Satellite Infrared Remote Sensing Monitoring Indigenous Coke-Production in Northern China

X. Kong [a, b], F. Miao [a], H. Liu [b], Y. Dong [b]
[a] Chengdu University of Technology, Sichuan, Chengdu 610059, China, emails305@163.com
[b] Taiyuan University of Technology, Shanxi, Taiyuan 030024

Abstract In recent years, although the China government has carried out some serious investigation and effort to shut down the indigenous coke-production, it has not achieved effective control. The main image TM754 (red, green, blue) false color composite of Shanxi province in northern China was chosen as the study area in this paper. The indigenous coke-production sites are regions which appear red and yellow and the flag is obvious. The result showed that TM7 channel was the most sensitive to indigenous coke-production, TM5 channel was the second. TM754 band composite can be used to interpret indigenous coke-production sites with 94% accuracy identified by the ground check**.**

Keywords: Monitoring indigenous coke-production satellite infrared remote sensing monitoring TM data.

1. INTRODUCTION

Indigenous coke-production pollutes the environment, destroys the ecological balance and wastes valuable coke-coal resources. It has become a problem that the government and the broad mass of people pay close attention to. The Chinese government has carried out some serious investigation into the extent of the problem and has attempted to shut it down. But because of its simple production method, low cost and generous benefit, and also the influence of regional protection, the government has not achieved effective control (G.Yang 2000).

Satellite remote sensing has macroscopic, dynamic, fast and objective characteristics, which have offered a new technological method for environmental monitoring. In recent years, many scholars have utilized NOAA satellite data and Landsat TM infrared band data to carry out research on city hot fields, geothermal resources, forest fires, coal fires and earthquake monitoring, etc. and have already obtained some application successes (Alexandrian 1995, X. Xu 1998, Belward, A.S. 1993). But there is no report concerning the use of remote sensing technology to extract high-temperature information to monitor indigenous coking sites in China or elsewhere. Using the advantages of the remote sensing technology and the characteristics of the environmental impact of indigenous coking sites, this paper utilizes TM remote sensing data to monitor indigenous coke production in China.

The main objective of this work was to develop a method for constructing interpretation flag of the indigenous coke-production sites on the Shanxi province using LANDSAT TM images.

2 Basic Principles of Monitoring Indigenous Coke-production sites by Remote Sensing

Satellite infrared remote sensing obtains signals from the earth's superficial infrared spectrum through the atmosphere window. According to Planck's Law, any object can launch (emit) and absorb electromagnetic waves when its absolute temperature is above zero. We can use the infrared wave band to measure the earth's surface heat radiation characteristics in order to monitor objects. The American Landsat with its Thematic Mapper instrument which provides very impressive color images covering an area of 180 x 180km with 30m resolution. TM data has proved advantageous in resource environmental monitoring, crop assessments, calamity monitoring, etc., and its data have already been widely used. It has seven channels. Table 1 lists the seven spectral bands and their wavelength ranges.

TABLE 1 Thematic Mapper Spectral Bands of Landsat5

Band	Wavelength (μm)	Nominal Spectral Location	Resolution (m)
TM1	0.45—0.52	Blue	30
TM2	0.52—0.60	Green	30
TM3	0.63—0.69	Red	30
TM4	0.76—0.90	Near infrared	30
TM5	1.55—1.75	Short wave infrared	30
TM6	10.40—12.5	Thermal infrared	120
TM7	2.08—2.35	Short wave infrared	30

The sun is the most obvious source of electromagnetic radiation for remote sensing. However, all matter at temperatures above absolute zero (0K, or -273°C) continuously emits electromagnetic radiation. Thus, terrestrial objects are also sources radiation, though of considerably different magnitude and spectral composition to that of the sun. This property is expressed by the *Stefan-Boltzmann law*, which states that

$$M_{\lambda} = x\varepsilon_1 / \lambda^5 \left[\exp\left(c_2 / \lambda T\right) - 1\right] \quad (1)$$
$$M = \varepsilon \delta T^4$$

Where M_{λ} = wavelength of maximum spectral radiant exitance
δ = Stefan-Boltzmann constant
c_1 = the first radiant constant
c_2 = the second radiant constant
M = total radiant exittance from the surface of a material
T = absolute temperature (K) of the emitting material
ε = emittance
λ = wavelength of spectral radiant exitance

The particular units and the value of the constant are not critical, yet it is important to note that the total energy emitted from an object varies as T^4 and therefore increases very rapidly with increases in temperature. Also it should be noted that this law is expressed for an energy source that behaves as a blackbody. A blackbody is a hypothetical, ideal radiator that totally absorbs and reemits all energy incidents upon it. Actual objects only approach this ideal. The energy emitted from an object is primarily a function of its temperature, as given by (1).

The *Stefan-Boltzmann law* expresses mathematically that the higher the temperature of the radiator, the greater the total amount of radiation it emits. As given by (2).

$$\lambda_m = \frac{A}{T} \quad (2)$$

where λ_m = wavelength of maximum spectral radiant emitance
A = 2898
T = temperature

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Thus, for a blackbody, the wavelength at which the maximum spectral radiant exitance occurs varies inversely with the blackbody's absolute temperature.

The temperature produced in the course of indigenous coking sites burning with a core heat approaching 950-1200°C should be higher than that of the surrounding environment, and its high-temperature area is steady. The radiation exitance value of the high-temperature area in the image will flood that of the background. Using the infrared wave band sensor data, we can clearly identify the radiation exitance between the object and background. According to Eq.2, the higher the temperature of the object, the shorter the dominant wavelength will be. From Wien's displacement law, the maximum spectral radiant exitance of indigenous coking sites occurs at about 1.97-2.7μm, which is therefore the area of the spectrum most sensitive to indigenous coking sites. This is the infrared spectrum sensed by the seventh channel of the Thematic Mapper carried on Landsat 5 (TM7). In addition, as the indigenous coking sites temperature can be higher than 1200°C, the TM fifth wave band (TM5) should also be used as it operates in the part of the spectrum sensitive to these higher temperatures. In other words, we can utilize both the CH7 and CH5 TM infrared bands to monitor indigenous coking sites. Information on indigenous coking sites can also be extracted from the combinations of TM bands.

Figure 1. Picture shows hot spots of indigenous coking sites

2 STUDY AREA DATASET AND IMAGE PROCESSING

3.1 Study Area and Dataset

According to the Chinese national statistics of indigenous coking sites output in 2003, indigenous coking sites is mainly concentrated in Shanxi Province, Shaannxi Province, Guizhou Province, Inner Mongolia Province and Yunnan Province. The total output of these five provinces together accounts for 84% that of China (The Ministry of Land and Resources P.R.C. 2002). The output of Shanxi province is the greatest, amounting to 48%. The Chinese coke-coal reserves distribution is shown in Table 2. The coke-coal reserve of Shanxi Province is 50.05% of the total for the whole country. Generally speaking, indigenous coking sites are found in areas with coke-coal reserves. According to the indigenous coking sites and coke-coal distribution, we chose the southeast of Shanxi province as our test region.

Only by choosing the correct remote sensing image, could we achieve the monitoring goal. An area of the spectrum is required which detects the high-temperatures in the target areas, and the spatial resolution must reflect the size of indigenous coking sites. A spatial resolution better than 60 metres was required. In addition, the most suitable dates for the images to be used in the study had to be decided, taking into account the time of year, the amount of cloud cover, the degree of coke production and the background temperature. A study of these factors led to the choice of the American Landsat 5 TM data, with its swath width of 185km and a repeat cycle of 16 days. Images in spring and winter were selected. The TM images for the study area were obtained on November 28, 1999 (thereafter referred to as the1999 image), and March 14, 2004 (thereafter referred to as the 2004 image).

3.2 Image acquisition and preprocessing

We choose special software to process the data. The main image is a TM754 (red, green, blue) false color composite. As we see in Fig. 2, the indigenous coke production sites are regions which appear red and yellow and the flag is obvious.

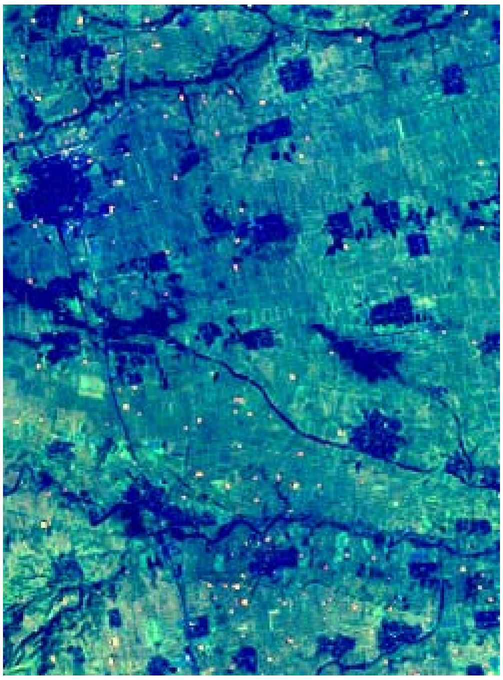

Figure 2. TM754 interpreting results of part study area of 2004

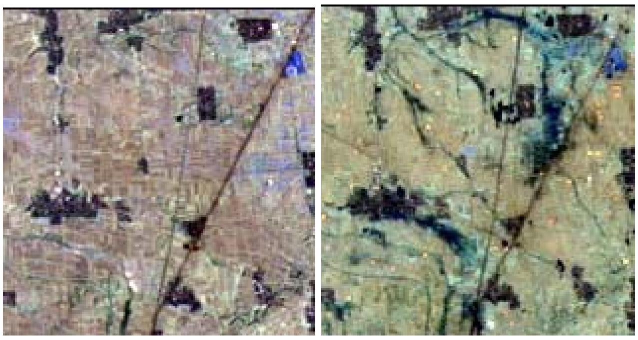

Figure 3. Left: TM754 false colour composite image of 1999
Right: TM754 false colour composite image of 2004

As we see in Fig. 2 and Fig. 3, the colour difference between the indigenous coking sites and the surroundings are obvious. It is red or red-yellow reflecting the high temperature. The geometric character is shaping a spot with a dimension of 1-3 pixels, which reflects the size of the indigenous coke-production sites.

As we see in Fig. 3, the change of indigenous coking sites was showed. After five years, the number of indigenous coke production sites has increased largely by more than 10 times. This is in line with the growth of indigenous coking sites in the whole study area.

Using the flags of indigenous coke production sites and a 1:100 000 topographic map of Shanxi province, we have chosen the 30*40 km plain area as the identify area. The interpretation accuracy rate amounts to 94%.

4 CONCLUSION DISCUSSION

Through the remote sensing monitoring of indigenous coke-production sites in the southeast of Shanxi, China, we can draw some conclusions as follows.

Landsat TM754 image can be used for monitoring indigenous coke-production sites; TM7 is the most sensitive and TM5 is the second.

Landsat TM image is good at showing the space distribution of indigenous coking sites. The sites mainly lie in the densely populated areas of hills and plain. The remote sensing method can offer a real-time, fast, and accurate survey method yielding a considerable range of information for environmental evaluation and for the supervision of the indigenous coking sites points. It can save a large amount of manpower, material resources and financial resources and can offer technical support and service to the government's environmental monitoring activities.

The fast development of the steel trade has caused the domestic and international coke markets to expand and various countries, such as U.S.A, Japan, Europe, etc., in order to lighten their environmental pollution, have centralised and reduced the production of coke. The main pollution due to coke production has thus transferred to the countries now active in coke production. China has already become the largest coke producing and exporting country in the world, the output accounting for 45.8% of the total world production and representing 60% of the volume of world trade in coke. However, in becoming the main coke producer, China has had to consume non-renewable resources and sacrifice the environment. The cost is high. Due to the pressure of enormous profits and the market, the indigenous coking sites will be a "persistent ailment". On the one hand, we should strengthen government's macro adjustments and reduce and limit the volume of coke exported; on the other hand, we should also encourage the merger of coking and iron and steel enterprises to save energy. In addition, we should strengthen environmental law. The environment department of government should rely on advanced technology to improve its capability of monitoring. The government should take some measures to improve the citizen's environmental consciousness and legal consciousness. These would all be effectual measures.

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