UDC 911.9+910.3:553.9:528.8

I.G. Chervanyov, *Doctor of Technical Sciences, Professor,*
I.K. Burdun, *Master of Geography,*
V. N. Karazin Kharkiv National University

GEOECOLOGICAL MONITORING OF DANGEROUS LOCAL GEOCHEMICAL OBJECTS IN URBAN ENVIRONMENT BY REMOTE SENSING

І.Г. Черваньов, Ю.К. Бурдун. ГЕОЕКОЛОГІЧНИЙ МОНІТОРИНГ ЗАГРОЗЛИВИХ ЛОКАЛЬНИХ ГЕОХІМІЧНИХ ОБ'ЄКТІВ У МІСЬКОМУ СЕРЕДОВИЩІ ДИСТАНЦІЙНИМ ЗОНДУВАННЯМ. *Значні маси гірських порід, будучи піднятими з глибин Землі на поверхню, мають ряд негативних властивостей, що визначаються умовами виникнення, які відрізняються від зовнішніх. Маси підземних порід, внаслідок їх зміни водними і повітряними компонентами, а також самозаймання, значно впливають на стан довкілля, зокрема – обумовлюють їх фітотоксичність. Була взята за основу гіпотеза про кореляцію між солоністю і фітотоксичністю відвалів гірничодобувної промисловості. Також за допомогою вегетаційних індексів була досліджена динаміка рослинності. Вегетаційні індекси були розраховані для аналізу стану рослинності відповідно до різночасових цифрових зображень. Кореляція була запропонована для дослідження з використанням методів дистанційного зондування.*

Ключові слова*: геоекологічний моніторинг, індекс солоності, вегетаційний індекс.*

И.Г. Черванёв, Ю.К. Бурдун. ГЕОЭКОЛОГИЧЕСКИЙ МОНИТОРИНГ УГРОЖАЮЩИХ ЛОКАЛЬНЫХ ГЕОХИМИЧЕСКИХ ОБЪЕКТОВ В ГОРОДСКОЙ СРЕДЕ ДИСТАНЦИОННЫМ ЗОНДИРОВАНИЕМ. *Значительные массы горных пород, будучи поднятыми из глубин Земли на поверхность, имеют ряд негативных свойств, определяемых условиями возникновения, отличающихся от наружных. Массы подземных пород, вследствие их изменения водными и воздушными компонентами, а также самовозгорания, значительно влияют на состояние окружающей среды, в частности – обуславливают фитотоксичность почвы. Была взята за основу гипотеза о корреляции между соленостью и фитотоксичностью отвалов горнодобывающей промышленности. Также с помощью вегетационных индексов была исследована динамика растительности. Вегетационные индексы были рассчитаны для анализа состояния растительности в соответствии с разновременными цифровыми изображениями. Корреляция была предложена для исследования с использованием методов дистанционного зондирования.*

Ключевые слова*: геоэкологический мониторинг, индекс солености, вегетационный индекс.*

Introduction. The research serving as the basis for this publication refers to a number of socially topical and scientifically meaningful ones. It is dedicated to one of the most important geo-environmental problems in Donetsk –one of the cities in Ukraine with over a million inhabitants. Several dozens of mining and processing plants are located in its city boundary. Within 200-year history of mining coal deposits more than 150 refuse dumps – slagheaps, which significantly affect the environment, have been made here. This effect is conditioned by the changes (metamorphosis) in topography and surface runoff, as well as geochemical transformations of overburden, which create specific geochemical arenas, by polluting the air, the surface runoff and creating a man-made landscape-geochemical system.

By virtue of the dynamic process of transformation of the earth surface, they are difficult to trace directly. Accordingly, it is necessary to use the indirect information, in particular the results of remote sensing.

This is facilitated by the availability of many satellite data, digital format of their presentation, which is convenient for computer processing and the visualization of landscape and geochemical occurrence through the physiognomic properties of soil and vegetation cover: color, pattern, tonality, texture etc. They form the view of any optical spectrum of satellite data.

The purpose of the work is to carry out experiments by identifying landscape and geochemical occurrence of refuse dumps in the city of Donetsk, as well as to assess their dynamics by comparing images at different time (within a 15-year period), by means of computer simulation and analysis of satellite data. In the course of the research work the following tasks were completed:

- selection of indicators that would provide the visualization of correlation between "artificial subsoil of refuse dumps - vegetation," available for the subsequent analysis of satellite data in a particular optical spectrum;
- calculation of the index of soil salinity, vegetation etc.;
- carrying out a temporary analysis of the obtained data.

Summary of the literature. Study of the refuse dumps on the territory of Donetsk is a topical issue. These technological formations are discussed by biologists, ecologists and geographers [1,7,8]. We are trying to understand all aspects of them. Some researches, including [5] about the salinity determination show the efficiency of salinity indices and its high correlation with the ground data. The authors examined the current state of the refuse dumps in the city of Donetsk using [8,9] and the hypothesis about their overgrowth was proposed using [2,3,6].

The explication of the object. For historical reasons the city of Donetsk happened to be the territory of intensive mining and beneficiation of coal territory, so it acquired a unique townscape which organically combines urban developments and giant dumps (of more than 50) - most of them are man-made relics of the early industrial era and coal mine construction. This type of townscape is characteristic for Donetsk, so it is even represented on its coat of arms. The city of Donetsk is characterized by the complicated combination of various spatial forms of land use and territory organization.

The urban development combines the radial type of main streets (avenues) and chaotic outlines of mining settlements. This arrangement could not but cause the emergence of geo-ecological problems in the city.

Methods. In this paper data from the satellite system LandSat 5 TM are used for the following dates: 07.08.86, 11.07.87, 05.07.88, 17.09.06, 21.06.09, 08.06.10, 13.07.11. The data for the summer and autumn periods are used for this research. Unfortunately, the data were obtained in different months, which is caused by technical issues of shooting conditions.

To highlight the areas with different levels of salt content Normalized Difference Salinity Index (NDSI) and Salinity Index (SI) were calculated [5].

$$NDSI = (RED - NIR)/(RED + NIR), \quad (1)$$

$$SI = RED / NIR \quad (2)$$

where RED - is the brightness of the pixel in the 3rd channel scan Landsat, which corresponds to red spectrum; NIR - is the brightness of the pixel in the 4th channel, corresponding to near-infrared spectrum.

For the analysis of vegetation we calculated the following vegetation indices: Moisture Stress Index (MSI) and the Normalized Differential Vegetation Index (NDVI).

$$MSI = SWIR / NIR, \quad (3)$$

$$NDVI = (NIR-RED) / (NIR + RED) \quad (4)$$

where SWIR - is the brightness of the pixel in the 5th channel scan Landsat, which corresponds to the near infrared spectrum, the latter was given above.

Further, we refer to the index numbers of the formulas (1) - (4) by putting them in parentheses.

Results. 11 refuse dumps were selected for the research where in 1986-88 the regions of relatively understated indices (1) and (2) - usually lower than 0.2 (Fig. 2) were fixed. The selection of refuse dumps was carried out according to the data of several shots, as salinity can vary depending on the weather because of the varied humidity of dump rocks. It has been established that there is an inverse relation between the salt content in rocks of refuse dumps and humidity, that is apparently due to the change in regimes of evaporation and infiltration, depending on weather conditions: evaporation during dry periods, humidification of soil and infiltration during atmospheric precipitation and subsurface moisture condensation during hot periods. Figure 1 shows the state of index (1) of the selected refuse dumps in 1987.

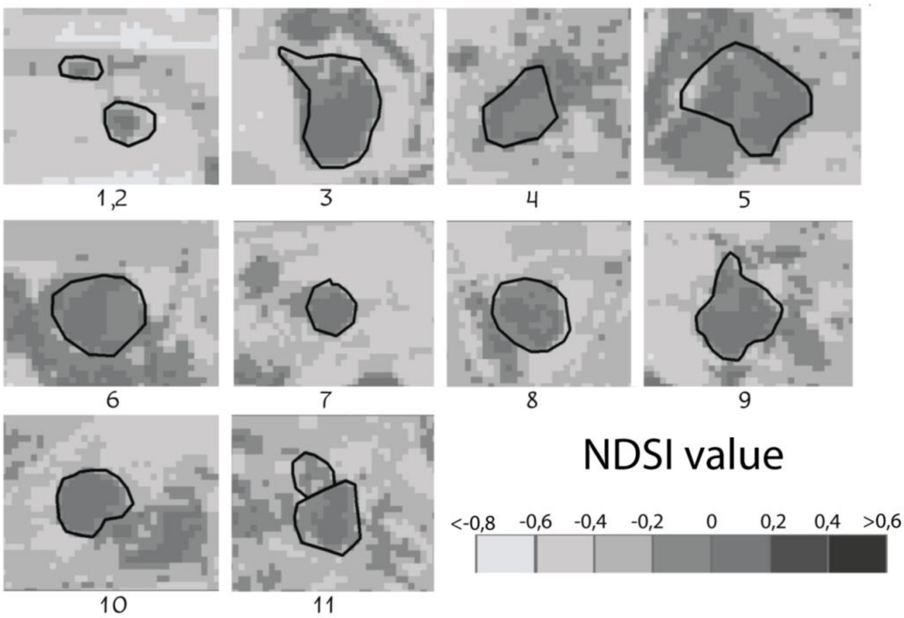

Figure 1. Index value (1) for the investigated mine dumps.

Index figures (3) for 1987-1988 are almost identical to index (1). At the same time, index figures (3) of the previous year (1986) radically differ from the values determined for 1987-1988: it is assumed that this might be caused by weather conditions which are different from those in the following years, whereas the districts of relatively reduced index (1) spatially coincide in the course of the above mentioned three years.

Index value (4) ranged from -0.01 to 0.01 in most parts of the prospected refuse dumps in 1986-1988. These figures are typical for index of wasteland, sands and open ground. In some areas index value (4) reaches 0.2, which is typical for low vegetation, while index figures (1) are high, which is likely to indicate the evaporative regime in arid weather conditions.

An inverse relation is clearly observed between indicators of index (1) and (4). The analysis of 86-88 data showed that refuse dumps with a relatively-reduced salinity are characterized by partial overgrowing, whereby, according to observers an air-water regime of the substrate is changing, and its moisture content is one of the main conditions for the further development of the vegetation [8]. Aging of refuse dumps is associated with a decrease in the content of maneuverable salts and increasing pH, which provides a more neutral soil reaction [7]. This trend has a positive effect for flora.

There was a partial overgrowth of vegetation on refuse dumps based on growth of index values (4), to 2009-11. This means that there is a positive dynamics in overgrowing of refuse dumps.

Vegetation index is used (4) to compare vegetation changes of mine dumps, its results are presented in Fig. 2.

The general trend of changes is the increase in the vegetation cover density primarily on the territories where relatively low salinity of refuse dumps was recorded in the 1980s. This feature looks natural. However, there are areas where vegetation decreased in 2011 in comparison with 1987 (1 and 2 refuse dumps, fragments of 5, 8, 9 refuse dumps). This may have been caused by the geochemical activity of refuse dumps in recent years because this process starts, as a rule, some time after storing the rocks [9].

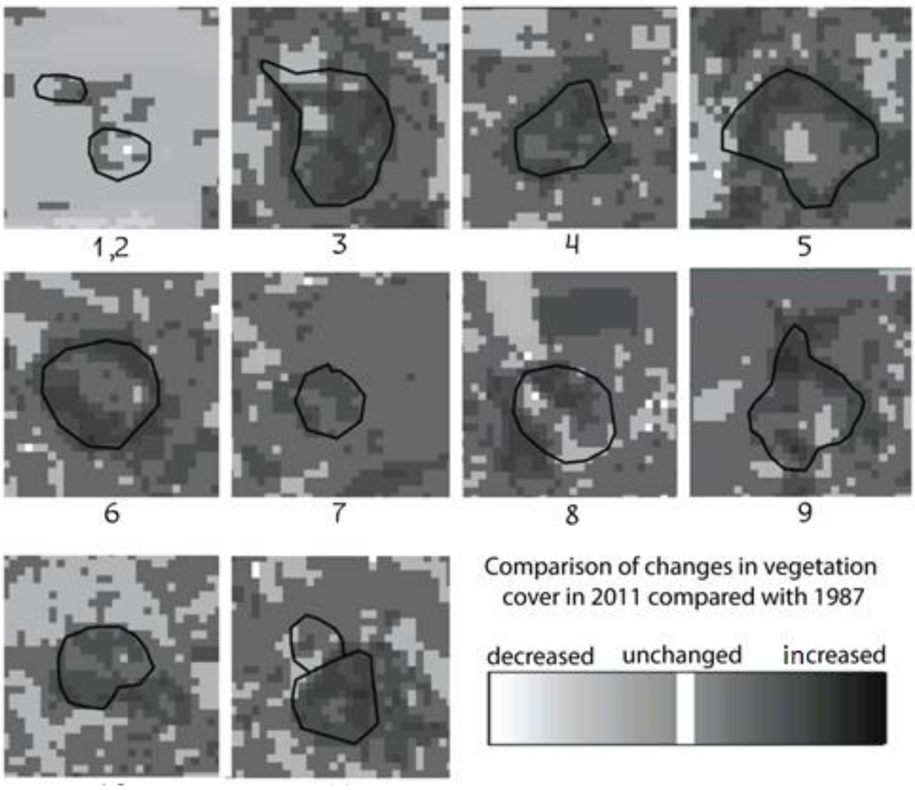

Figure 2. Comparison of changes in vegetation cover in 2011 compared with 1987.

Conclusion. The use of satellite data of LandSat 5 TM in assessment of landscape-geochemical characteristics of refuse dumps rocks and processing plants in Donetsk has showed the perspective of this scientific method in relation to other objects that undergo complicated processes of landscape-geochemical transformations. The effectiveness of Normalized Difference Salinity Index (NDSI) and Salinity Index (SI) calculation was confirmed by calibrated digital images of refuse dumps undergoing geochemical transformations.

Moisture Stress Index (MSI) and Normalized Difference Vegetation Index (NDVI) turned out to be effective. The comparison of indices NDVI, which was calculated for particular refuse dumps on different dates of the summer-autumn period within 15 years, enabled us to establish the trends of overgrowing the refuse dumps with natural vegetation, including those which may indicate geochemical activity of rocks.

Unfortunately, for technical reasons the months of shooting vary and it is caused by the shooting conditions.

Vegetation indices were calculated to analyze the state of vegetation according to digital images within the spectrums of satellite data obtained at different time.

The comparison of the obtained state of vegetation showed mainly positive trend of refuse dumps overgrowing and an ambiguous relation with it and the dynamics of soil salinity index.

Based on the correlation between the soil salinity of refuse dumps and the state of overgrowing with vegetation the ability to forecast the speed of phytocenosis was established. It gives an opportunity to plan the recultivation of refuse dumps in order to improve the townscape of Donetsk (and in other cities with the similar geo-ecological problems).

Taking into account the fact of overgrowing, the aesthetics and attractiveness of Donetsk will improve the quality of life of its inhabitants, not to mention the improvement of the above-mentioned geoecological situation. Unfortunately, the latest events in the city are recessing the implementation of such measures.

References

1. *Chervanyov, I. and Burdun, I. (2013). The researching of components of heat radiation of refuse dumps of refuse dumps on the territory of Donetsk. V. N. Karazin Kharkiv National University Bulletin. Series Geology, Geography, Ecology, 38, pp.173-176. (in Ukrainian).*
2. *Forman, R. (1995). Land Mosaics: The ecology of landscapes and regions. Cambridge, UK: Cambridge University Press, 632 p.*
3. *Glazovskaya, M. (1988). Geochemistry of Natural and Technogenic Landscapes of the USSR. Moscow, Russia: Vysshaya Shkola, p.328. (in Russian).*
4. *Malysheva, L. (1998). The landscape-geochemical evaluation of the ecological condition of the territories. Kyiv, Ukraine,131 p. (in Ukrainian).*
5. *Ochieng, G., Ojo, O., Otieno, F. and Mwaka, B. (2013). Use of remote sensing and geographical information system (GIS) for salinity assessment of Vaal-Harts irrigation scheme, South Africa. Environ Syst Res, [online] 2(1), 12 p. Available at: http://link.springer.com/article/10.1186%2F2193-2697-2-4#page-1 [Accessed 3 Jun. 2015].*
6. *Perelman, A. and Kasimov, N. (1991). Geochemistry of landscape. Moscow: MSU, 610 p. (in Russian).*
7. *Torokhova, O. (2007). On phytotoxicity of Donbass industrial waste discharge rock. Industrial Botany, 7, pp.80-84. (in Russian).*
8. *Torokhova, O. and Agurova, I. (2009). Dynamics of salification and humidity of substrates in coal mine dumps in Donbass area. Industrial Botany, 9, pp.97-100. (in Russian).*
9. *Chervanyov, I., Burdun, Yu. (2014). The Experience of Geoecological Monitoring of dangerous local geochemical objects of Cities Environment by treatment of space pictures "LANDSAT": some results of educational-research collaboration // The 1-th International Academ. Confer. "Fundamental and Applied Studies in America, Europe, Asia and Africa".Melbourn: Melbourn un-t. Vol. 1 Pp.213-219.*