• ARTICLE — VOL. 5

# Soil and Groundwater Standards in Asia PAH Degradation Tests with the Multi-Microbial Bio-Agent Oppenheimer Formula™

BioRangers

• Section 1

## Legislation on soil and groundwater contamination in Asia and a growing market

Over the past few years, Asia's economies and industries have developed remarkably. Soil and groundwater contamination has surfaced along with that growth, and legislation has begun to advance in each country.

Korea enacted its Soil Environment Conservation Act in 1995, Taiwan its Soil and Groundwater Pollution Remediation Act in 2000, and Japan its Soil Contamination Countermeasures Act in 2003; in 2016 Thailand followed (a Ministry of Industry regulation controlling soil and groundwater contamination), and China, which is attracting attention, promulgated its "Ten Measures on Soil". China faces severe soil and groundwater contamination, and its market is said to be far larger than Japan's.

• Section 2

## Regulated substances for soil and groundwater in Japan and other Asian countries

The number of substances regulated for soil and groundwater in Japan under the Soil Contamination Countermeasures Act is extremely small compared with other Asian countries (Korea excepted).

Another major difference from other Asian countries is that Japan's environmental standards for soil are set on "leaching" rather than on "content".

Regulated substances and standard values for soil and groundwater [PDF]

The soil and groundwater remediation market in Asia is expected to expand rapidly, but for Japan, with its few regulated substances, most of these substances are unknown territory. Can Japanese companies cope, whether in investigation, analysis or remediation?

Japan's environmental technology for soil and groundwater contamination can hardly be called advanced, and there is a real fear that other Asian countries will overtake it in the near future.

• Section 3

## About PAHs

Japan regulates few substances in soil and groundwater, and regulation of substances derived from petroleum products is extremely sparse in particular.

In other countries, not only in Asia, substances derived from petroleum products are regulated, with standard values set not just for TPH (total petroleum hydrocarbons) but also for BTEX (benzene, toluene, ethylbenzene, xylene) and PAHs (polycyclic aromatic hydrocarbons).

In Japan, although the Oil Contamination Countermeasure Guidelines exist, they deal mainly with oil odour and oil film, and no standard values are set for TPH or PAHs. (Benzene is regulated under the Soil Contamination Countermeasures Act, but toluene, ethylbenzene and xylene are not covered.)

PAHs in particular are little known in Japan and are not seen as a problem, but over the past few years enquiries from abroad have been gradually increasing.

### PAHs (polycyclic aromatic hydrocarbons)

A general term for hydrocarbons made of fused aromatic rings without heteroatoms or substituents, also called fused-ring hydrocarbons; more than 100 such compounds exist.

### Properties

They are lipophilic and poorly soluble in water, adsorb readily to soil, and are non-volatile.

Several PAHs are confirmed carcinogens, mutagens and teratogens.

### Sources of PAH contamination

They are contained in oil, coal and tar deposits.

They are also by-products of the combustion of fossil fuels and biomass fuels.

• Section 4

## PAH degradation tests with the multi-microbial agent Oppenheimer Formula™

### Degradation test 1

"Degradation test on PAHs contained in diesel oil"

Test period: 24 hours

Test medium: water

Table 1 PAH analysis results

| Compound | Initial concentration (mg/L) | Concentration after treatment (mg/L) | Reduction (%) |
|---|---|---|---|
| Acenaphthene | 69,891 | 4,736 | 93.22 |
| Acenaphthylene | 11,327 | 67 | 99.41 |
| Anthracene | 4,687 | 1,159 | 75.27 |
| Benzo(a)anthracene | 28,189 | 6,204 | 77.99 |
| Benzo(b)fluoranthene | 5,105 | 8 | 99.84 |
| Benzo(k)fluoranthene | 10,282 | 303 | 97.05 |
| Benzo(g,h,i)perylene | 5,332 | 121 | 97.73 |
| Benzo(a)pyrene | 8,722 | 346 | 96.03 |
| Chrysene | 74,245 | 4,619 | 93.78 |
| Dibenzo(a,h)anthracene | 8,279 | 2,166 | 73.84 |
| Fluoranthene | 674,730 | 132,581 | 80.35 |
| Fluorene | 96,801 | 6,160 | 93.64 |
| Indeno(1,2,3-c,d)pyrene | 22,433 | 6,306 | 71.89 |
| Naphthalene | 54,088 | 2,991 | 94.47 |
| Phenanthrene | 197,875 | 110,153 | 44.33 |
| Pyrene | 35,279 | 7,045 | 80.00 |
| Total | 1,307,265 | 284,965 | 78.20 |

Source: Oppenheimer Biotechnology, Inc

## Degradation test 2

"PAH degradation test with various microbial agents"

Test period: 15 days

Test medium: water

Table 2 Reduction of each PAH compound by three microbial agents
Unit: %

| PAH compound | FR | FC | TE | CK |
|---|---|---|---|---|
| Acenaphthylene(3) | 45.4 | 50.2 | 49.9 | 19.1 |
| Fluorene(3) | 23.1 | 43.5 | 22.5 | 2.6 |
| Phenanthrene(3) | 29.6 | 19.6 | 21.7 | 3.9 |
| Anthracene(3) | 48.1 | 56.5 | 44.2 | 30.0 |
| Pyrene(3) | 65.3 | 50.2 | 28.8 | 6.7 |
| Benzo(a)anthracene(4) | 81.4 | 63.2 | 49.4 | 18.1 |
| Chrysene(4) | 78.9 | 69.7 | 50.6 | 11.7 |
| Benzo(b)fluoranthene(4) | 88.5 | 82.8 | 66.8 | 18.1 |
| Benzo(k)fluoranthene(5) | 86.7 | 79.8 | 58.6 | 2.2 |
| Benzo(a)pyrene(5) | 87.9 | 81.5 | 67.8 | 24.4 |
| Dibenzo(ah)anthracene(5) | 83.6 | 76.8 | 54.7 | -0.8 |
| Benzo(ghi)perylene(6) | 85.2 | 79.0 | 57.5 | 6.4 |
| Indeno(1,2,3-cd)pyrene(6) | 89.6 | 85.4 | 80.1 | -0.8 |

* The number in brackets is the number of rings in the PAH.

Reference: Wang Xiaoju, Sugisaki Mitsuo, Hosono Shigeo (2010), Study on the remediation of soil contaminated with recalcitrant hazardous chemicals using bioremediation technology, Bulletin of the Center for Environmental Science in Saitama, No. 5, 135-140.