ESTIMATION OF WASTE DUMP VOLUME USING TERRESTRIAL LASER SCANNING

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ABSTRACT: Illegal storage and dumping of industrial waste is one of the environmental protection issues facing local governments in Taiwan. This study documents a case of waste slag dumping in violation of the Waste Disposal Act in Yilan County. The illegal dump was found at a two-hectare plot in an industrial park. While some of the waste slag was stored in a warehouse at the site, most was dumped in an adjacent fenced and gated area. This study shows how a terrestrial laser scanner can be used to measure the volume of the waste slag accumulated at the site both in the warehouse and in the outdoor fenced area. As a result of the measurement of the waste volume, the Local Enforcement Agency (LEA) could issue fines for the violation of the Waste Disposal Act to the responsible company.

1. INTRODUCTION OF LASER SCANNING

Illegal storage and dumping of industrial waste is one of the environmental protection issues facing local governments in Taiwan. The Local Enforcement Agency (LEA) is very serious about finding illegal dumping sites. However, oftentimes the illegal sites are disguised as warehouses or processing plants with tall fences. Even if the sites are discovered, the disguise makes it difficult to determine the extent and volume of illegal dumping. Terrestrial laser scanning (TLS) is a surveying and mapping technology that uses the reflection of laser beams from targets to quickly and safely determine the sizes and distribution of objects in a space. It has been used to map a landslide site (Chen et al., 2010), reconstruct tree trunks (Chen and Chen, 2010), monitor a bridge pier during a push-over test (Chen et al., 2011), reconstruct a building (Mendy and Chen, 2011), preserve a landmark (Tseng et al., 2013), and display a pedestrian bridge in a national park (Wang et al., 2013). We used the same laser scanning technology in this study to map and determine the volume of illegal dumping (Figure 1).

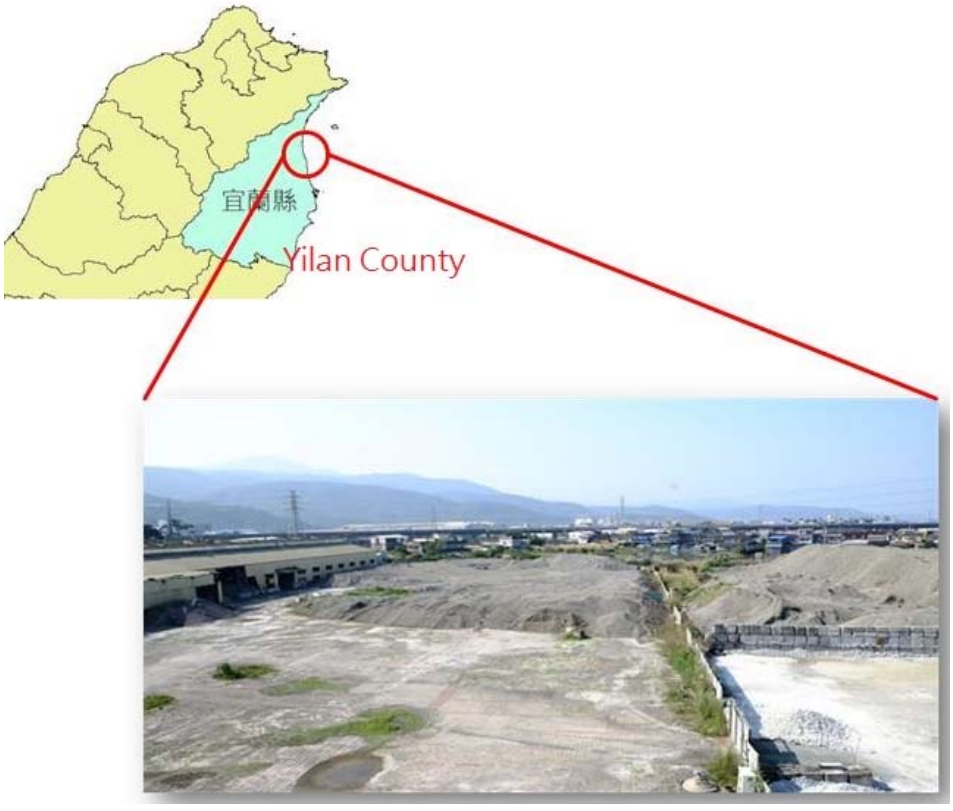

Figure 1 Location and photo of the illegal dumping site

2. RESEARCH PURPOSE

The purpose of this study is to help the Local Enforcement Agency determine the extent and volume of illegal dumping of waste slag. Previous site visits concluded that there was waste slag, both indoors and outdoors. Therefore, we were commissioned by the Center for Space and Remote Sensing Research (National Central University) to set up a total of 12 laser scanning stations to scan the entire site and calculate the volume of waste slag (Figure 2). Among the 12 stations, 10 were outdoors and two were indoors. The outdoor scan had a good coverage of the site, whereas the indoor scan was restricted by limited indoor space and obstacles.

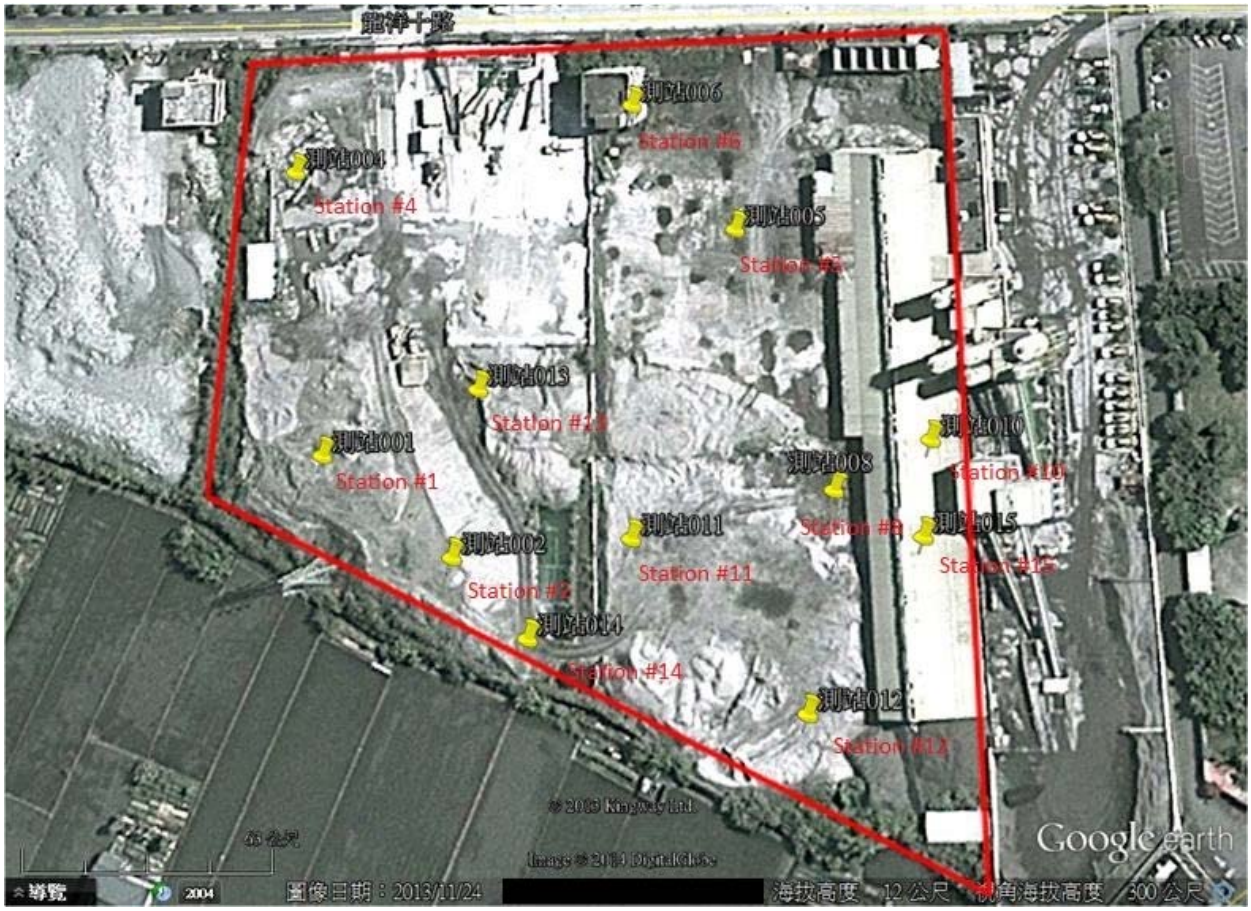

Figure 2 Locations of 12 laser scanning stations

3. RESEARCH PROCEDURES

This industrial park is located in an undisclosed location in Yilan County. The total area of the park is 236 hectares. About 229 businesses are at the industrial park, most of which are fishery and frozen food manufacturing, processing, and packaging plants. The illegal dump was found at a two-hectare plot in the industrial park. The scanning of the two-hectare plot took place on February 24 of 2014.

Figure 3 shows the photos of the field laser scanning activities in action. Researchers set up the terrestrial laser scanner at one of the 12 pre-determined scanning locations. The scanning range of the scanner is about 600 meters. Therefore, only 12 stations were needed to cover the two-hectare plot. To increase the precision of multi-station registration and minimize error propagation, four reflectors were placed at strategic locations on the site (not shown in Figure 2). The selection of reflector locations ensured a clear line-of-sight to the laser scanner.

4. RESULTS AND DEMONSTRATION

The point clouds generated from field laser scanning work were brought back to the office and processed by RiSCAN PRO software. After processing, a virtual 3D model of the site was created and used for subsequent analysis. The precision of matching point clouds was between 0.8 and 3.5 centimeters. To calculate the volumes, the waste slag was divided into four piles and numbered A01 to A04, as shown in Figure 3. The volume of slag piles A01 to A04 were calculated based on the 3D models generated from laser scanning, as shown in Figures 5 to 8. Their volumes were

measured to be from 2,528.7 m^3 to 18,934.9 m^3. The total volume of waste slag combined was 53,819.2 m^3. This number allowed the Local Enforcement Agency to issue fines for the violation of the Waste Disposal Act to the responsible company.

3(a)

3(b)

3(c)

Figure 3 Pictures of field laser scanning work: (a) scanner leveling, (b) scanner set-up, (c) scanner checkup

	Volume (cubic meters)
A01	17674.7
A02	2528.7
A03	18934.9
A04	14680.9

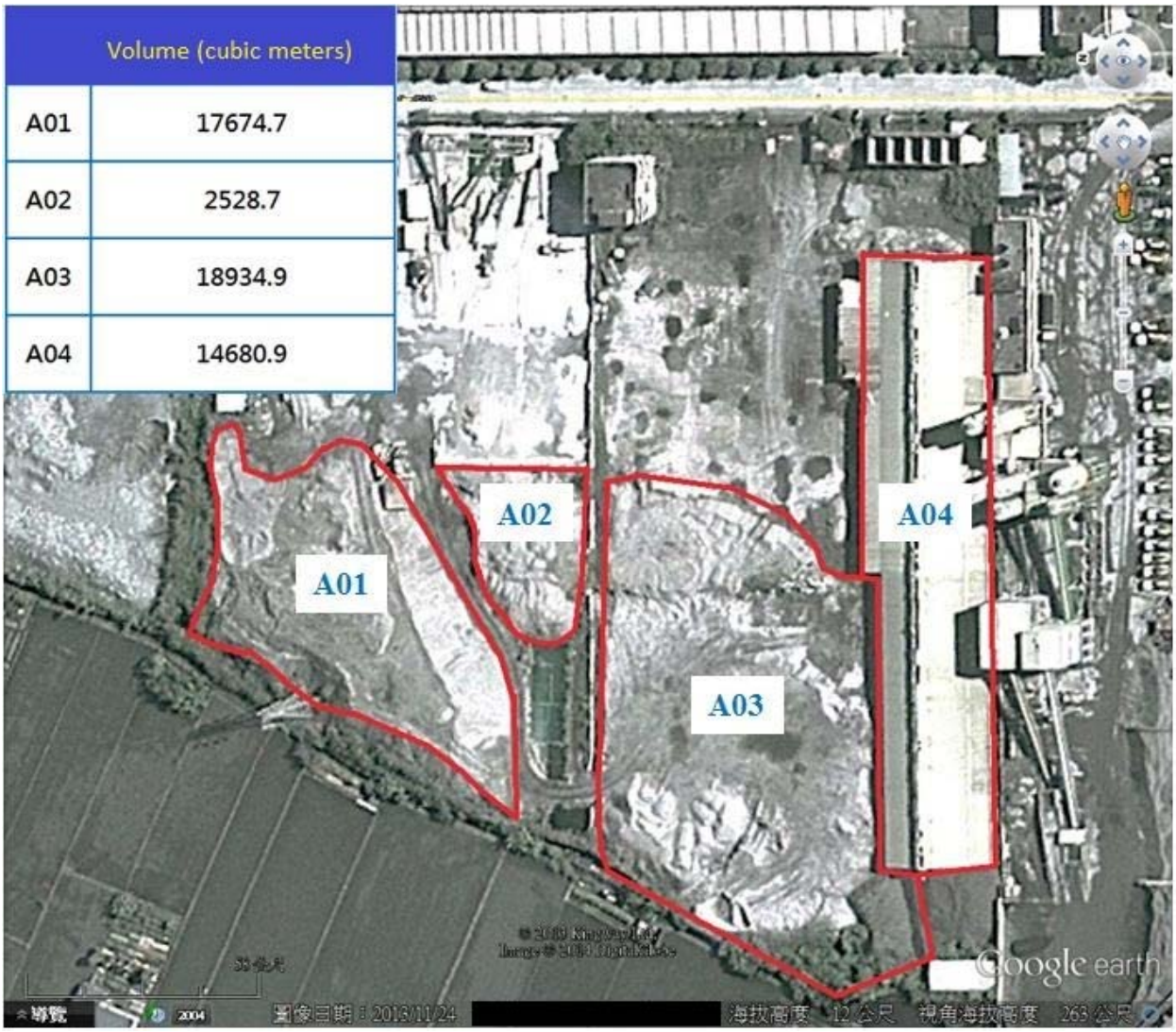

Figure 4 Volume of four slag piles of illegal dumping

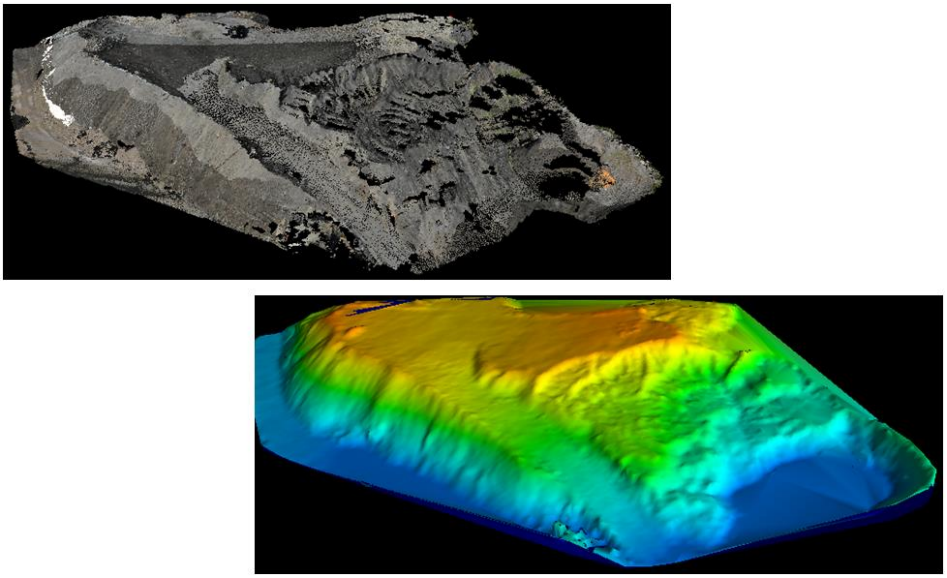

Figure 5 Waste slag pile A01 (outdoors)

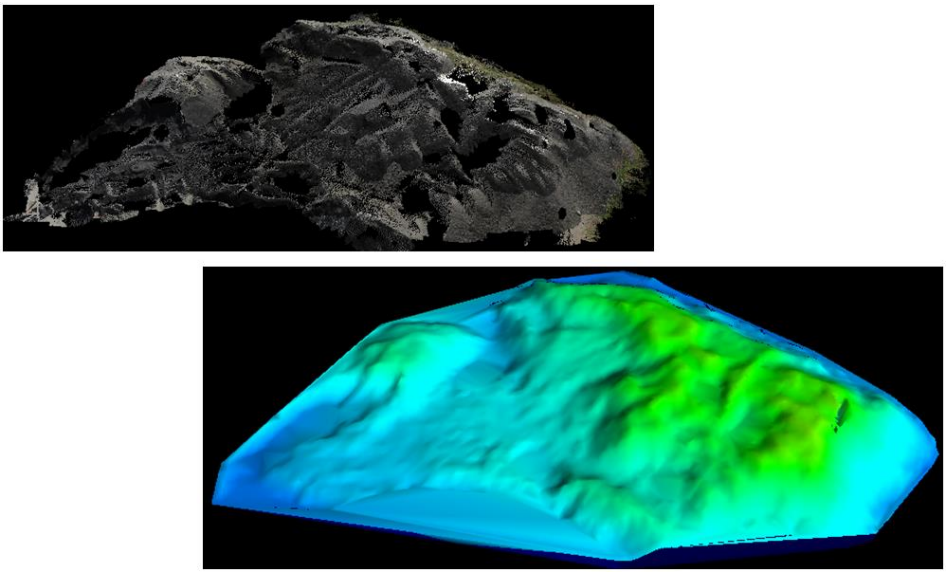

Figure 6 Waste slag pile A02 (outdoors)

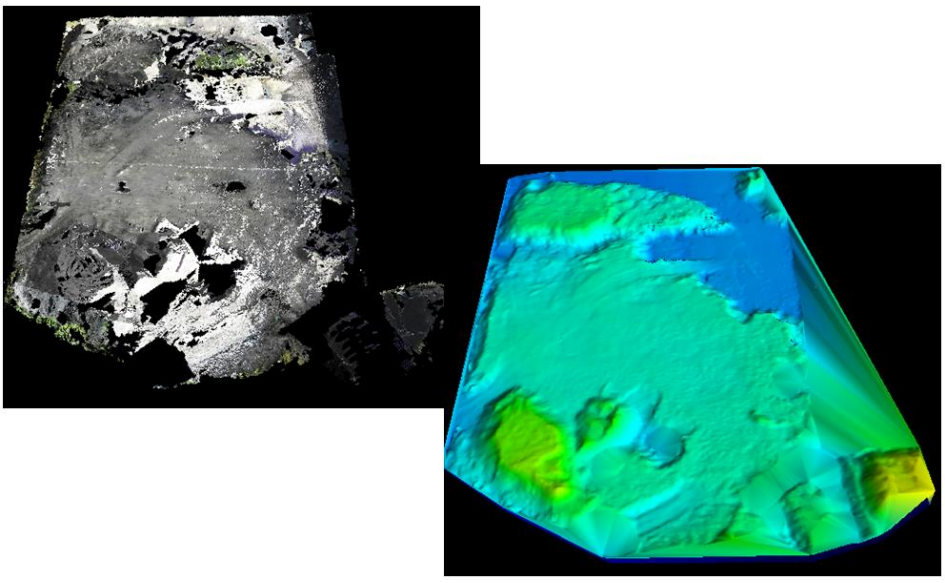

Figure 7 Waste slag pile A03 (outdoors)

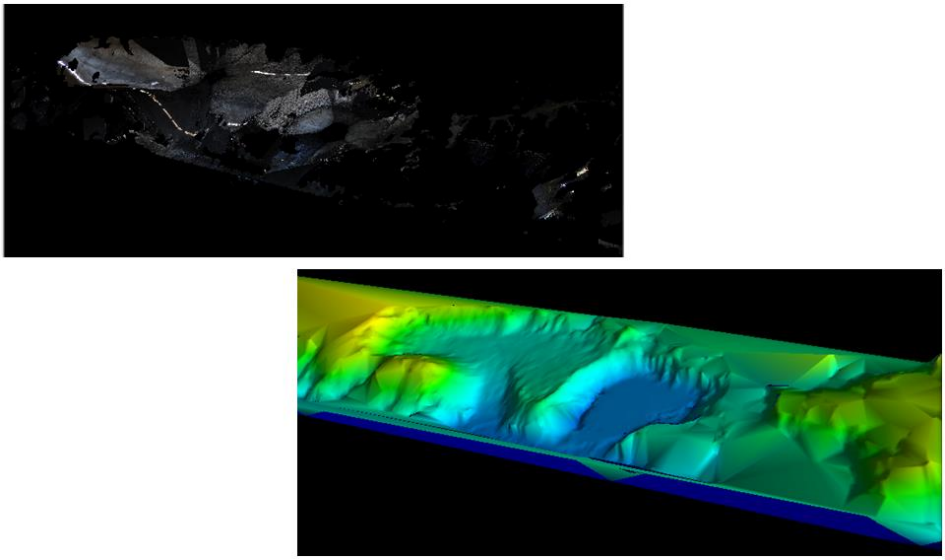

Figure 8 Waste slag pile A04 (indoors)

In addition to volume calculation, a touring video of the illegal dumping site was created using a virtual 3D model of the site (storyboard shown in Figure 9). It starts from the front side of the fenced illegal dumping site, goes through the front gate and between two piles of waste slag, enters the warehouse where more slag is stored, and ends at the back side of the dumping site. The regulatory agency can use the video to study the site and as evidence of violation.

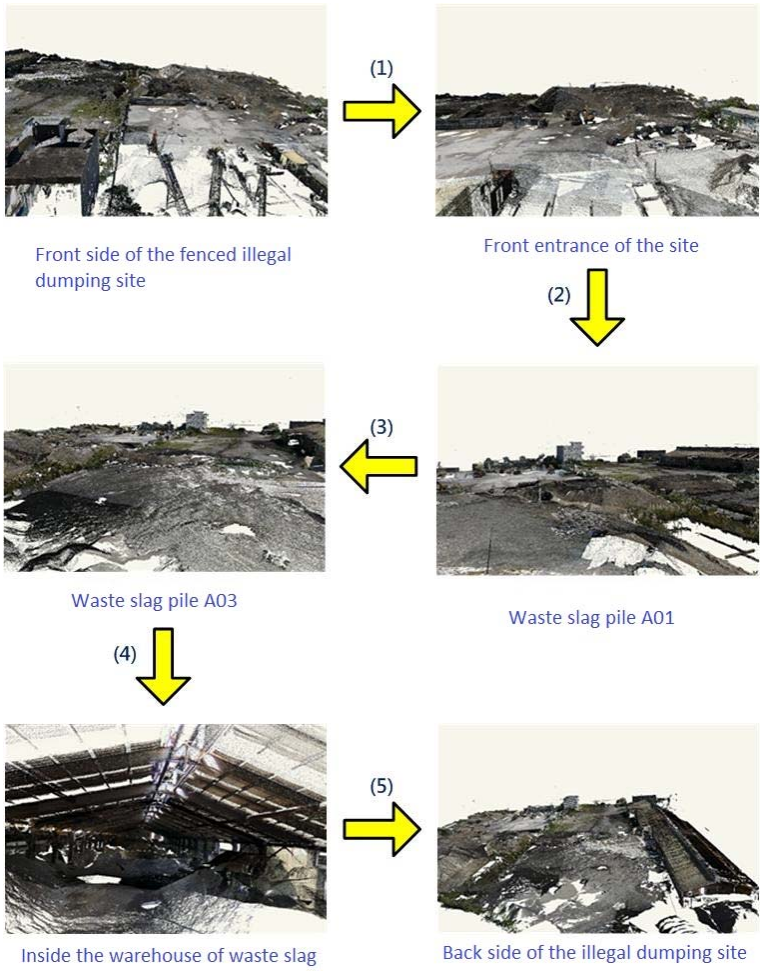

Figure 9 Storyboard sequence of a virtual tour of the illegal dumping site

Along with laser scanning, the GIS Research Center of Feng Chia University was also commissioned by the Center for Space and Remote Sensing Research to measure the volume of waste slag by using an Unmanned Aerial Vehicle (UAV). Figure 10 shows the photo taken by the UAV. It is worth noting that the UAV was unable to measure the volume of waste slag pile A04 because it was indoors and out of sight of the UAV.

Figure 10 UAV photo of the illegal dumping site (Tsai and Chen, 2014)

5. SUMMARY AND CONCLUSION

In this study, we documented a case of waste slag dumping in violation of the Waste Disposal Act in Yilan County. The illegal dump was found at a 2-hectare plot in an industrial park. While some of the waste slag was stored in a warehouse at the site, most was dumped in an adjacent fenced area. This study shows how a terrestrial laser scanner could be used to measure the volume of the waste slag accumulated at the site both in the warehouse (out of sight for UAV measurements) and in the outdoor fenced area. The volume of the four slag piles combined was 53819.2 m^3. In addition, a touring video of the dumping site was created from the 3D model of laser scanning and submitted to the regulatory agency. As a result of the measurement of the waste volume, the Local Enforcement Agency could issue fines for the violation of the Waste Disposal Act to the responsible company.

In conclusion, we have shown in this study that terrestrial laser scanners can be used in environmental protection. It has the ability to quickly scan a large outdoor area and create a virtual 3D model of the site. It can also scan an indoor space and be combined with an outdoor area, but a UAV cannot. Therefore, it is not surprising that laser scanning is finding more applications in hazard mapping and monitoring.

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