Ensuring environmental safety through detection of unauthorized solid waste dumps using geospatial technology

Sergij Vambol, Volodymyr Koloskov,
Department of Applied Mechanics and technologies of environmental protection
National University of Civil Defence of Ukraine
Address: 94 Chernyshevska Str. Kharkiv 61023 Ukraine

Viola Vambol, Vitaliy Sobyna,
Department of logistics and technical support of rescue operations
National University of Civil Defence of Ukraine
Address: 94 Chernyshevska Str. Kharkiv 61023 Ukraine

Iqbal Ansari
Department of Natural Resource & Environmental Management Group
AcSIR, CSIR-Central Institute of Mining and Fuel Research
Address: Barwa Road, Dhanbad-826015, Jharkhand, India

***Abstract*—Present paper describes improved general model which based on methods of remote scanning of Earth surface obtained by Space satellites with combination with GIS-technologies and methods of mathematical modelling. This model allows to allocate and analyze characteristics of carbon containing and organic components of places of accumulation of solid waste of domestic and industrial genesis of illegal waste dumps on Space images and also determine values of its area and dynamic of growth for monitoring of environmental safety level of urban systems.**

***Keywords*—wastes, environmental safety, geospatial technology**

I. INTRODUCTION

The one of important directions of waste handling area is ensuring of complete waste collection for their in-time deactivation and disposal with abidance of ecological safety regulations. Nowadays due to different reasons there is large number of illegal dumps. Under the term "dump" we understand the area of spontaneous accumulation of waste. The areas of location of sanitary landfills which are in exploitation in accordance with ecological regulations are known. Unlike them dump places are unknown and ecological consequences from it are not predictable.

As the rule, detection of waste dumps occurs accidentally. Wherein rates of decomposition of different substances in whole mass of waste are not the same. That why the influence of individual fractions of waste on formation of filtrate are different. That means that time period from the start of dump formation till the start of penetration of filtrate into ground waters is unknown. Therefore at the moment of dump detection negative consequences of filtrate influence on environment may be significant. Thus the early detection of places of illegal accumulation of different kinds of waste as well as continuous its monitoring are relevant tasks in area of ensuring of ecological safety.

Solid domestic wastes contains a components which can became the nutrients for pretty wide specter of types of microorganisms some of which are harmful for human and environment. The climate on territory of Ukraine promotes their intensive reproduction in such conditions. It is well known fact that all of life organisms, including microorganisms are mainly consists of hydrocarbons that based of carbon and therefore are the carbon containing component of waste dumps, namely organic. Monitoring of condition of microbiological pollution of urbanic systems on the territory of which surely there are solid waste damps as a part of level of technogenic and ecological safety of this systems, can take one of main places in structure of appropriate ecological safety management system.

Worded above became more relevant in case of application of activities for increasing of indicators of ecological safety level of legal and illegal places of accumulation of solid wastes that having a technological nature. Thus, for example, in the study [1] investigated methodological and technogenic and ecological aspects of technological process of utilization of polymers with nano inclusions by thermal decomposition. The results of its improvement also needs to verification which can be executed by processing of Space images.

Data of remote scanning of Earth (RSE) from the Space is such source of information, that allows to get actual operative picture of places of location of illegal waste dumps with lower time expenses. Articles [2, 3] is dedicated to analysis and searching of possibilities of application of multispectral Space images for identification of illegal dumps by the way of determination of its brightness characteristics. Articles of foreign scientists [4, 5] is dedicated to decoding of Space images.

RSE methods in combination with Geo Information Systems (GIS) and methods of mathematical modeling gives possibilities for complex studying of sources of formation of ecological danger and make decision about ways for handling of them. Using of worded above metodics proposes in works of Trofymchuk A.N., Gotynjan V.S., Grekov L.D., Fedorovsky

A.D., Jakovjev E.A. and ect. Methodic of allocation of contour of dumps with using of both brightness and texture methods is presented in works [6, 7]. Wherein constructing of artificial brightness attributes is possible.

Purpose of the study is researching of possibility of using of wide access data of remote scanning of Earth and GIS-technologies for operative detection of places of illegal accumulation of waste as sources of formation of danger of technogenic character.

II. METHODOLOGY

Development of a model for detecting illegal waste accumulation using a space image. For successful carrying out of tasks of the study it is can be used Space images of ultrahigh spatial resolution (0.5 – 15 m) in spectral diapason 0.4 – 1.1 microns, namely QuickBird, WorldView, GeoEye, Pleiades, Ikonos and etc. Such images can be obtained from archive data bases of cartographic servers in Internet web. The most available source of that images is online free service Google Earth. In this study used exactly the images of Google Earth were used

Instead digital equivalents of brightness directly in image points were used average values of brightness in surroundings of that points or median of sequence of brightness of elements in surrounding of the point. As brightness attributes of objects which includes some multiplicity elements of image using the histogram of brightness, that is average value of brightness, dispersion, coefficient of asymmetry, excess:

$$m = \frac{1}{n-1}\sum_{i,j} I_{i,j}, \quad (1) \qquad S = \frac{\sum_{i,j}(I_{i,j}-m)^3}{(n-1)D^{3/2}}, \quad (3)$$

$$D = \frac{\sum_{i,j}(I_{i,j}-m)^2}{n-1}, \quad (2) \qquad Kr = \frac{\sum_{i,j}(I_{i,j}-m)^4}{(n-1)D^4}, \quad (4)$$

where m – average value of pixels in scanning window; I – value of pixel brightness; i, j – coordinates of pixels in scanning window; n – quantity of pixels in scanning window; D – dispersion of value of brightness; S – asymmetry; Kr – excess.

For application computer processing of structure attributes of images it necessary to use special procedures of its formalization. At formalization of attribute of character of distribution of brightness on surface of object on image it using procedure of decomposition of field of brightness of image into specter of spatial frequencies. For linear processing by sliding square window the brightness of transformed image describes as:

$$f(i,j) = \sum_{i=i_0-w}^{i_0+w}\sum_{j=j_0-w}^{j_0+w}\begin{pmatrix} F(i,j)H\times \\ \times(i-i_0+w+1, \\ j-j_0+w+1)\end{pmatrix}, \quad (5)$$

where H – predetermined matrix of size (2w + 1)×(2w + 1) – mask of operator of linear transforming; f – field of parameters of transformed image.

Transformation is operation of discrete convolution of image with mask H. For decomposition of field of image F(j, k) into specter of spatial frequencies it used different procedures of unitary transformations: Fourier, Hadamard, Haar and oblique transformation. In general case for sliding window of square form of size N×N spectral coefficients f(u, v) describes by following formula:

$$f(u,v) = \frac{1}{N}\sum_{j=0}^{N}\sum_{k=0}^{N} F(j,k)A(j,k,u,v), \quad (6)$$

where A (j, k, u, v) – core of direct transformation.

Set of spectral coefficients is attribute which most fully characterized changing of brightness on surface of image. For formalization of that attribute also using simplified approaches. Essence of one of them is using of value of gradient of brightness. For its implementation it executes of procedure of spatial differentiation of analyzed fragment of image, that is founds of derivations dF/dx and dF/dy by the way of convolution of image with gradient masks Hx and Hy. As the formalized attributes it directly used values of dF/dx and dF/dy and values of module of gradient and tangent of angle of declination to axis Ox.

The most difficult task is formalization of texture of image, that is object that characterized forms, sizes and relative positions of elements whish consist the object. For texture is typical the spatial repeatability of local structure of brightness field. Therefore the qualitative characteristic of texture is value of period of repeatability.

For automation of the process attributes was integrated into program space Erdas in Model Maker. Using histograms (see Figure 2 in [8]) for determination of parameters for detection of places of accumulation of waste it creates the general model and allocate waste dump from other objects. Such approach allows to detect the dump, determine its area size and dynamic of its growth. But it is impossible to identify of sources of forming of ecological danger and determine of its level.

Following development of described above system of recognition of places of illegal accumulation of waste is lies in classification of objects of dump on the basis of degree of it influence on ecological safety level of urban systems.

Direct allocation of zone of carbon containing substances and organic components of dump from other inorganic part of dump is the task that solution implements with many errors of 1st kind. It explains by that the organic components of dump on Space images by brightness and texture parameters almost equal to surrounding vegetation (grass, forest, gardens) [6]. With taking into account of scientific and practical studies, accumulated to the present moment, the question arises about possibility of indirect determination of aerials of organic components of dump.

We propose the method for determination of aerials of observation that assumes excluding (“cutting-out”) from image

areas of dump with low degree of ecological danger, such as construction debris and rock masses. Such waste much easer identifies against background vegetative surface by their special brightness and texture attributes due to high contrast (threshold value) against the background.

For determination of sector with construction debris and rock masses it necessary to divide of surface of histogram into subdiapasons or creates again the data base of diapasons of statistic moments of identified objects by the way of allocation of its objects on picture with obtaining diapasons by histograms. After identification of sectors with construction debris and its contouring by the way of excluding from whole contour of landfill, we determines the rest part of dump area as its carbon containing and organic components. As result we obtained the image of part of dump with predomination of its organic components. On Figure 1 presented scheme of model automated recognizing of landfill of organic component on dump territory.

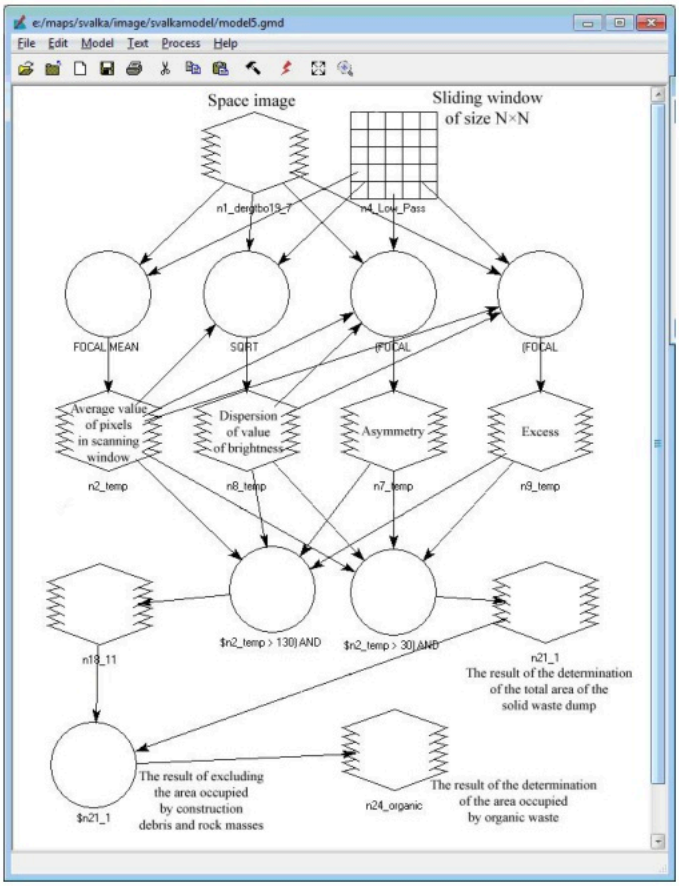


Fig. 1. Scheme of model automated recognizing of landfill of organic component on dump territory

For detection of place of accumulation of waste and determination of value of area of that territory it necessary to implement spatial reference of Space image.

At the 1st stage of model visually analyzed researched area for searching of objects that looks like illegal places of waste accumulation. In case of detection of such objects this area allocates, that makes spatial reference and saving image for following processing.

III. Results and Discussion

Practical realization of developed waste dump and determination of its parameters detection model. For example we implement the research for Dergachi landfill of solid domestic waste (Kharkiv region) (see Figure 2).

Spatial reference of the image performed also for determination of value of area of landfill. Program ArcGIS allows carrying out transforming type of reference .*w (reference in external file) in format *.img with reference in internal file (see Figure 3). After starting of program ERDAS it necessary to load into it Space image by executing the following sequences of actions: File/Open/Raster_Layer/Image _file_name. Spatial references of full set of Space images was transformed into references of geographical type WGS_84. Function of stapling of files in accordance with spatial coordinates allows to precisely matching pixel on one image with the same one pixel on other picture and trace of its changes.

But, as it can be seen, in the case of using of automatic classification of objects on the processed Space image roads and waste are painted in same color. Consequently, using of universal method we can not allocate the dump.

So we implemented allocation of presumably place of accumulation of waste using of model that based on analysis of statistical moments of different orders (average value, dispersion, asymmetry and excess). For execution of that tasks we will act in accordance with following algorithm:

– finding of average number of pixels in specific part of image by the way of developing of its model in program Toolbox/Model maker using the command Focal Scan/Fokal Mean;

– marking on the image the sector of landfill that corresponds to selected model for calculation of average number of pixels;

– developing of model of dispersion in Focal Scan/Focal Standard deviation and presenting it on picture and than selecting of diapason of values of dispersion using histograms;

– determination in accordance with histograms of required parameters for detection of zone of accumulation of waste (see Table 1) and than allocation of from other components of landscape (see Figure 4,a);

– loading of image in program ArcMap, creation of shape-files and classification (see Figure 4,b), vectorization and calculation of value of area.

Setting of parameters of vectorization allows to exclude the noises (small objects).

TABLE I. Diapasons of values of parameters of general model of detection of waste dump on space image

Parameter	Diapason in accordance with histograms
Average number of pixels	130…196
Dispersion	6…30
Excess	0…4
Asymmetry	0…14

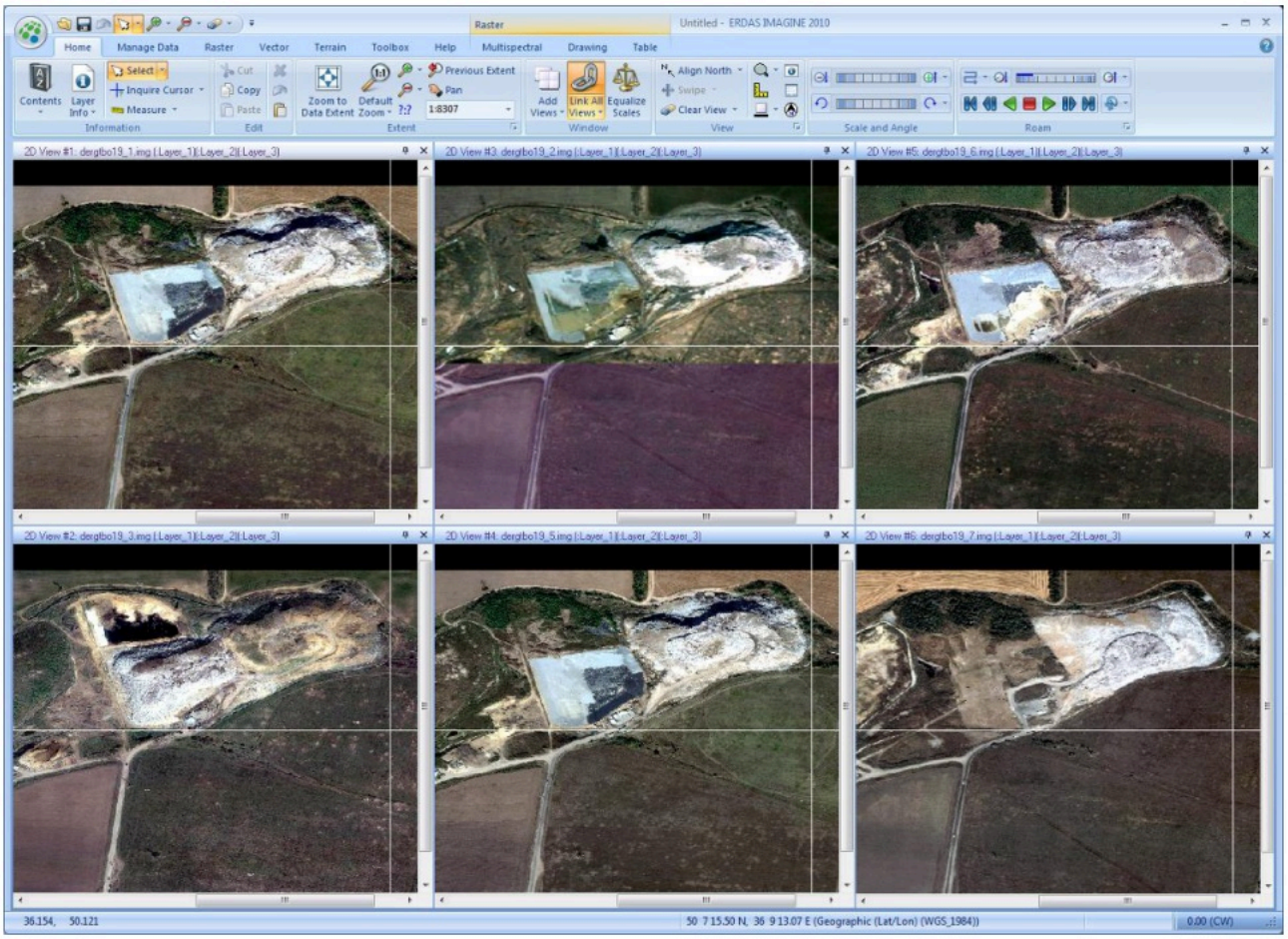


Fig. 2. Space images of Dergachi landfill of solid domestic waste

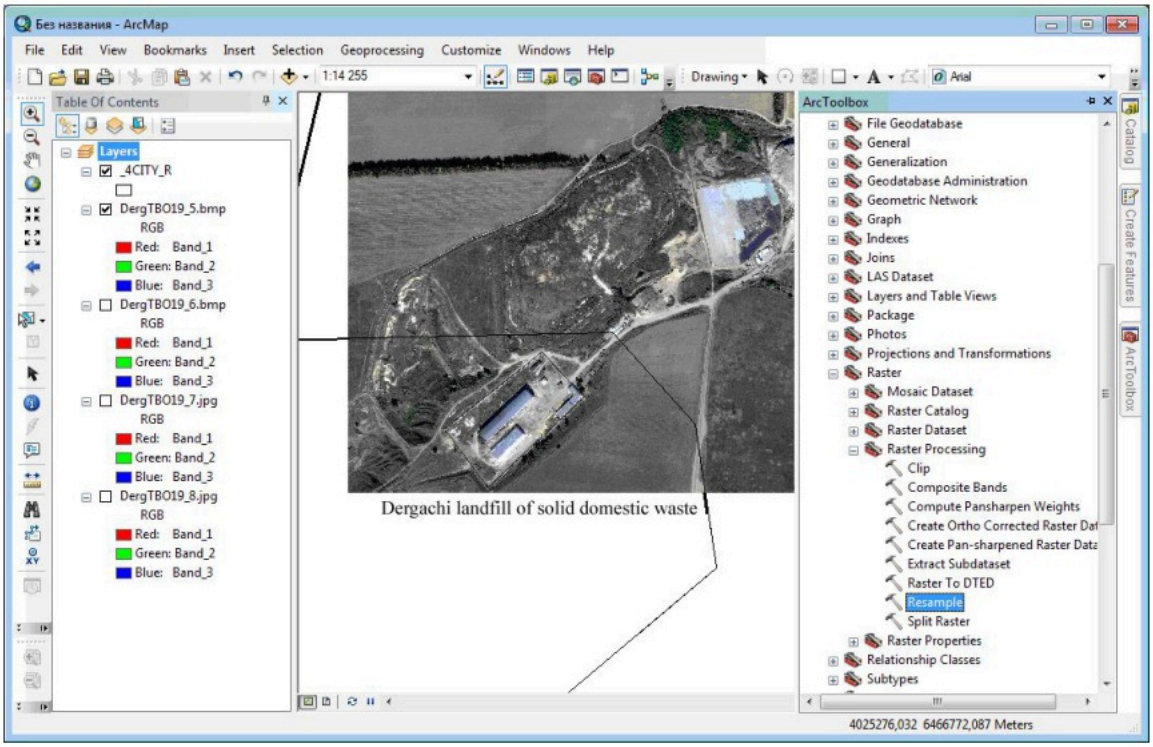
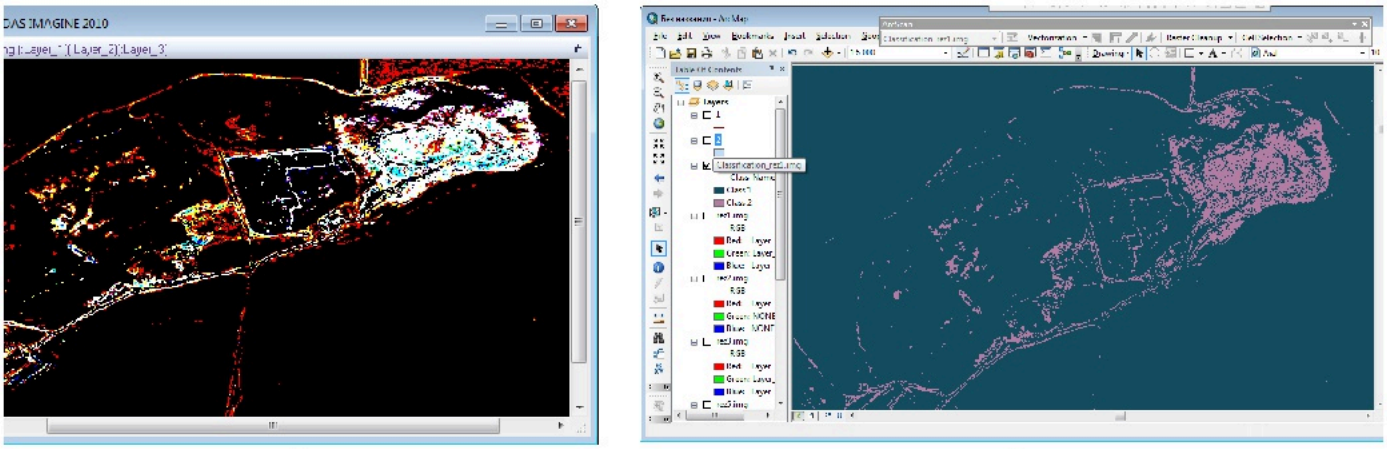


Fig. 3. Convertation of image formats in ArcGIS for following processing that united by geographical reference for different time periods



a b

Fig. 4. Borders of dump that detected on Space image (a) and Classified landfill (b)

Further, the total landfill area was calculated. Using the developed model, the landfill area of the Dergachevsky solid waste landfill was calculated for 15 months of its operation. The interval of the analysis of space images is 3 months. The results of the calculation are shown in Figure 5.

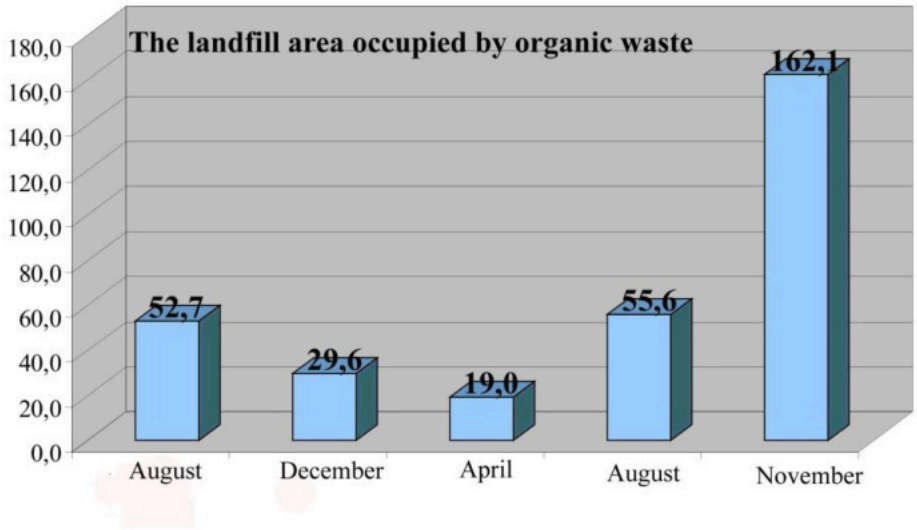


Fig. 5. Change in landfill area with predominance of carbon-containing materials in time

In Fig. 4 shows the change in the area occupied by the limited waste. As an example, we reviewed the landfill that functions. That is, the waste is sorted, the useful fractions are recovered, and the remaining waste covering over with soil. Therefore, within a few months, a reduction in the territory with waste can be observed. If unauthorized places of waste accumulation are found on space images and their area is increased, then it is necessary to liquidate the landfill for further environmentally friendly waste processing [10].

CONCLUSIONS

1. Researching and analysis of characteristics of places of accumulation of waste shows that materials and substances is heterogeneous. That's why application of method of universal classification of image for detection of places of accumulation of waste and determination of its area value with necessary accuracy do not gives positive result.

2. General model which based on methods of remote scanning of Earth with combination with GIS-technologies and methods of mathematical modeling allows to allocate the waste dump on images and also determine its area and dynamic of growth. But this model not allows to identify of elements which are sources of formation of ecological danger because this task solves with many errors of 1st kind.

3. Developed model that based on method of exclusion («cutting-out») on image of sectors of dump with low degree of danger such as construction debris and rock masses allows to allocate of areas of carbon containing materials and organic components of dumps.

4. Taking following development the general model of detection of places of accumulation of waste using Space images in form of specialization of allocation of aerials of dump with carbon containing materials and its organic

components. That allows to increase of efficiency of implementation of ecological monitoring and use of detected carbon containing wastes for obtaining of fuel products [9] and ensuring environmental safety [10].

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