

# Soil and Groundwater Investigation for Abandoned Industrial Sites

## 1 Background

It is generally considered that industrial manufacturing facilities are the major sources of soil and groundwater contamination. However, in Taiwan, the populous residential area near plants, high frequency of land transactions due to high cost of land, and high level of public interest cause the investigation and remediation of contaminated industrial sites much more complicated than those in the developed countries. To fulfill the need for proactive contamination management with incorporating relevant regulations such as Air Pollution Control Act, Water Pollution Control Act, Waste Disposal Act, Toxic Chemical Substances Control Act, Soil and Groundwater Pollution Remediation Act (SGPRA), Taiwan EPA not only put effort on the management of operating industrial facilities regulated by Article 9 of SGPRA but also on the management of industrial facilities established or terminated after January 1, 2005.

As for the industrial facilities terminated before January 1, 2005, for examples, the mercury contaminated site of Zheng-Tai Company, the lead contaminated site of Jin-Yu Company, and the dioxins contaminated site of China Petrochemical Development Co., their contaminations have caused the environmental damage and public illness which drew attentions to further investigation on other abandoned industrial sites (Figure 1).



◀ Figure 1. Soil contamination was found in An-Shun area. Mercury and dioxins contamination due to operation of China Petrochemical Development Co. have damaged public illness and environment and caused public interest.

## 2 Objectives

Up to date, there are more than 100,000 abandoned industrial sites in Taiwan. To protect the environment and human health, Taiwan EPA has started series of projects since 2004 on investigating the abandoned industrial sites terminated before January 1, 2005. The lack of operating records and history of the corporations makes it hard for the investigators to identify owner/operator liabilities of contaminations and to locate the hot spots. However, Taiwan EPA strives against the limitations to achieve the following objectives through executing series of the pollution investigation projects:

- The short-term goal is to implement the management strategy through data mining and to demonstrate effective investigations.
- The mid-term goal is to draft guidelines with compiled experiences from prior investigations and to provide professional trainings based on standard operating procedure of investigations.
- The long-term goal is to coordinate the relevant departments including the environmental, industrial, financial, insurance, and land administration departments to achieve comprehensive national land management.

## 3 Results

It is a challenge to efficiently screen the candidate sites for investigation without bias from 100,000 abandoned industrial sites with insufficient information of operating records and history of the corporation. Under the consideration of substantial land development, risk assessment and remedial resources, criteria of site screening guidance were conducted to produce immediate, efficient and beneficial results. Based on the creative criteria, Taiwan EPA built up an appreciable and localized guideline, named "conditional screening procedure", for site screening which is outstanding from existing guidelines of other counties with regards to the characteristics of small to medium businesses and case studies on soil and groundwater contamination in Taiwan. In compliance with "conditional screening procedure", the priority list of potential contamination in the screened categories of industry was determined. Several candidate sites from the list were efficiently investigated for demonstration. Thereafter, the demonstrations feed back to establish overall management policy and the nationwide standard procedure of investigation on abandoned industrial sites.

Since 2004, Taiwan EPA has accomplished four subsequent investigation projects. As a result, two thousand and fifty sites were selected from the suspended factories database of Industrial Development Bureau based on twenty high potential contaminated enterprises. With modification and verification of the basic information and site surveyed, two hundred and thirty-seven sites were selected to the score and screen system for the fifty priority investigation sites. Then, one hundred and thirty-five sites were investigated and finally seventy-six of these sites were identified as polluted and should be declared as control sites.

Additionally, to control the investigation quality in correspondence to the demand of SGPRA and to the highest efficiency in the limited resource, Taiwan EPA has compiled technical manuals for the fifteen categories of high potential pollution enterprises. Furthermore, nine seminars of staff training or sites interviews have been practiced (Figure 2, Figure 3, Figure 4).



◀ Figure 2. One hundred and thirty-five sites were investigated during four subsequent investigation projects.



◀ Figure 3. Taiwan EPA has compiled technical manuals for the fifteen categories of high potential pollution enterprises.



▲ Figure 4. Nine seminars of staff training or sites interviews have been practiced during four subsequent investigation projects.

The results of four subsequent investigation projects indicate that fifty-six percent of abandoned sites have been reconstructed for continuous industrial operation, and twenty percent have been redeveloped to residential or commercial land use (Figure 5). The results also show that sixty percent of investigated sites were contaminated (Table 1), which imply that comprehensive management of abandoned industrial sites is necessary to protect the public health and environment.



▲ Figure 5. High frequency of land transactions have caused most of the abandoned facilities been

Projects	Investigated Sites	Verified Sites	Discovery of Contaminated Sites	Ratio of Discovery
First	15	9	5	33%
First	20	10	11	65%
Third	50	32	32	64%
Forth	50	30	28	56%
<b>Total</b>	<b>135</b>	<b>82</b>	<b>76</b>	<b>56%</b>

▲ Table 1. The results of four subsequent investigation projects.





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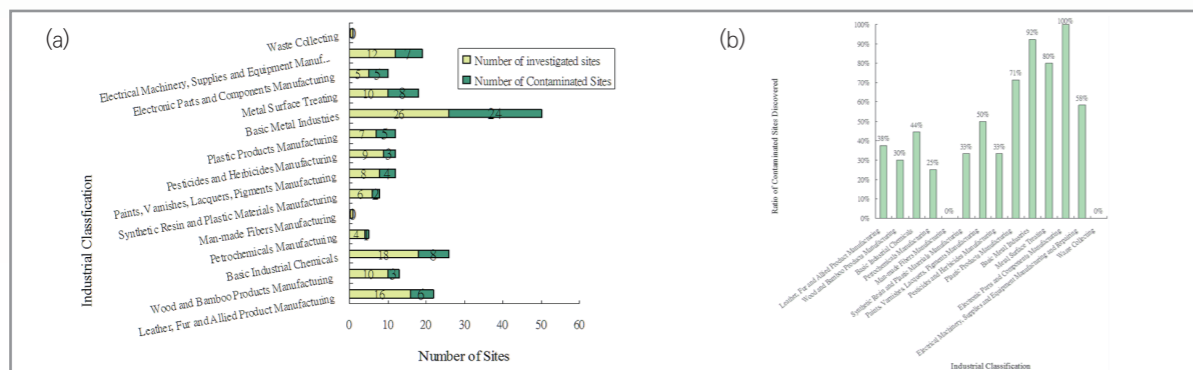
## 3 Results

According to the results of four subsequent investigation projects, most of the screened sites for investigation were verified as contaminated sites. The developed criteria of site screening guidance including characteristics of pollution, environmental risks and institutional control policies are fairly successful on screening the sites with highest contamination potential. It is also confirmed that the strategies applied in the investigation of abandoned site are appreciable to achieve the project goals. The followings present the analyzed results of four subsequent investigation projects:

### 1. Statistics by different categories of industry

According to Figure 6, seven industries were found with the ratio of discovery of contaminated sites greater than 50% :

- Electronic Parts and Components Manufacturing : 5 Sites investigated / 5 Sites pollution discovered ( Ratio of Discovery: 96% )
- Basic Metal Industries : 26 Sites investigated / 24 Sites pollution discovered ( Ratio: 92% )
- Metal Surface Treating : 10 Sites investigated / 8 Sites pollution discovered ( Ratio: 80% )
- Plastic Products Manufacturing : 7 Sites investigated / 5 Sites pollution discovered ( Ratio: 71% )
- Electrical Machinery, Supplies and Equipment Manufacturing and Repairing : 12 Sites investigated / 7 Sites pollution discovered ( Ratio: 58% )
- Paints, Varnishes, Lacquers, Pigments Manufacturing : 8 Sites investigated / 4 Sites pollution discovered ( Ratio: 50% )



▲ Figure 6. The results of four subsequent investigation projects (a) number of contaminated sites (b) ratio of contaminated sites discovered

### 2. Statistics by contaminated media and location of hot spot

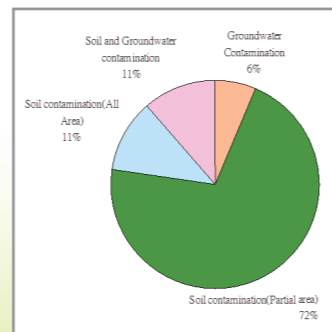
There were 74 sites identified as soil polluted from 76 investigated sites. The ratio of contaminated sites discovered is 97.4%. Of them, 61 sites were identified as partially soil polluted (82.4%) + 13 sites as fully soil polluted (17.6%) ; There were 14 sites identified as groundwater polluted from 79 investigated sites. The ratio of contaminated sites discovered is 18.4%.

There were 9 sites identified as both soil and groundwater polluted (11%), 9 sites identified as fully soil polluted but without groundwater polluted (11%), 56 sites identified as partially soil polluted but without groundwater polluted (72%), and 5 sites identified as only groundwater polluted (6%).

Hot spots of soil contamination were mainly located at manufacturing areas, waste water treatments, vacant lots, storage tanks and piping areas. Hot spots of groundwater contamination were mainly located at manufacturing areas and waste water treatment areas. The statistics of the number and ration of contaminated sites are shown in Table 2 and Figure 7.

Location	Numbers
<b>Hot Spots of Soil Contamination</b>	
Manufacturing area	49
Boiler area, Bake area, Stack, Dust accumulation	8
Storage tank and piping	13
Pool	6
Waste storage	12
Vacant lot	19
Waste water treatment	22
Warehouse	8
Others (pavement crack, Substation)	4
<b>Hot Spots of Groundwater Contamination</b>	
Manufacturing area	8
Storage tank and piping	1
Vacant lot	2
Waste water treatment	4
Warehouse	1

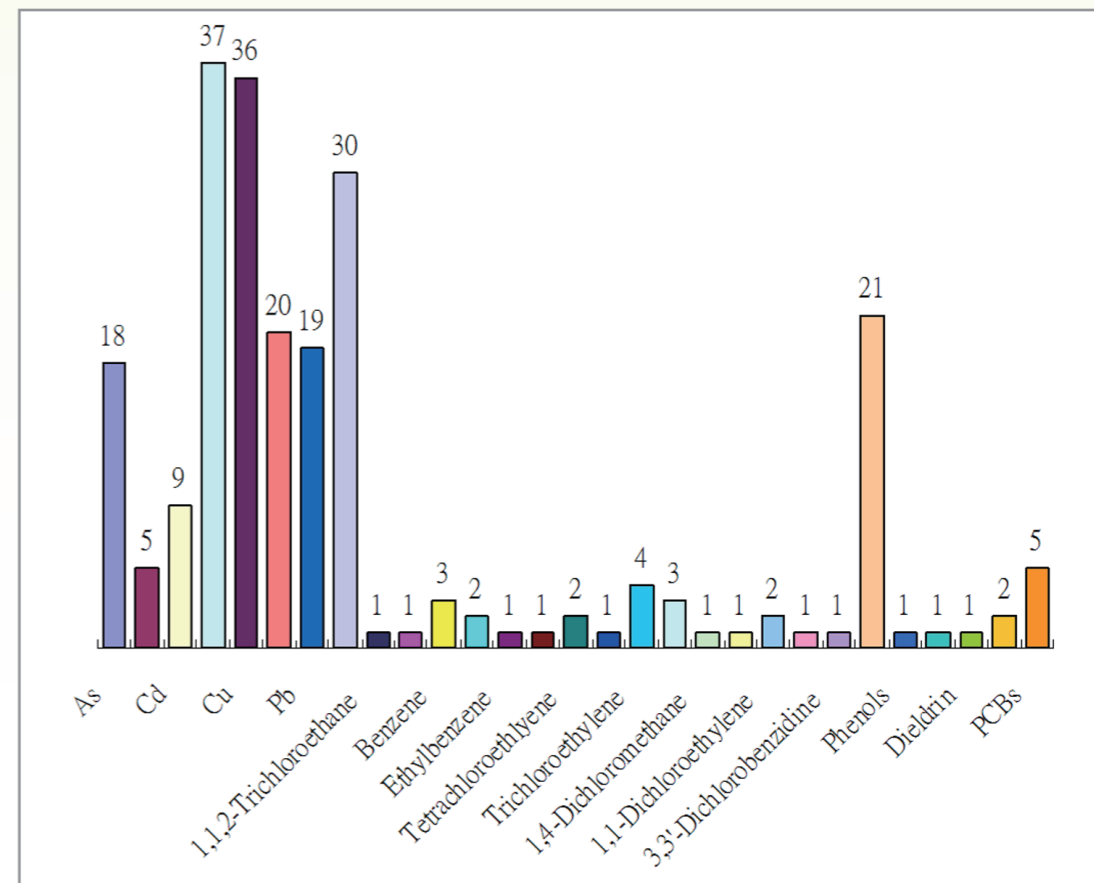
◀ Table2. The statistics of the number of contaminated sites by different location and media



◀ Figure 7. The statistics of the ratio of contaminated sites by different media

### 3. Statistics by pollutants

The identified pollutants are highly correlated to the raw materials and processes applied in manufacturing. The statistics of the ratio of contaminated sites by different pollutants are shown in Figure 8. There were 71 sites with soil contaminated by heavy metals, 22 sites with soil contaminated by TPH. As to groundwater pollution, most sites were contaminated by chlorinated hydrocarbons.



▲ Figure 8. The statistics of the ratio of contaminated sites by different pollutants

## 4 Prospect

“Brownfield” , as a worldwide issue, has been extensively discussed as the insufficient usage of land resources inducing social issues and impacts upon the communities. In Taiwan, the most famous “brownfield” is RCA site. This case educates the stakeholders to pay more attention to the balance between land redevelopment and public risk, and also to the verification of soil quality for abandoned sites.

To achieve the comprehensive estimation of potential pollution sites for the protection of public health and environment, Taiwan EPA has planned another four-year program including “Abandoned Industrial Sites Pollution Overall Review Project” and “Industrial Sites Screening Risk Map Project” . ArcGIS will be conducted to perform the approach by integrating site database, exposure parameters and multi-pathway models to manage the information of overall contaminated sites. Through the spatial analysis of nationwide sites distribution, the remediation site, brownfields and illegal disposal sites can be screened and shown on “Risk Management Map” .

To achieve long-term goal, Taiwan EPA will incorporate the resources from either government or the public sectors to accelerate the investigation of potential pollutions. By systematization of land pollution inspection to instantly reveal the contamination information, the efficient market of real estate management system would encourage land owner/operator to spontaneously inspect the soil quality for pollution prevention and substantial land development.

