national or federal level (e.g., Australia, Canada, the United States and Germany). Although most developed countries now collate such information at the national or federal level, it will take time for data collection methods at the local, state/provincial and/or regional levels to be harmonised. Therefore, inconsistencies are likely to persist for some time.

However, despite the gaps in data and the inconsistent methods used to collect information on site contamination around the world, it is possible to gain some idea of the estimated scale of site contamination. In general, it is not difficult to find information relating to countries which already have a long history of industrialisation, or highly urbanised countries. It is much more challenging to form a picture of the extent of site contamination in less developed, or developing, countries. In many cases, this information may not exist, be unavailable to the public, or require translation, a task which is beyond the scope of this book.

In Europe, there are estimated to be around three million potentially contaminated sites, of which about 250,000 are thought to be actually contaminated and in need of remediation (European Environment Agency 2010: 21). According to the European Environment Agency (2007b: 117), estimates of potentially contaminated sites in the European Union have increased significantly in recent years due to the progress made in conducting site investigations, monitoring and collecting data. Further increases in these estimates are expected in coming years as more information becomes available.

In the United States, around 1,300 sites are currently on the ‘National Priorities List’ for remediation under the federal Comprehensive Environmental Response, Compensation and Liability Act 1980 (also known as ‘Superfund’) and about 3,750 additional sites are in need of corrective action under the federal Resource Conservation and Recovery Act 1976 (United States Environmental Protection Agency 2012a, b). However, many other contaminated sites are also being addressed at the State level: an example is the remediation of over 11,000 underground petroleum storage tank sites in the 2011 fiscal year alone (United States Environmental Protection Agency 2011a).

Approximately 30,000 contaminated sites have been identified in Canada, of which about 21,000 are, or were previously, owned or operated by the federal government (Government of Canada 2012a, b). British Columbia alone has an estimated 9,000 potentially contaminated sites (British Columbia Ministry of Environment 2009: 1). Estimates of potentially contaminated sites in Australia range from 60,000 to 200,000, with no reliable source of national data available (Deegan and Ji 2008: 284, cited in Fowler and Cole 2010: 1). New Zealand has so far identified 559 'high-risk' sites for remediation, but there are likely to be many more contaminated sites, such as former sheep dip facilities, requiring some kind of remedial action (Ministry for the Environment (New Zealand) 2007: 247–248).

In Eastern Europe and the New Independent States of the former USSR, some data exists on the extent of site contamination, although it is now dated (e.g., Andersen 2000). In most South-Eastern European, Caucasus and Central Asian countries, the actual extent of contamination remains unknown, because inventories have only been made for specific sites—such as mining or landfill sites—or regions, or do not exist at all (European Environment Agency 2007b: 118).

Some efforts are now being made to quantify total site contamination in individual countries of the South and East Asian region, but they tend to be 'ballpark figures' rather than based on systematic inventories (European Environment Agency 2007b: 118). In China, an estimated 10% of the total arable land is affected by soil or water contamination, with contamination concentrated in the urbanised areas of the country (Xu 2007). The area of potentially contaminated land in Japan is believed to exceed 113,000 ha (Government of Japan 2007: 13–14). However, this figure relates only to privately-owned land, and contaminated land which is subject to public use may increase the estimate significantly.

In Latin America, individual countries are beginning to undertake inventories of potentially contaminated sites. Brazil, Chile and Mexico are in the process of establishing, or have already established, national inventories (Kadas et al. 2008: 1). However, little information is available as to preliminary estimates of site numbers or the proportion of land affected. There are thought to be approximately 50,000 ton of chemical waste requiring remediation throughout Latin America generally, although the number of sites over which the waste is distributed is not given (Hopkins 2005).

Estimates for particularly industrialised cities or regions are quite easy to obtain: for example, the state of São Paulo in Brazil had at least 700 contaminated sites in 2002 (Business News Americas 2003). Mexico, which has done considerably more than its southern neighbours to address site contamination, has identified 300 contaminated sites requiring remediation, which comprise a total area of 200,000 ha (Commission for Environmental Cooperation 2008: 46).

There is currently a lack of information on the extent of site contamination in Africa, even though the common types of contaminating activities are known (Coles 2008). One source estimates that at least 27 million kilograms of obsolete pesticides are causing significant soil contamination across the African continent (Food and Agriculture Organization of the United Nations 2012). This presumably does not include sites affected by other common sources of contamination in developing countries, such as mining operations, oil production and waste disposal. The extent of land affected in African countries may therefore be much higher than might otherwise be expected of less industrialised, urbanised countries.

2.4 Remediation of Site Contamination—Common Approaches

Remediation of a contaminated site essentially involves the removal of the risk of contaminants at a particular site from causing harm to humans or the environment. It does not necessarily involve removing the contaminants themselves, although that was a common practice from the 1970s to the 1990s and is still done today. The aim of remediation is usually to restore the relevant site to a standard at which the current or proposed site use may proceed with minimal risk to humans and the environment.

Generally, options for site remediation include the excavation and removal of contaminated materials for off-site landfill or treatment; treating the contaminated material on-site to remove or neutralise the contaminants; and securing or containing the contaminants to prevent further migration (Nathanail and Bardos 2004: 125; Langworthy 2007). If a variety of contaminants are present at a site, it may be necessary to use a combination of two or more remediation methods.

Until recently, the excavation and removal (or 'dig and dump') approach was favoured in the majority of remediation decisions in developed countries, and it continues to be widely used (Randall 2007: 61–62). In some countries (e.g., the Netherlands), this was because sites had to be restored to a high standard so as to be suitable for any use. Remediation to a high standard is no longer required in most cases, with the lower standard of 'fitness for current or proposed use' being applied in many developed countries (Preston 2008: 167; Luo et al. 2009: 1131).

In cases where time is not a critical factor, on-site and in situ remedial methods can offer a less expensive alternative, which is more closely attuned to the conditions and requirements of a particular site. Nathanail and Bardos (2004: 143) state that 'as a general rule of thumb, the greater the amount of time available for remediating a site, the greater the range of applicable in situ solutions.' Considerable research has been undertaken since the 1990s into the effectiveness of various on-site techniques, allowing for a more informed remediation decision to be made.

Apart from the regulatory context and applicable soil standards, several factors affect the decision as to which remediation method should be used for a particular site (Carlon et al. 2008: 113). These include the intended land use, time available for remediation, developer's knowledge, and available finances (Contaminated Land Rehabilitation Network for Environmental Technologies in Europe 2002: 1). As Pollard et al. (2001: 2) note,

> Increasingly, approaches to site remediation are being scrutinised by reference to their full life-cycle costs, and social, economic and technical factors are being considered alongside one another in appraising risk management options.

Other important factors include the results of the risk assessment and evaluation process, any liability issues, the outcome of any public participation, and the political sensitivity of the particular site. While not all of these factors may influence every remediation decision, it is evident that reaching a decision in itself can be a complex and detailed process. There is also the possibility that the remediation decision has to be revisited at a later date if the selected remedial method proves to be ineffective.

In general, excavation and removal of contaminated materials is a short-term remediation solution, which is used when remediation needs to be carried out quickly and completely (Carlon et al. 2008: 116). Where the excavated contaminated materials are not treated, but only removed to another location, the contamination is relocated but not resolved, and may present a problem in the future. However, the impact of the contaminated materials that have been relocated may be minimised if they are deposited at an approved landfill site where mitigation measures (e.g., liners) are in place to prevent seepage or leaching. Medium-term remediation options may involve removing the contaminated materials, treating them off-site to remove or neutralise the contaminants, and returning the treated soil or water to the site. Some ongoing monitoring may be required in these scenarios, but generally these methods are effective.

Long-term approaches tend to involve containment or securing of the contaminants in situ, because they normally require ongoing monitoring and possible future remediation if they are not fully successful. There is greater potential for remediation to be partially or even completely ineffective when these solutions are used, because the contaminants are still present. In addition, the 'brownfields movement' in countries such as the United States has resulted in the re-use of many sites retaining residual contamination. In response, developed countries have begun implementing institutional and engineering controls to ensure the long-term sustainability of sites.

Bioremediation, where natural processes and organisms are used to remediate the contaminated area gradually, is another long-term option. This method has received much attention in recent years, particularly in light of calls for a more sustainable and less costly approach to land management (United States Environmental Protection Agency 2008b: 1). It is also considered a very safe remediation method for people working on, or living near, the relevant contaminated site. Bioremediation can involve phytoremediation (using plants), bioventing (using air), biosparging (using air and water), and/or 'flushing' (with water). Phytoremediation is a relatively recent, innovative method. It uses plants in various ways to restrict the availability of contaminants to humans, by minimising surface erosion, runoff, dust generation and skin contact (Nathanail and Bardos 2004: 174–175).

2.5 Progress in Remediation

Progress in the remediation of contaminated sites in Europe has been slow, with only approximately 80,000 sites being remediated in the last 30 years (European Environment Agency 2007a). This is a reflection of the high costs and legal complexities involved in the remediation process. Nevertheless, some progress has been made in recent years in western and central European countries, and some south-eastern European countries, where the average number of cleaned-up sites increased by more than 150% between 2001 and 2006 (European Environment Agency 2007b: 119). This increase probably reflects a response by site developers and owners to the abandonment of the multifunctionality standard for remediation, together with the introduction of brownfield initiatives in some European countries.

At the same time, improvements to site identification and data collection procedures have resulted in an average 40% increase in the total number of sites awaiting remediation, and a doubling of the estimated number of sites at which potentially polluting activities have taken place (European Environment Agency 2007b). Preliminary investigations into potentially contaminated sites are well advanced in Europe, because this stage requires fewer resources and less time (European Environment Agency 2007a). However, the associated costs and effort increase with each stage after this point, including detailed site investigations, remediation decision-making and the actual remediation works, and this has been attributed to their much slower progress.

In the United States, cleanup remedies have been completed for about two-thirds of the sites listed on the National Priorities List over the past 30 years (United States Environmental Protection Agency 2011b: 1). Progress is good for the remediation of the less heavily contaminated sites, many of which are being returned to use under voluntary cleanup programs and other brownfield initiatives (United States Environmental Protection Agency 2005). In Canada, 650 federally-managed sites have been remediated since 2005, and thousands more have been cleaned up in the provinces to date. In addition, 6,400 federal sites have been assessed for potential contamination since 2005 (Government of Canada 2012b).

Remediation in Australia is progressing differently from state to state, with some reporting that remedial efforts are now catching up with the number of identified sites (New South Wales Department of Environment, Climate Change and Water 2006: Fig. 4.1; Queensland Environmental Protection Agency 2007: 124). Out of a total of 1,238 contaminated sites that were reported by regional councils in New Zealand for the period 2006–2007, just under half had been remediated (New Zealand Ministry for the Environment 2007: 249). In Japan, a total of 91 designated sites required remedial treatment between 2003 and 2007, but approximately 1,700 sites were remediated voluntarily in 2005 alone (Sato 2007: 7).

In Eastern Europe, the Caucasus and Central Asia, minimal progress has been made in the remediation of contaminated sites. While some remediation has been carried out by public authorities and private companies, the actions that have already been taken in the region are said to be ‘far from satisfactory’ (European Environment Agency 2007b: 119). Few countries in these regions have managed to compile national inventories of contaminated sites or establish national remediation programs, although the Blacksmith Institute’s Toxic Sites Identification Program aims to help rectify this problem in low- and medium-income countries (Blacksmith Institute 2012b).

The considerable costs of remediation are ‘frequently beyond the scope of the public purse in countries where the polluters often cannot be made liable’ (Blacksmith Institute Blacksmith 2012a, b, c, d). The situation is similar in Latin America.

While some Latin American countries (e.g., Brazil, Chile, Columbia, Mexico and Peru) are actively engaged in identifying and prioritising contaminated sites, and compiling inventories, they have yet to address the remediation issue in any substantive way (Kadas et al. 2008).

Specific information on site remediation is difficult to find for other developing parts of the world. Market research indicates that developing countries as a whole may represent only a ‘small fraction’ of the global demand for remediation services (United States International Trade Commission 2004: 7–2). Explanations for this include the lower levels of industrialisation (and hence less production of contaminants) in developing countries, a lack of public and political awareness of threats posed by existing contamination, a lack of data and documentation on the scope of contamination, and an absence of regulatory measures, enforcement infrastructure, and economic incentives relating to remediation (United States International Trade Commission 2004: 7–2).

However, the early results of Toxic Sites Identification Program so far indicate that remediation activities are likely to increase in developing countries in coming years due to a greater awareness of contaminated sites and their detrimental impact on public health (see, e.g., Ericson 2011). International efforts to identify contaminated sites and help governments to prioritise their remediation are underway (see, e.g., Blacksmith Institute 2012c), and producing some positive results (Ericson 2011). Remediation efforts may also be driven by the increasing visibility of pollution, and the implementation of new regulatory measures (United States International Trade Commission 2004: 7–4).

Where remediation is already being undertaken in developing countries, it is usually funded either by a multilateral lending institution, a multinational corporation or an international organisation. According to the United States International Trade Commission (2004: 7–1),

> Anecdotal evidence suggests that demand for remediation services in developing countries may be driven by the cleanup activities of European- or North American-based multinational corporations which have established operations in developing economies.

However, most remedial works carried out by international organisations or multinational corporations tend to focus on a particular industry, such as mining, or a group of contaminants, such as pesticides or persistent organic pollutants (e.g., the Obsolete Pesticides Programme of the Food and Agriculture Organization). Except in a handful of cases, they are unlikely to lead to the implementation of a nationwide remediation strategy to address all types of site contamination.

One interesting example of remediation work led by a group of international organisations across several countries is the Health and Pollution Fund (formerly the Global Pollution Remediation Fund). This project was launched in 2007 by representatives of five developing countries and two developed countries, as well as the World Bank, the United Nations Industrial Development Organization (UNIDO), Green Cross Switzerland, the Blacksmith Institute and ‘leading researchers from within the public health and pollution remediation fields’ (Health and Pollution Fund 2012a).

An ‘inception meeting’ of these participants was sponsored by the Rockefeller Foundation and coordinated by the Blacksmith Institute in Bellagio, Italy, in 2007. A consensus was reached and the ‘Bellagio Principles’ were agreed at that meeting, resulting in the launch of the Fund (Health and Pollution Fund 2012b). The Bellagio Principles state at the outset the rationale for collaborative global action to address the worst contaminated sites (Global Pollution Remediation Fund 2007: 1):

> Toxic pollution is found throughout the developing world. It is [a] significant cause of disease and death and especially harms children. It is a moral imperative to deal with this issue, one made all the more compelling by the globalization of industry.

There is also a clear recognition of the responsibility on developed countries to share their knowledge and experience on managing contaminated sites (Global Pollution Remediation Fund 2007: 1):

> Technologies for cleaning up these problems are well known in the west, but little has been done because of inadequate resources at the local level, and a lack of technology transfer. Affected communities and local authorities often struggle to do what they can with very limited financial and technical resources.

The HPF initiative is primarily sponsored by the United States and Germany, although funding is sought from various national development agencies, multilateral development banks, international aid organisations and ‘high net-worth individuals’ (Health and Pollution Fund 2012a). The project aims to remediate the worst contaminated sites in the developing world at a cost of US $400 million over the next 5–10 years. Although the HPF does not necessarily provide funding for full completion of remedial works at all sites, it focuses on achieving sufficient remediation to meet specific health targets. In addition, local people are to be trained to carry out any further necessary remediation.

At the launch of the Fund, it was indicated that remediation would be undertaken at 420 ‘critical’ sites—including 250 small-scale, 150 medium-scale and 20 large-scale sites—in China, India, the Philippines, Russia, Kenya and Mozambique (Health and Pollution Fund 2012c). Many of these sites have been contaminated by industrial, mining and military activities (Health and Pollution Fund 2012a).

According to the HPF website, the intention is that ‘projects initiated by HPF will efficiently channel funds to local stakeholders with technical support and oversight provided by a central, international, Secretariat’ (Health and Pollution Fund 2012a). Already it appears that work has commenced, or indeed has already been completed, at some HPF-nominated sites (e.g., Dzerzhinsk, Russia; Rajasthan, India; Manica, Mozambique; Haina, Dominican Republic; and Wenshan, China: Blacksmith Institute 2012b).

The Blacksmith Institute also launched the ‘Global Alliance on Health and Pollution’ (GAHP) in mid 2012, in an effort to bring the global problem of toxic sites to ‘the next level’ on the international agenda (Blacksmith 2012c). The GAHP brings together several governments, international agencies and organisations (such as the United Nations Environment Programme and the Asian Development Bank) and aims to assist countries in developing national strategies for tackling pollution ‘hotspots’. More specifically, GAHP will be helping countries (e.g., Senegal, Indonesia and the Philippines) conduct technical investigations and implement remediation projects (Blacksmith Institute 2012c). It is hoped that initiatives such as this will contribute significantly to the progress of remediation in developing countries, as well as raising political awareness of the issue more generally.

2.6 Economic Considerations in Remediation of Site Contamination

It is widely recognised that contaminated site remediation can be an expensive process, and that the associated costs often present an obstacle to the timely clean-up and re-use of contaminated sites. Nathanail and Bardos (2004: 6) observe that

> A major issue for all industrialised countries is how to reduce the cost of dealing with land contamination without compromising public health and water quality, or business confidence in the benefits of land regeneration and sustainable use of soil.

As noted earlier, publicly-funded site remediation is beyond reach for some developing countries, because other public health or environmental issues (e.g., such as sewage treatment and air pollution) are more immediately felt and are prioritised accordingly (United States International Trade Commission 2004: vii; Cairney and Hobson 1998: 9). Privately-funded remediation in developing countries generally does not take place in the absence of a strong regulatory regime for site contamination.

However, a small amount of remediation is undertaken by multinational corporations and international organisations in developing countries even in the absence of a strong legal regime. The work of international organisations in particular tends to be highly dependent on political and economic factors in both the donor and recipient countries, and operational issues also present problems. For example, the Africa Stockpiles Programme (2008) reported a funding gap of US $10.5 million in 2007–2008, together with other economic and logistical obstacles to the successful implementation of its goals.

It is also possible to develop a remediation approach that matches the financial capability of an individual country, where funding is very limited. Hanrahan et al. (2007: 2) note that

> [M]any clean-up initiatives can be accomplished with minimal amounts of money and can achieve substantial results in short time periods. It is often possible to clean up the worst aspects of a particular polluted site with inexpensive and effective technologies, and mitigate much of the health risk to quite a large population as a result.

The Blacksmith Institute's Toxic Sites Identification Program promotes the prioritisation by governments of their worst polluted sites, with a view to committing funds and taking 'intervention' measures as soon as possible. The Blacksmith Institute refers to 'initial intervention' to mitigate the health impacts of contaminated sites, rather than full site remediation (Ericson 2011: 38).

In Europe, the costs of remediation works to date have been substantial, although only a small percentage of historical site contamination has yet been remediated (European Environment Agency 2007a). Expenditure on managing contaminated sites also varies widely between countries. While most European countries spend between 100 and 250 million Euro per year on contaminated land management, some countries spend much less (e.g., Macedonia) or considerably more (e.g., France) (European Environment Agency 2007a). The factors affecting remediation costs are diverse, and include the extent of site contamination, awareness of the issue, the regulatory context, the remediation methods used, and the current and future land use. On average, about 60% of each country's total costs of managing site contamination are for remediation measures, and the remaining 40% are for site investigations (European Environment Agency 2007a).

Likewise, there is much variation between European countries in the extent to which private actors are made to pay for remediation. On average, approximately one-third of total expenditure on contaminated site management comes from public funds (European Environment Agency 2007a). However, there are notable exceptions to this figure: in some countries, taxpayers provide 100% of the funding (Czech Republic, Spain and Macedonia), but in others, private actors meet almost all of the costs themselves (France, Italy and Norway) (European Environment Agency 2007a). To some extent, the high figures for public funding reflect the proportion of sites that were contaminated by state-owned entities. However, governments may also undertake remediation on the assumption that it will not be completed quickly enough if left to private actors.

In the United States, the federal Environmental Protection Agency (USEPA), under the auspices of the Superfund Program, allocated nearly US$443 million to emergency response and removal operations at contaminated sites for the 2010 financial year (United States Environmental Protection Agency 2010b). For the same period, USEPA also secured private funding commitments of nearly US$1.6 billion for both future remediation works and in repayment for past remediation actions carried out by USEPA (United States Environmental Protection Agency 2010a: 3). In Canada, CDN$344 million was earmarked for the remediation of around 380 high-priority federal contaminated sites for the period 2012–2013 (Government of Canada 2012b). The total cost of remediating contaminated sites in Australia is purportedly in the range of US$3–4 billion (Cooperative Research Centre for Contamination Assessment and Remediation of the Environment 2012: 2).

As the past 30 years have shown, there are also regulatory challenges to the effective management of site contamination. Until recently, regulation of site contamination in most developed countries was fragmented and ad hoc, as it was generally thought that existing measures for environmental protection, waste management, pollution control and planning were sufficient (see, e.g., New Zealand Ministry for the Environment 2006: 28). This approach prevented the effective and prompt remediation of many contaminated sites for a few reasons.

First, it was rarely possible under such general legislation to impose liability retrospectively on site operators or owners who had caused site contamination, so the financial burden of remediation was eventually passed to the taxpayer (see Kingsbury 1998; Environment Protection Authority (South Australia) 2004: 3–4). Second, the use of scientific values underlying remediation decision-making was not clearly regulated, resulting in the wrong values being used to trigger remediation works or set cleanup standards (National Environment Protection Council (Australia) 2006: 3). Third, the piecemeal approach to site contamination could mean that one aspect of the issue was well regulated while others were not, leaving site contamination professionals without any clear legislative guidance when making complex site-related decisions.

The allocation of legal and financial responsibility for remediation of contaminated sites has been a particular challenge facing regulators, but it is seen as essential for stimulating the clean-up and re-use of contaminated sites. According to the United States International Trade Commission (2004: vii),

> The primary force behind the establishment of remediation services markets worldwide has been the passage of legislation which requires cleanup of polluted sites and which assigns liability for the associated costs.

While the 'polluter pays' principle is the legislative ideal in many developed countries, in practice there are difficulties in its implementation for all contaminated sites. In the context of Europe, it is observed (European Environment Agency 2007b) that

> Contamination can be a legacy stretching back many decades or centuries. As a consequence, the responsibilities for pollution and, therefore, remediation are often difficult to identify because the polluters are often no longer in business. This in turn contributes to making it difficult, time-consuming and costly on the public purse to manage contaminated sites.

Developed countries have generally accepted that, where the original polluter of a site no longer exists or is insolvent, other parties may be required to pay for remediation. These include 'knowing permitters', that is, anyone who knowingly permitted contamination to occur at a site, even though they did not actually cause the contamination themselves (e.g., 'Class A persons': sect. 78K(1), Environmental Protection Act 1990 (UK)). Liability may alternatively be imposed on site owners or occupiers, regardless of whether they actually caused the contamination (e.g., 'Class B persons': sect. 78F(4), Environmental Protection Act 1990 (UK)). Where no alternative liable party can be found or made to pay, the government must take on the responsibility of remediating the site at the cost of taxpayers. This is also the case where publicly-owned companies or agencies have caused much of the contamination (Boyd 1999: 6).

In developing countries, the challenges to implementing the polluter pays principle are even greater because the requisite political and regulatory conditions may be absent (Luo et al. 2009: 1126). The successful implementation of the polluter pays principle depends on four preconditions: the legislation of environmental standards, a climate of regulatory enforcement, an absence of bureaucratic corruption, and an environmentally conscious public opinion. Often, not all of these factors are present in developing countries. While this may not prevent multinational companies from bearing responsibility for sites they have contaminated in developing countries, it can be a major impediment to enforcing liability on domestic companies.

2.7 Regulatory Trends in Remediation of Site Contamination

2.7.1 Historical Perspective—Trend to Site-Based Risk Assessment

Early approaches to the remediation of contaminated sites generally reflected a lack of understanding as to how contaminants could spread, how they affected humans and the environment, and what constituted a 'safe' standard of remediation. In the 1970s and 1980s, remediation was largely carried out on an ad hoc basis, as and when governments became aware of sites which were heavily contaminated (Vegter 2001: 100). Identification and remediation of sites took place in the absence of an overarching regulatory framework. Contaminated sites were mostly perceived and treated as isolated incidents rather than as part of a widespread problem requiring a systematic approach (Nathanail and Bardos 2004: 1).

Two countries that are widely considered 'pioneers' in the formulation of national site contamination law and policy are the United States and the Netherlands. In 1976, the United States Government passed the Resource Conservation and Recovery Act, which enables site contamination on licensed, operating industrial facilities to be regulated. The discovery of large-scale contamination at Love Canal in New York State in 1977 led to the passage of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, commonly known as 'Superfund') in 1980, which deals primarily with abandoned or 'orphan' contaminated sites. Both of these statutes are designed to ensure that the polluter pays principle is applied wherever possible and that orphan sites are remediated (United States International Trade Commission 2004: vii). Some other jurisdictions have subsequently adopted the Superfund model in their own domestic approaches to site contamination (United States International Trade Commission 2004: vii; Fletcher 2003: 35–36).

In 1983 the Dutch Government introduced the 'multifunctionality' approach to remediation of contaminated sites in response to a high-profile contamination incident at Lekkerkerk in 1980. This was implemented through the Soil Cleanup (Interim Measures) Act 1983 and the Soil Protection Act 1987 (de Roo 2003: 169; Honders et al. 2003: 2). The multifunctionality approach aimed to maximise risk control by setting very high standards for soil quality in remediation (Luo et al. 2009: 1131). The approach was intended to render sites safe for any use, regardless of their actual or proposed use (Luo et al. 2009: 1131; Visser 1993: 45–46).

However, by 1997, the costs of the multifunctionality approach proved prohibitive, and the Dutch Government turned to a site-based risk assessment approach and other strategies for contaminated site management (Dutch Ministry of Housing, Spatial Planning and the Environment 1997; Luo et al. 2009: 1131). Under this approach, the need for, and means of, remediation are determined by reference to the current, or proposed, use of the relevant land and may also take into account the likelihood of human exposure by reference to bioavailability and other attributes of the contamination.

At first, several countries emulated the Dutch multifunctionality approach throughout the 1980s and 1990s, but eventually they also found the costs excessive (Layard 2006: 136). Since the late 1990s, most developed countries have moved to adopt less stringent remediation standards. As Nathanail and Bardos (2004: 1) observe:

> It is now widely recognised that drastic hazard or contaminant control, e.g. cleaning up all sites to background concentrations or to levels suitable for the most sensitive landuse, is neither technically or economically feasible nor is such control compatible with sustainable development.

This is particularly relevant for 'brownfields' and 'orphan' sites, many of which are likely to remain unused for a considerable time if a rigid and expensive cleanup standard is applied to any potential redevelopment (Preston 2008: 167). It has therefore become more common to apply a standard of remediation that renders sites sufficiently 'clean' for their current or proposed use. A site-based risk management approach can be used to inform the decision as to which standard and method of remediation is appropriate in each case (Preston 2008: 167).

One of the consequences of the multifunctionality approach, particularly at the time it was first implemented, was that it necessitated the use of intrusive remedial techniques. To ensure that a very high standard of soil quality was attained, contaminants were often removed and treated off-site, or secured within thick concrete casing (Vegter 2001: 98). The 'dig and dump' approach to remediation (which usually involves the removal and disposal of contaminated soil to landfills) became a widespread practice in developed countries, attracting criticism that it was simply moving the contamination problem elsewhere (Luo et al. 2009: 1126). In response to the adoption of less stringent remediation standards, and calls for more 'sustainable' and cost-effective remediation approaches, techniques for the retention of contaminants in situ began to emerge in the 1990s (Nathanail and Bardos 2004: 111; Preston 2008: 166–167).

2.7.2 Modern Approach—From Regulation to Brownfields Redevelopment

It was only in the 1990s that most developed countries began to take stock of their site contamination legacies and formulate strategies for progressive, prioritised remediation. Most developed countries now have nationwide remediation programs in place, and other countries are in the process of preparing their own. Those countries with national programs usually prioritise particular sites, such as those with the heaviest contamination or presenting the highest risk to surrounding populations.

However, in tandem with the departure from the high remediation standard of multifunctionality in the late 1990s, there has been a shift in focus in many developed countries from a regulatory (or ‘command and control’) approach to a market-based one (see generally, Fowler 2007). This is due not only to the high costs of regulatory compliance and enforcement, but also to the associated liability issues and procedural delays involved in redeveloping contaminated sites. Few developers would knowingly take on previously contaminated sites, resulting in many sites remaining idle for years.

The United Kingdom and the United States are examples of countries that now address most of their less contaminated sites (particularly ‘brownfields’) through a market-driven approach (Guignet and Alberini 2008: 1). Voluntary remediation of such sites—which is often undertaken by developers—is encouraged through a combination of measures, such as liability relief and financial incentives (Guignet and Alberini 2008: 1–2; United States Environmental Protection Agency 2006a, b). This has resulted in significant reductions in the number of sites awaiting remediation (United States Environmental Protection Agency 2005: 23–24). In this regard, the market-driven approach has so far been viewed as more effective than the command and control approach, although more sites are now being remediated to a lower standard and with minimal regulatory supervision. This in itself has the potential to cause problems in terms of liability for any residual or new contamination, and long-term restrictions on site uses. It is important that these issues be addressed adequately in any modern regulatory framework for site contamination.

2.7.3 Post-remediation Measures (‘Long-Term Stewardship’)

As preferences have grown for more cost-effective remediation solutions, and there has been greater reliance on in situ and on-site cleanup methods, it has become more important to consider ‘aftercare’ or post-remediation measures. In the United States, this is called ‘long-term stewardship’ (LTS), and it generally applies to ‘sites where long-term management of contaminated environmental media is necessary to protect human health and the environment’ (United States Environmental Protection Agency 2006b).

Post-remediation measures should be part of the overall management plan for any site at which there remains a risk of future contamination following the completion of remediation works. The proportion of remediated sites at which such a risk remains is growing (e.g., in the United States), but the regulatory regimes in many developed countries have been slow to recognise the need for clear and detailed regulations on post-remediation.

Post-remediation measures usually involve a combination of two broad types of measures: engineering (or ‘physical’) controls and institutional (legal and/or administrative) controls. Engineering controls comprise the physical barriers or structures designed to monitor and prevent or minimise exposure to contamination, such as gas extraction and combustion, or containment (United States Environmental Protection Agency 2006b: 6). Institutional controls include administrative or legal instruments that minimise the potential for human exposure to contamination by limiting land or resource use, such as zoning, notices and warnings, easements, restrictive covenants, permits and administrative orders (United States Environmental Protection Agency 2006b). All of these measures need to be able to adapt to changing uses and conditions of the relevant site over time, to ensure ongoing requirements for protection are met.

Long-term stewardship is becoming a contentious issue, due to the questions of liability that arise in connection with the transfer of affected sites, the potential for remedial works to be re-opened in the future, and the uncertainties regarding costs (United States Environmental Protection Agency 2006b: 1). USEPA noted in 2006 that roles and responsibilities for long-term stewardship stakeholders were often not clearly delineated and required elaboration, along with other issues (United States Environmental Protection Agency 2006b: 14–15).

The duration of the post-remediation phase depends on many factors, such as the characteristics of the contaminant(s), their ability to migrate, proximity to receptors, the sensitivities of the surrounding population, and the intended site use. The use of a site may be restricted until the necessary aftercare is completed, which may be several months, years or even indefinite (United States Environmental Protection Agency 2006b: 1). Post-remediation measures normally include regular monitoring as a minimum, but may also involve ongoing passive or active controls.

There may be several private and public stakeholders involved in the aftercare of a particular site. These may include government agencies (sometimes at both a national and sub-national level), private parties who either own the site or have an interest in it, local communities and other interest groups affected by the site, together with developers, lenders, insurers and trustees. Each stakeholder has a particular role in the aftercare process, whether it is implementation, monitoring or enforcing the relevant institutional and engineering controls. Ideally, their responsibilities are clearly defined in a legal or other formal document to ensure the smooth and timely operation of post-remediation measures (World Federation of Scientists 2004: 4).

However, legal, political and practical obstacles often do prevent remediated sites from being returned to use within an appropriate timeframe. In response to these problems, and in an effort to achieve a consistent approach to long-term stewardship across the United States, a model law has been developed and actively promoted over the past several years (Strasser and Breetz 2002; see also Chap. 5, Case Study 5.2). The Uniform Environmental Covenants Act (UECA), which by 2012 had been enacted in 24 states across the country (Uniform Law Commission 2012), aims to eliminate the obstacles to using institutional controls to manage sites where residual contamination remains.

The UECA allows the use of voluntary environmental covenants that attach permanently to individual sites. An environmental covenant may involve a land use control such as protection of a concrete cap, a restriction on certain site uses, or maintenance of monitoring equipment. Environmental covenants are binding on subsequent site purchasers and tenants, and are therefore enforceable. They are also listed on the local land registry (Kerr 2006: 1).

However, the UECA leaves some aspects of long-term site management to be dealt with by Federal or State governments. For example, each State may decide the relevant remediation standards that are to apply to affected sites, and whether liability for remediation should be limited and/or transferable between parties. Individual site remediation plans must still be approved by Federal or State regulatory agencies, and one of these agencies must be a signatory to the environmental covenant. In addition, notice of the environmental covenant must be provided to all relevant parties with an interest in the site (Kerr 2006: 1).

The UECA effectively removes the practical and legal barriers standing in the way of site redevelopment, and facilitates greater certainty in real estate transactions (Strasser and Breetz 2002). As a result, valid environmental covenants cannot be inadvertently extinguished by application of various common law doctrines, adverse possession, tax lien foreclosures, less restrictive zoning changes and marketable title statutes (Kerr 2006: 2).

Proponents of the UECA (Strasser and Breetz 2002) noted in the early stages of its drafting that

> Institutional controls offer great promise to improve environmental cleanup and the reuse of contaminated property. These controls make risk based cleanups possible by protecting against the risks presented by the residual contamination. Yet to achieve this protection, the terms of the controls must be clearly established and their enforcement must be realistically assured.

The need for effective, practical post-remediation measures is particularly evident at former landfill sites, where a wide range of contaminants may have been deposited over many years, potentially forming a highly toxic and unpredictable combination. Monitoring of former landfill sites may be required for at least 15–30 years, depending on the jurisdiction. For example, India requires post-closure monitoring for 15 years, Australia for 25 years and the United States for 30 years (Agamuthu 2006). In the European Union, there is no specified timeline at all, but monitoring of former landfills must be carried out for as long as necessary and until the site is certified safe (Agamuthu 2006, citing the European Directive on Landfill of Waste 1999, art. 3).

In relation to other high-risk contaminated sites, the World Federation of Scientists (2004) has prepared a draft memorandum of understanding (MOU) on aftercare measures for sites contaminated with radioactive materials and hazardous wastes. The purpose of the MOU (World Federation of Scientists 2004: 2–3) is to initiate a dialogue that will

> promote a greater level of consistency, effectiveness and public health and environmental protection at contaminated properties associated with government activities throughout the

world and should help foster a stewardship ethic into remediation and post-remediation activities.

The MOU outlines several principles to guide the design, management and implementation of long-term stewardship functions and activities (World Federation of Scientists 2004: 4–6). It also sets out the ‘site components’ that should be included in all aftercare situations, such as documentation on site history and contamination, aftercare management plans and several other plans and procedures for a range of stakeholders and activities (World Federation of Scientists 2004: 6–7).

2.8 Conclusions

Site contamination has presented a major challenge to developed countries since the 1970s, particularly in heavily industrialised regions, and regulatory measures have evolved significantly over the last decade. Non-regulatory measures for addressing contaminated sites, particularly brownfield sites, have also been formulated in some developed countries to encourage the prompt remediation and re-use of sites which might otherwise be sidelined. Issues of funding and liability are most likely the main impediments to remediation in countries that do not yet have such initiatives in place.

Different regulatory approaches, site management methods and remediation standards are used around the world to address site contamination, making it difficult to discern one common approach, method or standard. However, it is recognised that the introduction of relevant regulations is essential to instigating the identification and remediation of contaminated sites in any country. As the United States International Trade Commission (2004: vii) notes:

> The primary force behind the establishment of remediation services markets worldwide has been the passage of legislation which requires cleanup of polluted sites and which assigns liability for the associated costs.

In developing countries there is a need to promptly identify which sites need remediation, and prioritise them, so that adverse effects can be minimised and sites can be returned to their intended use as quickly as possible. Through initiatives such as the Obsolete Pesticides Programme and the Toxic Sites Identification Program, developing countries are gradually compiling inventories of potentially contaminated sites. Although their progress in remediating sites has so far been modest, it is likely to gain strength in the future as specific policies and regulations are introduced (United States International Trade Commission 2004: 7–4; Blacksmith Institute 2012c).

As the rate of site identification and assessment increases, developing countries will need to have clear and comprehensive national laws or policies in place to guide decision-makers and other stakeholders in remediation efforts. As Amparo et al. (2011, citing Hanrahan et al. 2007: 9) observe:

> Developing countries are particularly vulnerable to the effects of toxic pollution on human health due to insufficient technical and financial resources as well as a lack of regulation and enforcement; remediation is often considered secondary to more pressing government priorities such as education and primary health care. This lack of resources means it is crucial that cleanup efforts be focused and effective.

This highlights the need for either some form of international instrument concerning site contamination or other means of ensuring take-up of ‘best practice’ legislation by developing countries.

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