



*A COMMERCIAL APPLICATION OF  
VIROMINE™ TECHNOLOGY*

**CASE STUDY  
REMEDIATION OF AN IRON ORE  
MINE SITE, ULSAN, SOUTH KOREA**

*“Without the addition of Neutra B™ reagent, this project could not have proceeded, as there was no other technically or commercially viable option available in Korea...After one year, we have seen very satisfactory results, with Arsenic at low or non-detectable levels in the leachate from site.”*



*This derelict mine site was contaminated by arsenic generated from abundant arsenopyrite, but successfully remediated using ViroMine™ Technology*

## PROBLEM

Previous iron ore mining operations in the South Korean port city of Ulsan, 250km south-east of Seoul, had contributed to substantial heavy metal and metalloid contamination (including arsenic, cadmium, nickel and zinc). Approximately a third of the entire site and most groundwater was contaminated by arsenic generated from abundant arsenopyrite, the most common sulphide mineral at the site.

In 2002, the landholder, Hundai Industry Development, recognised the potential to remediate the derelict mine in order to construct a large residential apartment complex on the site.

The Korea Agriculture and Rural Infrastructure Corporation (KARICO) was commissioned by Hyundai to research available technologies and propose the best technology to immobilise heavy metals from the soils and lower the arsenic concentration in groundwater, without altering the existing neutral pH.

## VIROTEC TOTAL SOLUTION

In 2002, KARICO contacted Geoenvirontec, a strategic partner of Virotec, to establish laboratory test work to demonstrate the efficacy of ViroMine™ Technology for immobilising heavy metals in soil and removing heavy metals from water, whilst achieving a near-neutral pH in the soil and solution. Together with KARICO staff, Geoenvirontec and Virotec field technicians determined that Virotec's uniquely blended Neutra B™ reagent specifically developed for the dual role of modifying soil pH and binding arsenic and other heavy metals, was ideally suited for the remediation project.

## BACKGROUND



*Ulsan's former Iron Ore Mine*

The Ulsan Iron Ore Mine is in the Ulsan metropolitan area in Korea. Geologically, the area around this mine consists of limestone, serpentine, shale and horfels, and a biotite granite intruded into these sedimentary strata. The iron ore deposits are formed by contact replacement along bedding planes in the limestone or in the contact zone between the limestone and the serpentine. The average ore grade at the Ulsan mine is Fe 43 percent, and individual deposits yield up to 1,708,400 tonnes of iron ore.

The 396,700m<sup>2</sup> mine had been exploited since the 12th century, and was finally closed down in 1992 owing to poor economic prospects. In 1994 Hundai Industry Development purchased the derelict mine site and in 2002 decided to construct an apartment complex on the site. A government-related environmental institution was subsequently engaged to carry out an evaluation of soil and groundwater contamination.



*The Ulsan mine site is 250 km south-east of Seoul in South Korea.*

## > The transformation of Ulsan

Ulsan was largely a small farming village until 1967 when Hyundai Motors was first established, building their first car plant in Yeompo-dong which still exists today downstream from the centre of Ulsan city. In 1974, the first Korean car to bear the Hyundai Motors brand name was unveiled to the world and exported.

In the last five years Ulsan has experienced huge growth from Korea's expanding automotive industry, with chemical companies being established locally to create dashboards from resin, produce paint, etc. With Ulsan's industrial expansion the population of the city has also increased rapidly, creating a demand for land suitable for residential development and leading to Hundai's decision to remediate the disused mine site.



*Arsenopyrite mineral deposits had generated elevated arsenic concentrations in the region*

## TREATMENT METHODS

Bench-scale trials in the Geoenvirontec laboratory determined the effectiveness of Neutra B™ reagent for removing heavy metals from water. The Permeable Reactive Barrier (PRB) configurations below were especially designed so that leachate could be collected and analysed to determine metal concentrations and pH after contaminated water passed through the Neutra B™ reagent layer.

The ViroMine™ Technology applied at the mine incorporated a large-scale impermeable capping method, utilising a layer of Neutra B™ reagent to mitigate further contamination of groundwater. The schematic diagram of the PRB encapsulation indicates the extent of containment of mine waste and control of potentially contaminated fluids (see overleaf).

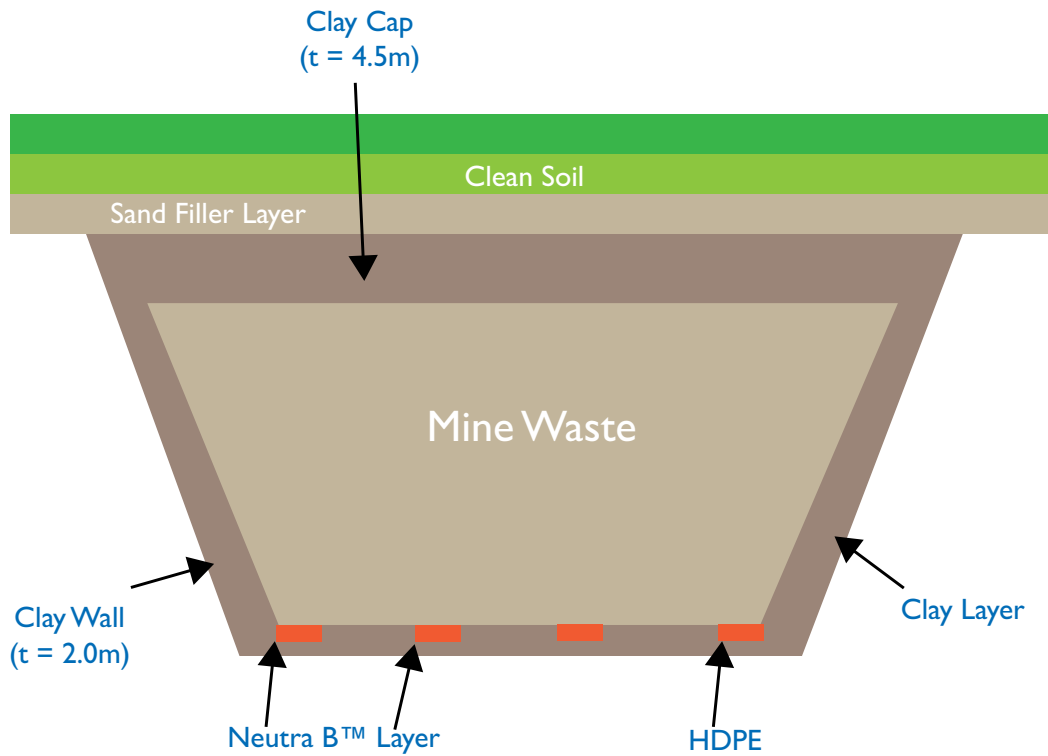


*Ulsan has grown into an industrialised city, with the continued international success of Hundai Engineering and Construction and Hyundai Motors Corporation*

The consistency of the mine waste varied between fine grade and coarse grade. All waste was placed over four layers including two layers of clay, a layer of high density polyethylene plastic (HDPE), and a layer of Virotec's specially formulated Neutra B™ reagent. The Neutra B™ reagent layer was designed to bind to heavy metals effectively and permanently, so that any fluids passing beyond the Neutra B™ reagent layer into the first layer of clay would be free from heavy metals and arsenic.

Additionally, unlike alternative treatments such as liming, a major advantage of using Neutra B™ reagent is that the existing neutral pH at the site would not be jeopardized, due to the unique mineralogy of Virotec's product. Achieving the objective is particularly important because the mobility of arsenic increases as pH increases above about 8.0; the higher pH conditions associated with the use of lime commonly cause an increase in arsenic concentrations in leachates.

TABLE 1: SCHEMATIC OF VIROMINE™ TECHNOLOGY TREATMENT METHOD



## RESULTS

From the bench-scale testing of ViroMine™ Technology's Neutra B™ reagent, a customized blend with most efficient metal-binding properties was derived and applied in the field.



Test work being carried out in the laboratory to determine field application rates of ViroMine™ Technology

During testing, each blend was subjected to about five days of gravity-fed flow of typical mine rock leachate from the area. The metal concentrations and pH were analysed regularly to confirm the stability and overall long-term effectiveness of the Neutra B™ reagent.

Results of laboratory testing indicated that the pH remained near-neutral and stable relative to the control, while all leachates passing through the Neutra B™ reagent layer showed a substantial and sustained reduction in metal concentrations over time.

**TABLE 1: ANALYSIS OF METAL CONCENTRATIONS AND PH USING VIROMINE™ TECHNOLOGY**

| Time Elapsed (hours) | pH      |                   | Arsenic |                   | Nickel  |                   |
|----------------------|---------|-------------------|---------|-------------------|---------|-------------------|
|                      | Control | Neurta B™ Reagent | Control | Neurta B™ Reagent | Control | Neurta B™ Reagent |
| 3                    | 7.3     | 7.0               | 1.0     | 0.04              | 0.22    | 0.39              |
| 9                    | 7.5     | 7.0               | 3.2     | 0.002             | 0.07    | 0.41              |
| 21                   | 7.3     | 7.2               | 3.6     | 0.01              | 0.03    | 0.45              |
| 45                   | 7.7     | 7.2               | 3.6     | 0.01              | <0.001  | 0.43              |
| 69                   | 7.7     | 7.7               | 3.5     | 0.02              | <0.001  | 0.43              |
| 114                  | 7.7     | 7.6               | 3.5     | 0.001             | <0.001  | 0.12              |

The Neutra B™ reagent was particularly effective in lowering arsenic concentrations from 3.5ppm to 0.01ppm (99.7 percent reduction over five days), and cadmium from 0.11ppm to < 0.001ppm (99+ percent reduction over five days).

**TABLE 2: ANALYSIS OF METAL CONCENTRATIONS USING VIROMINE™ TECHNOLOGY**

| Time Elapsed (hours) | Cadium (ppm) |                   | Zinc (ppm) |                   |
|----------------------|--------------|-------------------|------------|-------------------|
|                      | Control      | Neurta B™ Reagent | Control    | Neurta B™ Reagent |
| 3                    | 0.11         | 0.003             | <0.001     | <0.001            |
| 9                    | 0.10         | 0.003             | <0.001     | <0.001            |
| 21                   | 0.12         | 0.003             | <0.001     | <0.001            |
| 45                   | 0.12         | <0.001            | <0.001     | <0.001            |
| 69                   | 0.11         | <0.001            | <0.001     | <0.001            |
| 114                  | 0.11         | <0.001            | <0.001     | <0.001            |

## CONCLUSION

For Hundai Industrial Development, ViroMine™ Technology was a cost-effective and practical solution for remediating the former Ulsan Iron Ore mine site, to a condition that would be safe to go on with plans to develop an elaborate apartment complex on the site.

Virotec's Neutra B™ reagent has achieved permanent binding with heavy metals and metalloids, and continues to remove these contaminants from the mine waste leachate long after completion of the project.

## TESTIMONIAL

*“The ViroMine™ Technology solution to arsenic removal at the Ulsan Iron Ore Mine was a critical component of the larger site remediation work carried out by Hundai Industry Development. Without the addition of Neutra B™ reagent, this project could not have proceeded, as there was no other technically or commercially viable option available in Korea.*

*After one year, we have seen very satisfactory results, with As at low or non-detectable levels in the leachate from the site. As a result of this successful project, the first of its kind in Korea, we are pursuing other opportunities for the promotion of ViroMine™ Technology in South Korea.”*

### **DR JEONGYUL SUH**

Chief Executive Officer  
Geoenvirontec Co. Ltd.



*Hyundai Motors built their first car plant not far from the centre of Ulsan city – and operations have expanded greatly since.*

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