Towards efficient policies for soil pollution prevention and remediation of contaminated sites in Korea

Sang Il Hwang[1] and Eung-Ryeol Park[2]
1) Research Division, Korea Environment Institute. Tel 02 380 7756. email sangilh@kei.re.kr
2) Soil Conservation Division, Nature Conservation Bureau, Ministry of Environment. Tel 02 504 9290 email parker@me.go.kr

Abstract

The objectives of this paper are to overview present status of soil pollution in Korea, to review the current policies and management strategies for soil pollution prevention and remediation of contaminated sites, and to suggest some recommendations to be considered toward more efficient policies. Soils in Korea are contaminated mainly by industrial facilities, landfills, underground storage tanks, abandoned/inactive mines, military camps, and other sources. Concentrations of most of soil pollutants were similar to the background levels, except for a few heavily contaminated sites such as industrial sites or abandoned/inactive mines. The Soil Environment Conservation Act (SECA), which was effective from 1995, provides a comprehensive legal framework for both preventing soil pollution and remedying contaminated sites in Korea. The Act includes various management policies such as the designation of standards and soil pollution policy area, soil monitoring networks, management of suspected contamination sources, and extended 'polluter-pays' principle. To make current policies more efficient and reasonable, some policies or strategies such as the establishment of national priority list, more detailed standards, risk-based cleanup goal, fund raise, soil erosion problem, and finally, integrity between soil and groundwater management frameworks may need to be pursued in the long term.

1. Introduction

With rapid industrialization and urbanization since the 1960s in Korea, large quantities of contaminants have been discharged into the environment, thus giving rise to serious environmental pollution problems. Once contaminants enter the environment, some of them are very difficult to remove. Especially when the contaminants are carried into soil, they tend to accumulate there with time, and enter into the groundwater system or the food chain, causing harm to human health. However, given its latency and invisibility, soil pollution has received less attention, compared with other environmental problems such as water and air pollution.

During the past decade, Korean government, especially the officers of the Ministry of Environment (MOE), and related researchers have done many works to establish more efficient policies for both protection from soil contamination and remediation of contaminated sites. In this paper, we overview the present status of soil pollution in Korea, followed by a brief explanation for their previous works. Then, we discuss the perspectives towards efficient policies in soil quality management in Korea.

2. Present status of contaminants in Korean soils

2.1. Major sources of contaminants in soils

In Korea, there are five main causes of soil pollution: (1) landfills, (2) underground storage tanks, (3) abandoned or inactive mines, (4) closed-down military camps, and (5) industrial sites (Park et al., 2002).

2.1.1. Landfills

In Korea, landfills today are built with elaborate leak-prevention system, but the older ones were poorly designed and are leaking leachates, which are contaminating surrounding soil and shallow groundwater. There are approximately 2395 open dumps and 24000 to 36000 closed or abandoned landfills in the United States (Bedient et al., 1994). In Korea, there are 1565 landfill sites that are being used or closed. Many older landfills were located by not fully taking into account soil and hydrogeologic conditions, and consequently have been situated in environmentally sensitive area. Therefore, the closed landfills occupying 75 % among total number of the existing landfills are becoming one of the major sources for soil and groundwater contamination, because most of their leachates are not being treated properly (Park et al., 2002).

2.1.2. Underground storage tanks

A source of potential soil and groundwater contamination that has become an important concern in Korea is leaking underground storage tanks (USTs). USTs can leak due to corrosion of the metal or faulty piping. In the United States, the Office of Technology Assessment (OTA, 1984) has put estimates on the number of hazardous and non-hazardous USTs at 2031 and 2.5 million, respectively. Prior to December 22, 1998, about 80% of USTs were made of unprotected bare steel, which can corrode and leak (Michigan Office of the Auditor General, 2002). Predpall et al. (1984) estimated that as much as 23% of all tanks leak. The American Petroleum Institute has estimated that approximately 50% of the bare steel USTs will develop a leak within 15 years after being installed (Michigan Office of the Auditor General, 2002).

In Korea, the number of USTs containing petroleum hydrocarbon and hazardous materials is estimated to be approximately 26000 and 600, respectively. Steel tanks are being replaced by double-walled or fiberglass reinforced plastic (FRP) tanks, but faulty piping and subsequent leaks still occur (MOE, 1998). The National Institute of Environmental Research (1997) found that approximately 36% of the 529 investigated USTs leak and older USTs are more corroded.

2.1.3. Abandoned or inactive mines

Abandoned or inactive mines contain a lot of highly toxic chemicals such as arsenic and cyanide, resulting from past mining operations. Water seeping through, and flowing out of mine workings tends to leach many chemicals out of the rocks. Highly contaminated water frequently collects in pits, holding ponds or natural depressions. Such standing water is likely to be acidic and also contain heavy metals and other hazardous compounds that can be toxic at the high concentrations. Dangerous combinations of lead, mercury, zinc, arsenic and even cyanides can pose direct threats to human health and induce soil and groundwater contamination.

The tailings and waste rock left over from mining and processing the ore is usually left behind in large piles or left as large waste dumps at the exit of the mine tunnel. Coal Industry Promotion Board (1994) has estimated that there are 344 abandoned and inactive coal mines in Korea. They reported that about 300 sites among these mines have untreated tailings and waste rocks and so surrounding soil and groundwater is contaminated. The Commerce, Industry, and Energy

(MoCIE, 1998) estimated that there are approximately 900 abandoned or closed mines in Korea.

2.1.4. Closed-down military camps

Military camps typically have two kinds of sources, i.e., (1) USTs for fuels and (2) on-site landfills for treating their own wastes and so can contaminate surrounding soil and groundwater systems. Park et al. (2002) estimates that there are approximately 100 military camps that have been relocated or closed down since 1990 in Korea.

2.1.5. Industrial sites

Industrial facilities usually have a greater possibility to contaminate surrounding soil and groundwater. Little comprehensive investigation has been yet taken to identify contaminated soils around these sites (Park et al., 2002). However, Park et al. (2002) assumes that soil and groundwater around most of industrial sites would be already contaminated.

2.2. Background levels of contaminants in Korean soils

Background levels of contaminants are fundamental to understand the natural soil environment. They provide clues for tracing soil contamination history, stipulating environmental protection criteria, and their control in contaminated soils (Wang, 2000). In an attempt to determine the degree of pollution by contaminants in soils, it is of primary importance to establish the natural background levels of these contaminants, and then subtract them from existing values of contaminant concentration to derive the contribution caused by anthropogenic influences. Such analysis can also tell us where treatment measures should be carried out in these contaminated soils.

Background levels of some heavy metals in soils of Korea are shown in Table 1 and compared with those of Japanese soils. Background levels of heavy metals in Korean soils are generally lower than those found in Japan (Table 1). This difference is possibly due to the difference in soil parent materials between the two countries, where granite is the major parent material in Korea and volcanic ash in Japan (Yang et al., 2000).

Table 1. Background levels of some heavy metals in soils of Korea and Japan*

Soils	Cd	Pb	Hg	Cu	Zn	As
			mg/kg			
Korea[a]	0.140	5.38	0.09	4.00	4.36	0.560
Japan[b]	0.410	6.70	-	9.10	15.20	8.500

*0.1 N HCl-soluble Cd, Pb, Hg, Cu, Zn, and 1 N HCl-soluble As

[a]Topsoils (0~15 cm) were collected during 1987-1988 from the unpolluted paddy soils (Rhu et al., 1988).

[b]Yang et al., 2000.

2.3. Distribution of contaminants in soils

According to results of the nationwide soil monitoring networks operated by the MOE, heavy metal distribution of the agricultural lands are similar to those of the background levels in Table 1 (Yang et al., 2000). Most of heavy metal concentrations in soils are fairly constant with time; however, concentrations of some metals such as lead tended to decrease with time. Especially, lead concentrations in soils from the roadside are higher than those in soils from other areas, but decreased with time. This distribution pattern is probably related to the use of unleaded gasoline in motor vehicles. Concentrations of metals in soils from residential areas were lower than other industrial areas but were also similar to the background levels. These results indicate that the average values of the metal concentrations were similar to the background levels and seem to be safe for crop cultivation, except for a few contaminated areas (Yang et al., 2000). Also, other hazardous chemicals such as PCBs, cyanides, phenols, and total petroleum hydrocarbons are found to be negligible, except for a few contaminated sites, on the basis of the results from the nationwide and regional soil monitoring networks.

3. Towards efficient management strategies

In recent years, there have been increasing occurrences of soil contamination having heavy metals and organic chemicals from the mines, urban, and industrial areas. A separate law dealing with soil pollution had not been enacted in Korea by 1994, and rather few articles were included in the Water Quality Conservation Act and Mines Recovery Act that dealt especially with contamination of agricultural land and abandoned/inactive mines. The Soil Environment Conservation Act (SECA) was promulgated in 1994 by the MOE and was effective from 1995, in which provides a comprehensive legal framework for both preventing soil pollution and remedying contaminated sites. The following is the present legal framework of SECA and then we discuss the perspectives towards efficient policies in soil quality management.

3.1. Soil quality standards

For target soil pollutants, the SECA has designated total of 16 substances such as heavy metals (Zn, Ni, Cd, Cu, As, Hg, Pb, Cr^{+6}), organophosphate compounds, PCBs, cyanide, phenol, petroleum hydrocarbons (total petroleum hydrocarbon and BTEX), fluorides, TCE, and PCE. Two separate standards are set for all pollutants, i.e., soil pollution *potential* levels and *regulatory* levels. Soil pollution *potential* and *regulatory* levels are designated as concentrations of the pollutants that are considered to cause *possible* and *unacceptable* harms, respectively, to human health, animals, and plants. In addition, these levels are designated separately for two broad-categorized land use types, i.e., agricultural and industrial areas. Stricter levels are applied for the latter type.

3.2. Soil monitoring networks

Two separate *nationwide* and *regional* monitoring networks are being operated after several modifications since 1987. The *nationwide* monitoring network consisting of 1500 measurement sites is established to identify temporal change of overall soil contamination across the country and is operated by the MOE. The *regional* monitoring network focuses mainly on finding out where the contaminated sites are. It consists of approximately 2000 measurement points (mainly near industrial areas, inactive/abandoned mines, or landfills) and operated by local governments. For soils where concentration of a pollutant is found to be above the targeted soil pollution *potential* level, more detailed investigation is taken for the corresponding contaminated area, and then remedial action is taken to recover the contaminated areas.

3.3. Suspected contamination sources

Facilities or USTs that contain soil pollutants designated in the SECA are listed and specially managed according to the procedure in the SECA. These suspected contamination sources listed include USTs (containing petroleum hydrocarbons or hazardous liquids) and oil pipelines. Anyone who wants to install these suspected contamination sources must notify specifications of his/her facilities (which must include equipments for preventing soil pollution) to local government. Investigation must be made on a regular basis to determine if soils near these sources are contaminated. More detailed investigation is made for contaminated areas where concentrations of related pollutants are found to be above the targeted soil pollution *potential* level, and then remedial action is taken to recover the contaminated areas.

To trigger self-managed investigation and remediation, the MOE has signed an agreement with five oil refineries (covering over 90% of the total oil being distributed in the country) that are operating most of large-sized suspected contamination sources, on December 2003. This agreement encourages them to play a leading role in self-managed investigation and remediation.

3.4. Soil pollution policy area

The MOE may designate soil pollution policy areas in which (1) concentration of a certain soil pollutant is found to be above its soil pollution *regulatory* level or (2) local government suggests the MOE for seriously-contaminated area to be specially regulated. After the designation of a policy area, the corresponding local government is authorized to establish a remedial action plan. Actual remedial actions are carried out by local government or polluter(s).

3.5. "Polluter-pays" principle

In accordance with the "polluter-pays" principle within the SECA, the party who caused the pollution must pay for compensation plus remediation costs. In addition to the polluter, the owner or occupier is also responsible for the costs. So, both the seller and buyer may want to investigate in detail the degree of soil contamination of the corresponding suspected contaminated site because both parties want to make clear their liability for possible compensation plus remediation costs. To achieve this process legally, the Soil Environment Assessment is introduced in detail by the SECA. It triggers now self-managed investigation and remediation.

3.6. Remediation for inactive/abandoned mines

The MOE is playing a leading role in investigating in detail and remedying inactive or abandoned mines that are one of major contamination sources in Korea.

The MOE has been conducting detailed investigation and remedial actions on 158 suspected contaminated mines since 1995. Approximately US$ 28 million has been spent since 1995 for this project.

3.7. Next steps for efficient soil quality management

3.7.1. National priority list

The MOE and local governments have operated two separate nationwide and regional monitoring networks, respectively. The MOE has investigated suspected contaminated sites on an irregular basis. But, through this procedure, the MOE found out only limited number of contaminated sites that need to be remedied because more systematic and detailed investigation has not yet been carried out. More systematic investigation needs to be made for suspected contaminated sites across the country such as inactive/abandoned mines, landfills, closed-down military camps, industrial complexes, individual industrial plant areas, existing contaminated sites reported by accidents and the public. And then, a *national priority list* needs to be established on the basis of soil analysis, future land use, and risk.

3.7.2. Standards according to more detailed land use types

Standards are currently designated for two land use types that are very simply categorized. Standards need to be set (1) for more detailed land use types and (2) on the basis of risk assessment for human health and ecosystems.

3.7.3. Risk-based remediation strategy (RBRS)

Under the current SECA, all contaminated sites where the concentration is found to be above standards must be remedied, regardless of the potential for exposure and the toxicity of the contaminants of concern in soil. Risk-based remediation strategy (RBRS) needs to be established to set up soil cleanup goals on the basis of more scientific background.

3.7.4. Funding for soil investigation and remediation

Although the SECA have established the "polluter-pays" principle, it is not uncommon that there are contaminated sites that need to be remedied, but the polluter(s) cannot be identified or is not able to pay for compensation or remediation costs. For these sites, funds like Superfund in the United States need to be raised because of possible financial difficulty of the corresponding local governments.

3.7.5. Soil erosion

Approximately 84% of all Korean landscapes have a slope above 7% and Korea has very heavy rainfall records in summer season. Together with rapid industrialization and urbanization since the 1960s, these conditions make soils more erodible. Efficient management strategies need to be studied scientifically and set up legally.

3.7.6. Integrity between soil and groundwater management frameworks

Groundwater contamination problem is closely related to the corresponding soil contamination. There is no integrity between soil and groundwater management frameworks because they are separate. For example, soil contamination problem is dealt with under the SECA and groundwater problem under the Groundwater Act. More integrated legal and organizational framework needs to be pursued in the long term.

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국문요약

본 논문은 한국의 토양오염 현황과 관리정책을 현 시점에서 정리하고 좀 더 효율적인 정책을 추구하기 위한 여러 정책적인 제안점들을 살펴 보았다. 한국의 토양은 주로 매립지, 유류 및 유해물질저장소, 휴폐광산, 군부대, 산업시설 등에 의해 주로 오염되고 있다. 토양오염물질의 농도는 대체적으로 배경농도와 비슷하나, 일부 단위산업시설 주변이나 휴폐광산 등에서 오염도가 오염기준이상인 것으로 나타났다. 1995 년에 제정된 토양환경보전법은 오염의 방지뿐만 아니라 오염된 환경의 개선에 대한 종합적인 법률적 토대를 제공하고 있다. 본 법에는 토양오염물질 및 기준의 설정, 토양오염대책지역의 설정 및 관리, 토양오염측정망 운영, 토양오염유발시설의 설정 및 관리, 토양환경평가제도, 확대된 오염원인자 범위 등 다양한 정책들이 제시되어 있어 오염지역에 대한 조사와 복원을 활성화하고 토양오염관리를 강화할 수 있는 제도적 기반을 마련하였다. 현재의 보전정책을 좀 더 효율적으로 하기 위하여, 국가우선순위 복원목록 수립, 토지이용을 고려한 좀 더 자세한 환경기준설정, 위해성에 기반을 둔 복원기준 설정, 오염지역의 적극적인 탐색과 복원을 위한 재원 마련, 토양침식의 고려, 토양 및 지하수관리정책의 통합체계 구축 등 여러 정책들이 동시 또는 순차적으로 도입될 필요성이 있다.