Vegetation and Water Quality Analyses of Industrial Waste Using Remote Sensing

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Abstract

After an illegal dumping site was found on the border between Iwate and Aomori Prefectures, an environmental monitoring system using artificial satellites and ground observation apparatus was established to constantly monitor and analyze environmental changes. In this study, the data collected using this system, including satellite data, on-site, infrared camera images, and water quality data, was analyzed to establish the level of on-site contamination and state of recovery. Some SPOT images were compared to establish the on-site vegetation changes using the NDVI (Normalized Difference Vegetation Index). The relationship between changes in water quality and rainfall was established. It was confirmed that the removal of fluid waste and extensive work carried out on the site reduced the alkalinity of the water.

Key Words: industrial waste, remote sensing, vegetation analysis, water quality

1. Introduction

One of the biggest illegal dumping sites in Japan was found on the border between Iwate and Aomori Prefectures. Its area is 27 hectares, and the total amount of waste is about 820,000 m^3. It caused major social problems such as environmental contamination [1)]. Fig. 1 is an aerial photograph taken on April 25, 2005 showing the state of the illegal site and the various methods used to treat the waste. The waste is taken away in trucks, but this will take several years to complete. In the meantime, the waste has been covered with tarpaulins to avoid pollution spreading before disposal. Waterproof walls will be set up around the site. An environmental monitoring system was established to collect and analyze the environmental data on-site. The satellite data such as multispectral SPOT image was analyzed for environmental analyses in the wide area, and the data from on-site sensors was analyzed in detail. This system is very useful for establishing the level of contamination and state of recovery on and around the site.

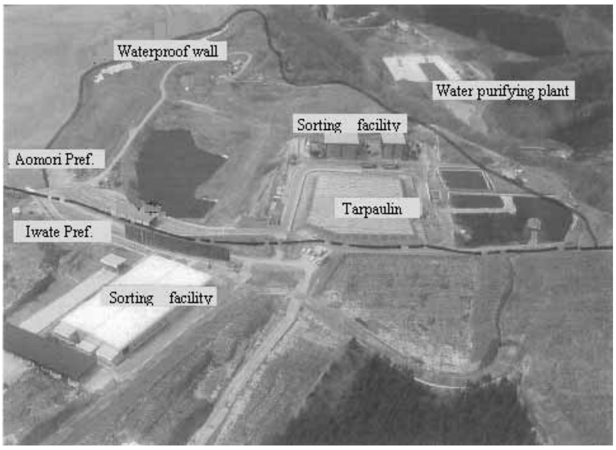


Fig. 1 Aerial photograph of illegal dumping site (April 25, 2005)

2. Remote sensing systems and analysis methods

Artificial satellites and ground observation apparatus were used in this environmental monitoring system. Data from NASA’s Terra-1 and Aqua EOS satellites was received directly by an antenna installed on the roof of a building on our campus. SPOT images, DEM (Digital Elevation Model) data, and Quickbird images were analyzed by ENVI software. Two high spatial resolution SPOT images were compared to establish the changes in on-site vegetation using the NDVI (Normalized Difference Vegetation Index).

Five water quality analyzers, weather measuring equipment, and two infrared cameras were set up at the dumping site. Data was then transmitted to the monitoring PC in the university every three minutes. The items measured were pH, electric conductivity, temperature, flow rate, wind direction, wind velocity, air temperature, and rainfall. Fig. 2 shows an example of an on-site image taken by infrared cameras that can be operated remotely. Environmental changes and on-site work progress can be checked using this data. This ground observation system and field work back up the satellite images for better accuracy.

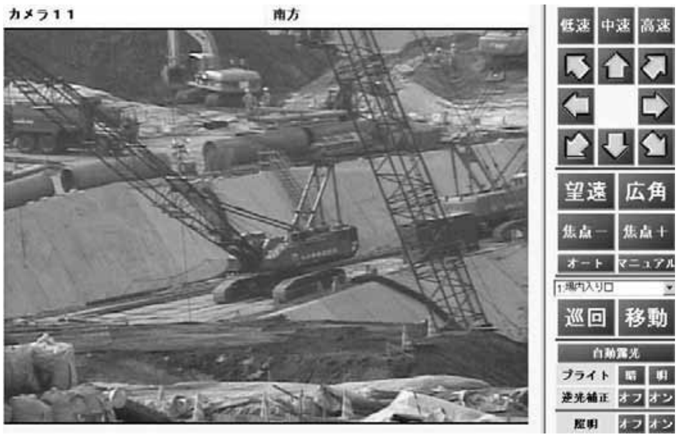
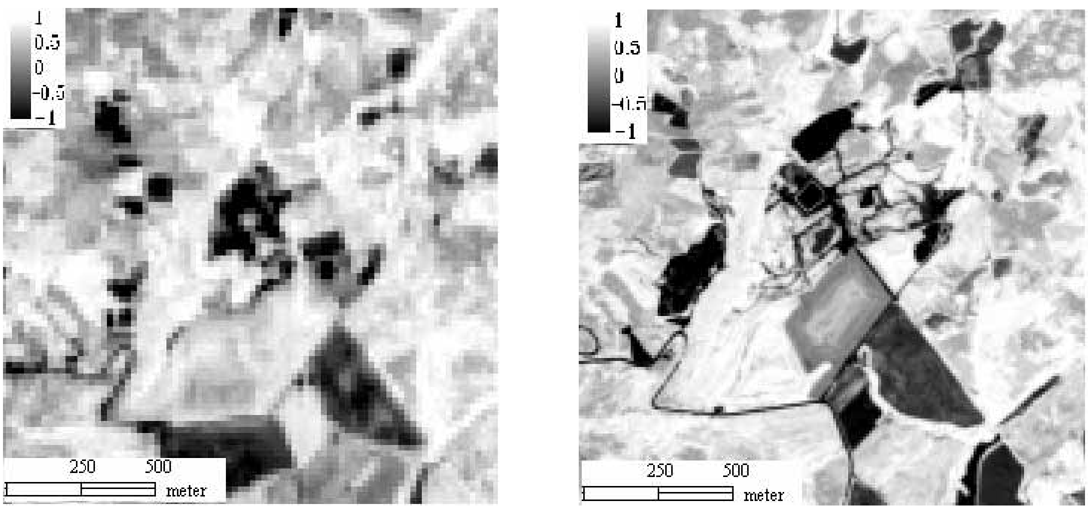


Fig. 2 Image from infrared camera (November 4, 2005)

3. Result and discussion

3.1 Vegetation analysis using SPOT images

Two high spatial resolution SPOT images were analyzed in this study. One is a SPOT 2 image of 20 m spatial resolution taken on July 20, 1992, and the other is a SPOT 5 image of 10 m spatial resolution taken on June 17, 2004. The NDVI was used to transform multispectral data into a single image band representing vegetation distribution [2]. The NDVI values indicate the amount of green vegetation present in the pixel — near-infrared radiation minus visible red radiation divided by near-infrared radiation plus visible red radiation [3]. This formula is called the Normalized Difference Vegetation Index. Written mathematically, the formula is: NDVI = (NIR - RED)/ (NIR + RED). For SPOT data, NIR represents Band 3 (0.78-0.89 µm) and RED represents Band 2 (0.61-0.68 µm).



(a) July 20, 1992 (b) June 17, 2004

Fig. 3 Changes in NDVI data on dumping site

Fig. 3 (a) shows the on-site vegetation on the site before the waste was dumped and Fig. 3 (b) shows the on-site vegetation after the waste was dumped. Very low NDVI values (0.1 and below) correspond to barren areas of rock, sand, or water. Moderate values (0.2 to 0.4) represent shrub and grassland, while high values (0.6 to 0.8) indicate forest. The on-site NDVI value was lower, meaning that there was less on-site vegetation than in the surrounding area. There are signs of human activity such as narrow paths in Fig. 3 (b), in contrast to the natural montane vegetation shown in Fig. 3 (a). Furthermore, these figures show a reduction in vegetation, and we can determine those areas that had changed in that period. This vegetation analysis will be a useful tool for identifying and confirming illegal dumping sites.

3.2 Analysis of water quality using ground observation apparatus

Water quality data plays an important role in observation and analysis of the level of on-site contamination. Five water quality analyzers were installed at the former water supply source (Point 1), the new water supply source (Point 2), in the vicinity of the Kumahara River (Point 3), at the intake (Point 4) and the outlet (Point 5) of the water purifying plant as shown in Fig. 4 [4]. Fig. 5 shows the changes in water quality in September 2005. In this figure, the pH and electric conductivity of on-site water (Point 4 and 5) were higher than normal water (Point 1, 2, and 3), and the pH at Point 4 reduced on rainy days (September 2, 7, 14, and 22).

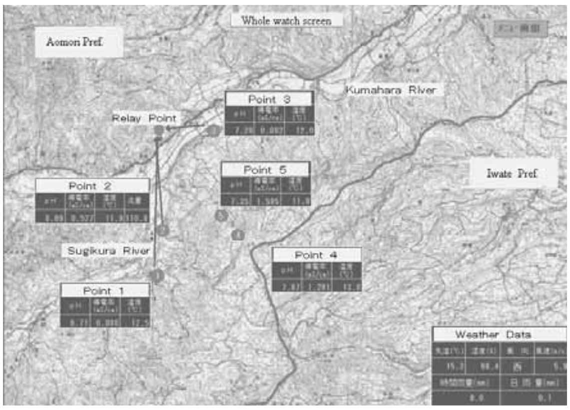


Fig. 4 Distribution of water quality analyzers

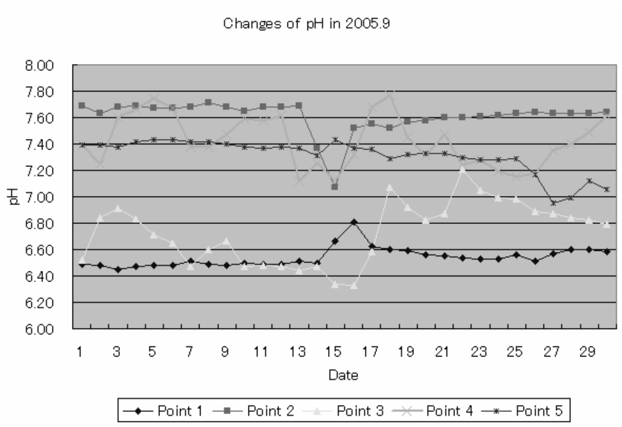


Fig. 5 Changes of pH in September 2005

The removal of waste began in September 2004, and 34,428 tons of waste (26,668 tons of solid waste and 7,760 tons of fluid waste) was removed by November 2005. Although only 4% of the total waste in Aomori Prefecture has been removed, almost all the fluid waste has been removed. Furthermore, the extensive work carried out as mentioned above has improved the water quality. The changes in pH at Points 4 and 5 are shown in Table 1. We found that the alkalinity of the water was reduced by the water purifying plant — the mean pH in September 2004 fell from 7.92 (Point 4) to 7.41 (Point 5), and in September 2005 fell from 7.34 to 7.18. The mean pH at Point 4 also fell from 7.945 (September and October 2004) to 7.46 (September and October 2005).

Table 1 Changes in water quality (pH)

	September 2004	October 2004	September 2005	October 2005
Point 3 (Kumahara River)	7.34	7.15	6.93	6.48
Point 4 (entrance of the water purifying plant)	7.92	7.97	7.34	7.58
Point 5 (exit of the water purifying plant)	7.41	7.27	7.18	6.85

In addition, it is thought that the water quality will improve further after waterproof walls are built around the dumping site as shown in Fig. 1.

4. Conclusions

A remote sensing system was established to monitor and analyze the environmental data at the illegal dumping site on the border between Iwate and Aomori Prefectures. In this paper, the data collected using this system, including satellite data, images from on-site infrared cameras, and water quality data, was analyzed to establish the level of on-site contamination and state of recovery.

Multispectral SPOT images of high spatial resolution were analyzed using the NDVI to establish changes in vegetation at the dumping site. We found signs of human activity such as narrow paths and a substantial reduction in on-site vegetation when the waste was dumped. This system will help identify and confirm other illegal dumping sites. Changes in water quality are important in assessing contamination and were analyzed, along with rainfall, as the waste was removed. The removal of waste and other on-site work reduced the alkalinity of the water. In the future, new satellite data and ground data will be sequentially collected by this system. This will be compared with current data to understand and forecast environmental changes.

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