TECHNIQUES AND STRATEGIES

Thermal imaging analysis of local climate in relation to air quality in surroundings of the paper mill industry

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Abstract. The objective of this study was to explore a new method of using thermography to analyze the local climate of industrialized areas by observing the main source of pollution and finding correlations between pictures from a thermographic camera and selected climatic conditions and pollution data. We converted pictures into numerical data expressing the number of pixels in different shades of greyscale. We used these to create a ratio and observed its relation to selected climatic conditions including aerosols, humidity, temperature, carbon dioxide, carbon oxide, sulphur dioxide, benzene, nitrogen dioxide, and surface ozone. The detection of significant correlations suggests that this method is applicable in the area of environmental research.

Key words: infrared thermography, aerosols, CO₂, surface ozone, cloud cover, paper mill industry

Introduction

Industrialization, population growth and rapid developments in technology have all resulted in enormous human impact on the environment. Various methods are being used to examine the quality of environment not only in the wilderness but also in populated and industrialized areas.

Infrared thermography (IRT) is a contact-less optical imaging technique for detecting invisible infrared radiation (Hung et al. 2008). IRT is used to determine the superficial temperature of objects. Detectors collect infrared radiation, transform it into electrical signals and create a thermal image based on the superficial temperature distribution. In this process, each color represents a certain temperature range (Barreta and Freitas 2005).

IRT can be used in many fields, including medicine, agriculture maintenance, non-destructive evaluation, and thermo-fluid dynamics (Meola and Carlomagno 2004). According to previous research, the IRT method may also find an application in environmental sciences (Sedláč 2015). For example, IRT is used to monitor the temperature of lakes. It can detect places with still water by measuring the temperature and thus identify potentially dangerous localities for certain plants and animals. IRT can also provide monitoring of the temperature conditions to a certain degree, such as the monitoring of hurricanes and storms, etc. (Šimko 2011). This method has been successfully used in monitoring the crater of an active volcano in Japan and has been preferred to other methods for its high temperature and spatial resolution (Furukawa 2010). Recently, in natural sciences the IRT found an application in botany where novel methods are being developed to geoshow gas exchange through stomata (Costa et al. 2013).

Many chemicals are used in the chemical and pulp production industry, both in the processing of cellulose and in the addition of chemical admixtures during paper production. Polymerization is reduced at the scission of cellulose by glycozidic bonds, which is the basis for creating carbon dioxide and various carbohydrate derivates (Poletto et al. 2013). Through this process, emissions are created and released into the atmosphere. Emission concentration is highly influenced by pollution from burning sources (Brasseur et al. 2006).

Primary pollutants include carbon oxides, sulphur oxides, carbon oxide and solid particles. Secondary pollutants are ozone, which reacts directly with the emitted compounds in the atmosphere (Cohen et al. 2004).

The objective of this study is to explore a new method of analyzing the local climate of the industrialized area in the city of Ružomberok by taking and evaluating infrared pictures of local industrial compounds. The study area is highly affected by a local paper mill. The main goal is to analyze local climate and find relationships between the impact of industrialization and local climate by considering values of aerosols, CO₂, and surface ozone in the air and their effect on thermal inversions and cloud cover. Then, this data will be used to find a correlation between the thermal stratification of atmosphere above the paper mill on the infrared pictures and directly measured values of mentioned climatic and air quality factors from the Slovak Hydrometeorological Institute and the local field station at the Institute of High Mountain Biology.

Material and Methods

We collected data from four sampling sites close to the paper mill in Ružomberok. Two of them were in locality Lisková and other two in nearby locality in village Štiavnička (Fig.1).

We have created a total of 176 images. They were captured in two time periods. The first time period was between the 23rd of January 2015 and the 17th of April 2015. During this time period we
made 36 images from localities 1 and 2. The second
time period was between the 8th of September 2015
to the 24th of April 2016. In this time period we cap-
tured 80 images from localities 1 and 2.

For a more precise analysis we added two lo-
calities during the second time period. Localities 3
and 4 were sampled between the 5th of October to
15th of March 2016. 60 images were made. The im-
ages were made during night-time between 23:00
and 05:00. We chose to take images during night-
time for three reasons:
- almost no movement of local inhabitants
- a suitable time for inversion
- we predicted a larger amount of emissions.

During the first time period we always started with
locality 1 and continued with 2. During the second
time period we started with locality 3, then contin-
ued with 4, 2 and 1.

To capture the images we used a handheld termo-
vision camera ISG K 1000 Elite. Parameters:
- spectral feedback: 8μm - 14μm
- detector resolution: 76,800 pixels
- focus: automatic, from 1 m to infinite
- sensitiviy: 50 mK nominal
- angle of sight: 50°

Through use of an RCA cable we uploaded the im-
ages from the termovision camera (Fig. 2) onto a
computer, where they were converted with Video
studio editor software into BMP format. Subse-
quently, we converted the image into Gray Scale 8
using Image-Pro Plus software.

Next we used the Blue to Red Pseudocolor
function on this image. This enabled us to put the
shade into five colours (red, yellow, green, cyan and
blue). The red colour characterised backgrounds
with the highest temperature, which occured clos-
The most significant correlations between typology (ratios) of pixels and CO₂, air humidity and temperature values were noted at locality 1 (Table 1). This location was nearest to the factory out of all four locations. We had 59 values for each environmental variable.

The values are significant for all three ratios and air humidity. The highest coefficient is with Y/G ratio, however, this did not reach even a slight negative correlation. Temperature shows a negative correlation with all of the three ratios, and the ratio of C/G is not significant. This interpretation means that closer to the factory the the ratio Y/G is higher in very cold winter periods in the region of Ružomberok.

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The measure of other environmental variables showed us that thermal imaging may be a suitable tool to measure not only the temperature but also the amount of dust particles in the air (PM 2.5, PM 10), SO₂, NO₂, or TRS (Table 2).

Discussion

This study indicates that IRT may be a useful tool in the area of local climate research. By converting pictures to different colour scales we were able to get numerical data from pictures based on the number of pixels and then calculate ratios between three groups of data. We found that there is no need for additional sampling sites but rather the key is seeking sites that have a clear view of the subject and thus collect more accurate data. This fact is supported by at least two studies (Voogt and Oke 2003, Roth 1989). Subsequent research using this technique could include expanding the number of grayscale categories in the most variable shades.
to get more detailed results. This could assist with the implementation of methods of application and use of the IRT to determine local climatic conditions solely from reading thermal images.

When we look at the correlations between color ratios and the climatic conditions, the highest number of correlations were with temperature and humidity. The coincidence of correlations in temperature and humidity were expected since these variables are in direct relation to each other. This is a well-known fact supported by scientific studies (Wentz and Schabel 2000).

The highest rates of correlation among pollutants were observed in data on particulate matter. While in the Lisková location there was only moderate correlation between groups, correlation in the Štiavnička location was strong. Numerous studies have shown that paper and pulp industry workers are at an increased risk of lung cancer from pollution (Torén et al. 1996).

On the other hand, burning biomass and fossil fuel is the most common way to produce aerosols. Therefore it was not clear whether the source of aerosol pollution was the paper mill compound or traffic. The strength of correlation suggests moderate to strong relationships between the character of compound thermal images and aerosol concentrations. This may point us to a causal relationship and show that the paper mill is responsible for a major portion of pollution. Conversely, character of the picture may be influenced by the climatic phenomena of thermal inversion which can “trap” emissions in the thin layer of atmosphere above the ground without an option to identify the source of pollution. These factors should be taken into consideration by the responsible authorities as particulate matter, especially PM 2.5, is known to have negative impacts on the human respiratory system.

Several recommendations are proposed for subsequent research. Firstly, samples should be shot from locations that have a direct view of the compound. Secondly, each sample must be 100% backed up with climatic data. Finally, we suggest that dividing the categories with the most variety would most likely result in higher accuracy.

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**References**


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**Table 2.** Correlation between colour ratios of thermal images and different environmental variables at different localities. Significant correlations are in bold.

<table>
<thead>
<tr>
<th></th>
<th>Locality 1</th>
<th>Locality 2</th>
<th>Locality 3</th>
<th>Locality 4</th>
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<tbody>
<tr>
<td></td>
<td>PM 2.5</td>
<td>PM 10</td>
<td>SO₂</td>
<td>PM 10</td>
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<td>-0.02</td>
<td>-0.04</td>
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