

## LOCALIZATION OF THE GAMMA-RADIATION SOURCES USING THE GAMMA-VISOR

by

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The search of the main gamma-radiation sources at the site of the temporary storage of solid radioactive wastes was carried out. The relative absorbed dose rates were measured for some of the gamma-sources before and after the rehabilitation procedures. The effectiveness of the rehabilitation procedures in the years 2006-2007 was evaluated qualitatively and quantitatively. The decrease of radiation background at the site of the temporary storage of the solid radioactive wastes after the rehabilitation procedures allowed localizing the new gamma-source.

*Key words:* gamma-visor Cartogam, dose rate, radioactive waste

### INTRODUCTION

The gamma-visor Cartogam equipped with the special software [1] was used for the express remote localization of the  $\gamma$ -sources and the dose rate evaluation. It is of great interest for the studies of nuclear power plants (NPP), radioactive waste storage sites, spent nuclear fuel, *etc.* The gamma-visor can be used for the diagnostics of radiation sources at "hot" facilities as well as during nuclear reactor shutdowns. These measurements are critical for the reduction of the personnel exposure dose during maintenance and rehabilitation, as well as for the determination of exposition time for people and equipment in contaminated zones. The gamma-visor allows the express and remote localization of  $\gamma$ -sources even in the presence of other sources inside or outside the field of surveillance at NPPs, radioactive waste storage sites and other nuclear sites.

This work was carried out in the frame of the scientific direction: Development of the techniques of remote integral and differential measurements of radia-

tion background and its structure at the site of the temporary storage of the solid radioactive wastes in Ostrovnoi, Russia (fig. 1). The objectives were: the assemblage, installation, tuning and adaptation of the gamma-visor Cartogam to the field conditions of Northern Russia; radiation measurements at the site of the temporary storage of solid radioactive wastes (STSSRW) in order to conduct the monitoring and to analyze the dynamics of the radiation situation at the site during the rehabilitation work in 2006-2007; the evaluation of the relative  $\gamma$ -dose rates from the main sources.

### EXPERIMENTAL

Gamma-visor Cartogam produced by CANNBERA [1] consists of a registration block, a handheld computer equipped with the software GammaView 4.03, and a 30 to 200 m long protected cable. The registration block is a 17.7 kg 414 mm long cylinder of 80 mm diameter protected by tungsten alloy. This block consists of a  $\gamma$ -radiation collimator, a 4 mm thick CsI(Tl) scintillator and an amplifier. A 0.25 mm inlet collimates  $\gamma$ -quants that are transformed into photons on the scintillator. After the amplification the photons are registered with the matrix. For visible light the inlet works as a lens. It enables obtaining a visible image of the studied object with the same matrix. As a result, one can get a visible image combined with the images from the  $\gamma$ -sources. The energy registration range of

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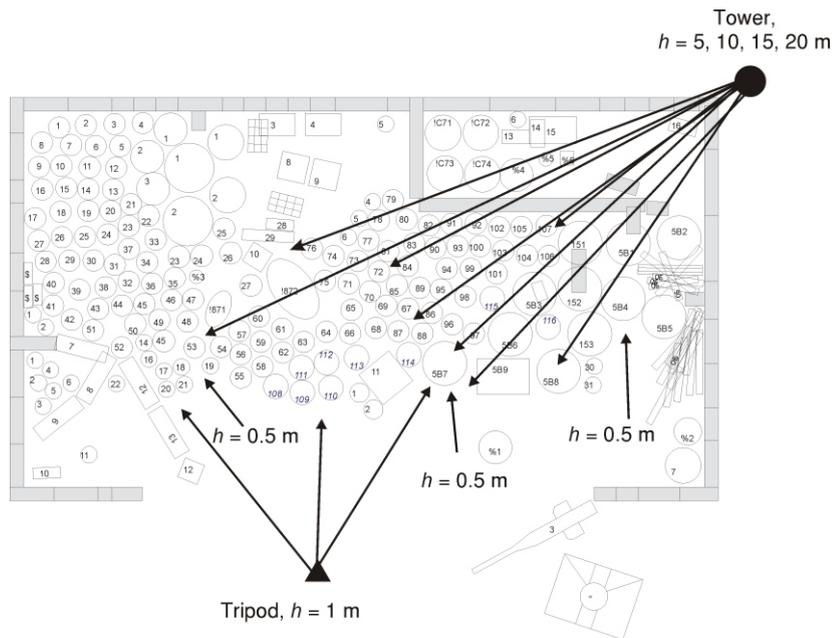
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**Figure 1. The scheme of STSSRW. The directions of the Cartogam measurements are shown as arrows**

the detector is 50 keV to 1.5 MeV. The spatial resolution is from  $2.5^\circ$  for  $^{137}\text{Cs}$  to  $4.5^\circ$  for  $^{60}\text{Co}$  with the standard ( $50^\circ$  4 mm thick scintillator) collimator. The sensitivity for the  $\gamma$ -radiation of 662 keV ( $^{137}\text{Cs}$ ) is from 100 nGy/h to 500 mGy/h. The gamma-visor is equipped with a remote control positioning system.

The gamma-visor can locate  $\gamma$ -radiation sources and determine absorbed dose rates (ADRs) at the detector point. The measurements can be done from a standard (1 m high) tripod. Images collected from different positions provide better determination of the  $\gamma$ -radiation source locations. The images can also be collected from a special tower, as it is shown in this work. The telescopic tower (PA/SM 35.15-020) with the height variable within 5 to 20 m was established at the STSSRW southern corner. The detector on the positioning block was fixed on the top of the tower (fig. 2). In case of bad weather conditions the tower can be dismantled within 30 minute.

**Measurement technique.** The measurements at the STSSRW were conducted from the 1 m high tripod from the entrance as well as from the 5, 10, 15, and 20 m tower (fig. 1). A special handheld computer equipped with the special software GammaView 4.03 was used for data processing. The control for the positioning block and data processing can be done remotely from up to 200 m. The gamma-visor sensitivity decreases from the center of the image to its periphery. The ADR error for the point sources is 30% to 50%, which is often acceptable. At long distances the angular resolution can be insufficient to resolve close  $\gamma$ -sources.

**Data processing.** The first step of measurement is the visual image (photograph) and the  $\gamma$ -image of the studied object. A high or a low count rate mode can be chosen for the measurement. In this work the low count rate mode was used. The  $\gamma$ -image processing includes the variation of certain parameters like segmen-



**Figure 2. General view of the gamma-visor Cartogam on the tower**

tation (separation of sources of different  $\gamma$ -intensity), discrimination threshold (0 to 0.9), energy of the standard line for the ADR calculation (in this work it was  $^{137}\text{Cs}$  – 662 keV). As an example we can take the ADR measurement from the 10 m tower for the STSSRW center (figs. 3 and 4).

In all instances, the ADR measurements were done according to the following scheme: the visual image (photograph), the  $\gamma$ -image (exposition time 15 minutes), the composite image. It resulted in the picture with the  $\gamma$ -spots of the calculated ADRs depending on the chosen discrimination threshold 0.0–0.9. The images for the zero discrimination threshold and

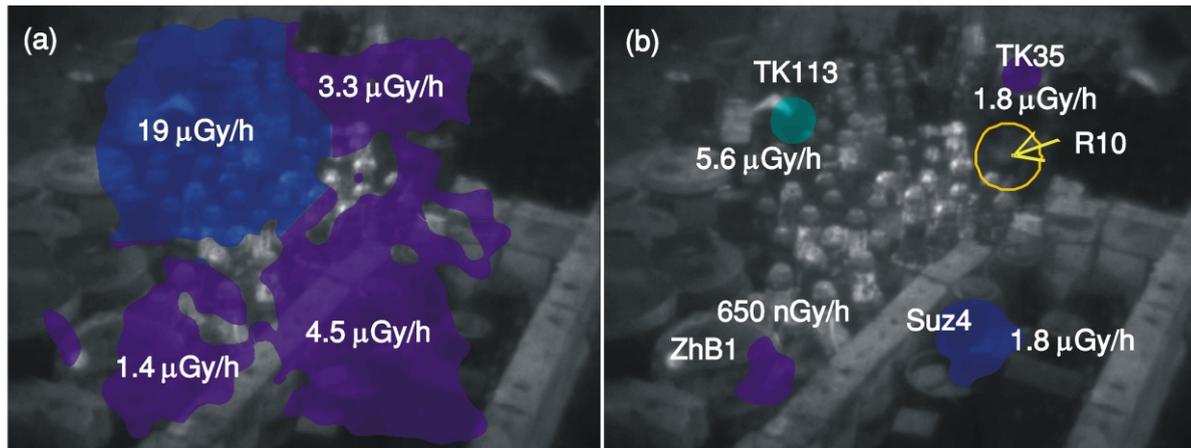


Figure 3. Composite images for the gamma-dose rates at the discrimination thresholds: (a) 0,0 and (b) 0.5. The gamma-dose rates were registered in the point of the gamma-visor location on the 10 m tower

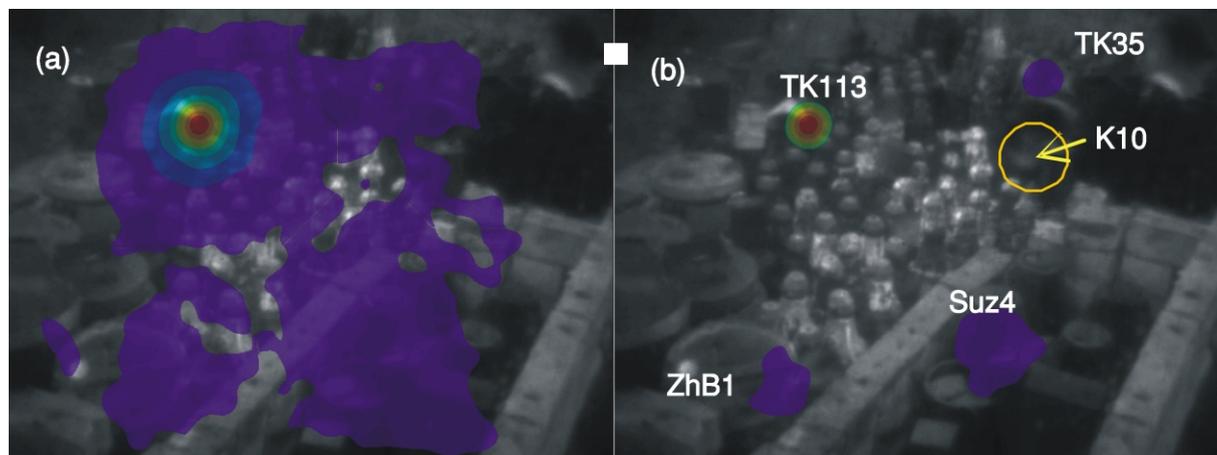


Figure 4. Composite images for the iso-impulse count rates at the discrimination thresholds: (a) 0,0 and (b) 0.5. The measurements were done from the 10 m tower

ADR calculated for  $^{137}\text{Cs}$  (662 keV) are given in (fig. 3a). The optimal discrimination threshold was 0.5. It yields a picture with the  $\gamma$ -spots reduced to the object size (fig. 3b). A more precise location of the  $\gamma$ -source can be drawn at the discrimination threshold of 0.9.

To evaluate an ADR at a  $\gamma$ -source one has to know the distance to this source and the information on other  $\gamma$ -sources around it. This evaluation was done in this work (tab. 1). The ADRs calculated in this work were compared to the results of the dosimeter measurements [2].

In all instances the composite images for the iso-impulse count rates at the discrimination thresholds 0, 0.5, and 0.9 were obtained as well. These images indicate the dose rate gradient using colors (fig. 4). The composite images for the iso-impulse count rates at the high discrimination thresholds also allow more precise locating of the  $\gamma$ -source (fig. 4b).

Figures 3b and 4b show that the brightest  $\gamma$ -sources are: TK113, TK35, ZhB1, and Suz4.

## RESULTS AND DISCUSSION

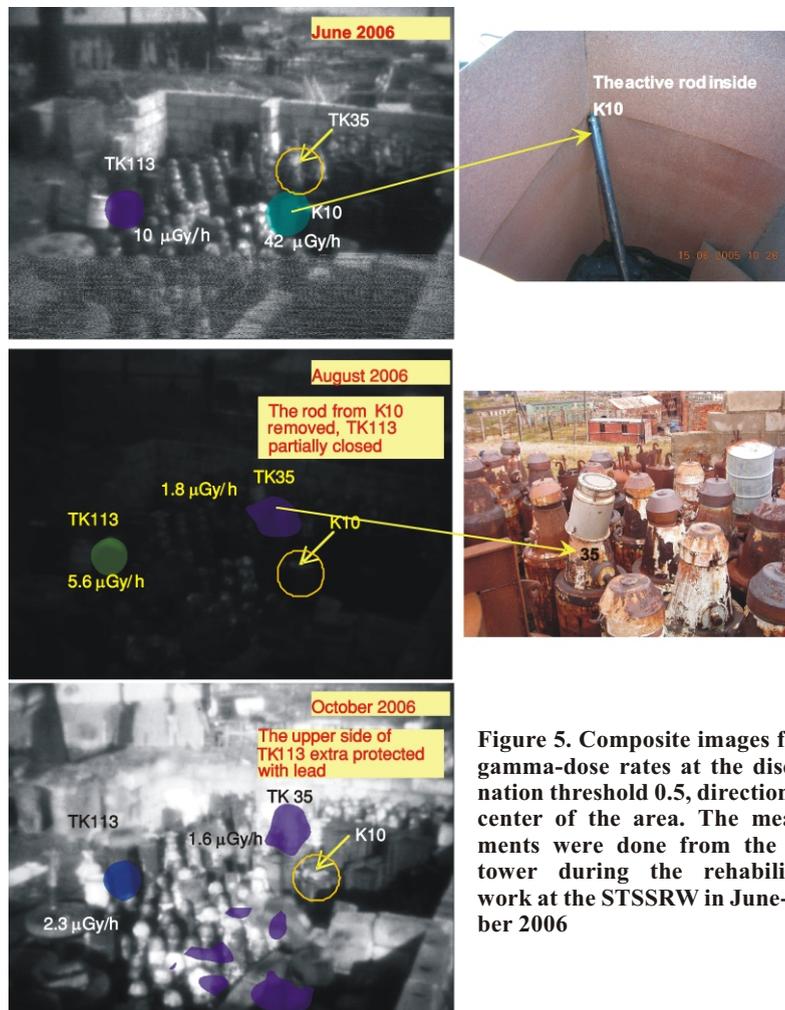
All ADR measurement results at the STSSRW can be presented as following: (a) a black and white visual image; (b) an original (unprocessed)  $\gamma$ -image; (c) a processed  $\gamma$ -image; (d, e, f) composite images for the  $\gamma$ -dose rates at the discrimination thresholds 0, 0.5, and 0.9; (g, h, i) composite images for the iso-impulse count rates at the discrimination thresholds 0, 0.5, and 0.9 (see, for example, [3]).

The discrimination threshold variation enables displaying the maxima of the  $\gamma$ -peaks and the shapes of the sources (figs. 3 and 4). Despite the fact that the main  $\gamma$ -sources at the STSSRW were determined earlier using dosimeters [2], these data were specified more accurately in the present work using the gamma-visor Cartogam. The present results show that the brightest sources at the STSSRW were K10, TK113, containers 35, K15, Bet2, Bet4, ZhB1, and Suz4, what agrees with the dosimetric data [2]. It was

**Table 1. Gamma-source at the STSSRW. Distance tower-source  $x$  [m], tower height  $h$  [m], and relative absorbed dose rates\* calculated on the basis of the gamma-visor measurement data [mGy/h] for the discrimination thresholds 0 (0.5)**

Object	$x$ [m]	$h$ [m]	June 2006	June-August 2006	September-October 2006
			Absorbed dose rate [mGy/h]		
Metal container K10	21	5	51.3 (9,8)	Not observed (background level)	Not observed (background level)
		10	102.8 (22.7)		
		15	159.8 (28.0)		
Metal container 113	19	5	12.4 (2.4)	10.6 (2.6)	(1.1) (1.7) (1.5)
		10	21.2 (4.6)		
		15	39.8 (7.6)		
		20			
Metal container K15	9	10	7.2 (3.3)	4.0 (1.9)	(1.4)
		20	41.8 (13.5)		
Transport container 35	24	10	Not observed (background level)	7.4 (1.2)	(1.1) (1.1) (1.2)
		15			
		20			

\* Absorbed dose rates for the discrimination thresholds 0.5 are given in parentheses



**Figure 5. Composite images for the gamma-dose rates at the discrimination threshold 0.5, direction – the center of the area. The measurements were done from the 10 m tower during the rehabilitation work at the STSSRW in June-October 2006**

found that as the tower height increased the ADRs for K10, TK113, and K15 grew (tab. 1). This can be explained by the fact that the upper parts of these containers are less protected than their bodies. The ADRs measured at the point of the gamma-visor location allow only qualitative evaluation of the real dose rates around the sources. If the measurements were done

from exactly the same position under the same conditions and parameters, the data could be comparable and qualitative and quantitative conclusions about the situation at the STSSRW could be yielded (figs. 5-7).

After the first series of gamma-visor measurements (June 2006), a stage of rehabilitation work on the protection of the most dangerous sources was per-



Figure 6. Composite images for the gamma-dose rates at the discrimination threshold 0.5 measured from the tripod (1 m high) installed at the central entrance at 5 m from the containers before and after TK113 closure in June-August 2006. Direction – containers 109-110

formed. Thus, the upper part of TK113 was covered by lead sheets and then it was extra protected with lead balls. The gamma-visor measurements from the 10 m high tower in August-October 2006 showed that the ADR from TK113 was reduced (fig. 5, tab. 1). The measurements from the tripod in June and August 2006 showed a small ADR decrease from TK113 (fig. 6).

After the removal of the active rod from K10 to the container 55 in June 2006, the ADR from K10 dropped to the STSSRW background level (fig. 5b). The ADR from the container 55 also remained at the background level. After K15 had been covered by lead sheets, its ADR was reduced about twice (fig. 7, tab. 1). The most active containers located at the STSSRW entrances (Bet4, Bet8, TK113, L18, L20, L21) were studied from the close distance (3-5 m, fig. 1) from the tripod. The shapes and positions of the  $\gamma$ -sources inside these containers were determined (see [3]).

Unfortunately, the ADR yielded by the gamma-visor is measured directly at the detector. To evaluate the

ADR  $P_0$  [mGy/h] at the source one has to use the formula  $P_0 = P R^2$ , where  $P$  is the ADR gamma-visor, and  $R$  – the distance gamma-visor – source [4].  $R$  [m] can be calculated as  $R^2 = x^2 + h^2$ , where  $h$  is the height of the tower, and  $x$  – the distance tower – source (tab. 1). Thus, for K10  $x = 21$  m and  $h = 5, 10, \text{ and } 15$  m at the discrimination threshold of 0.5 the ADRs  $P_0$  are 9.8, 22.7, and 28.0 mGy/h, respectively (tab. 1). This indicates a significant anisotropy of radiation from this container. For K15 ( $x = 9$  m, at  $h = 10$  m and 20 m) at the discrimination threshold of 0.5 the ADRs at the container are 3.3 mGy/h and 13.5 mGy/h, respectively. The last value coincides with the dosimeter measurement data for K15 [2].

The relative ADR  $P$  [ $\mu$ Gy/h] depends on many factors not considered in the present work. The first stage of the work was to draw a correlation between the gamma-visor data and other measurement data, in particular, dosimetry data at the STSSRW by NIKIET [2]. However, the accurate ADRs are difficult to

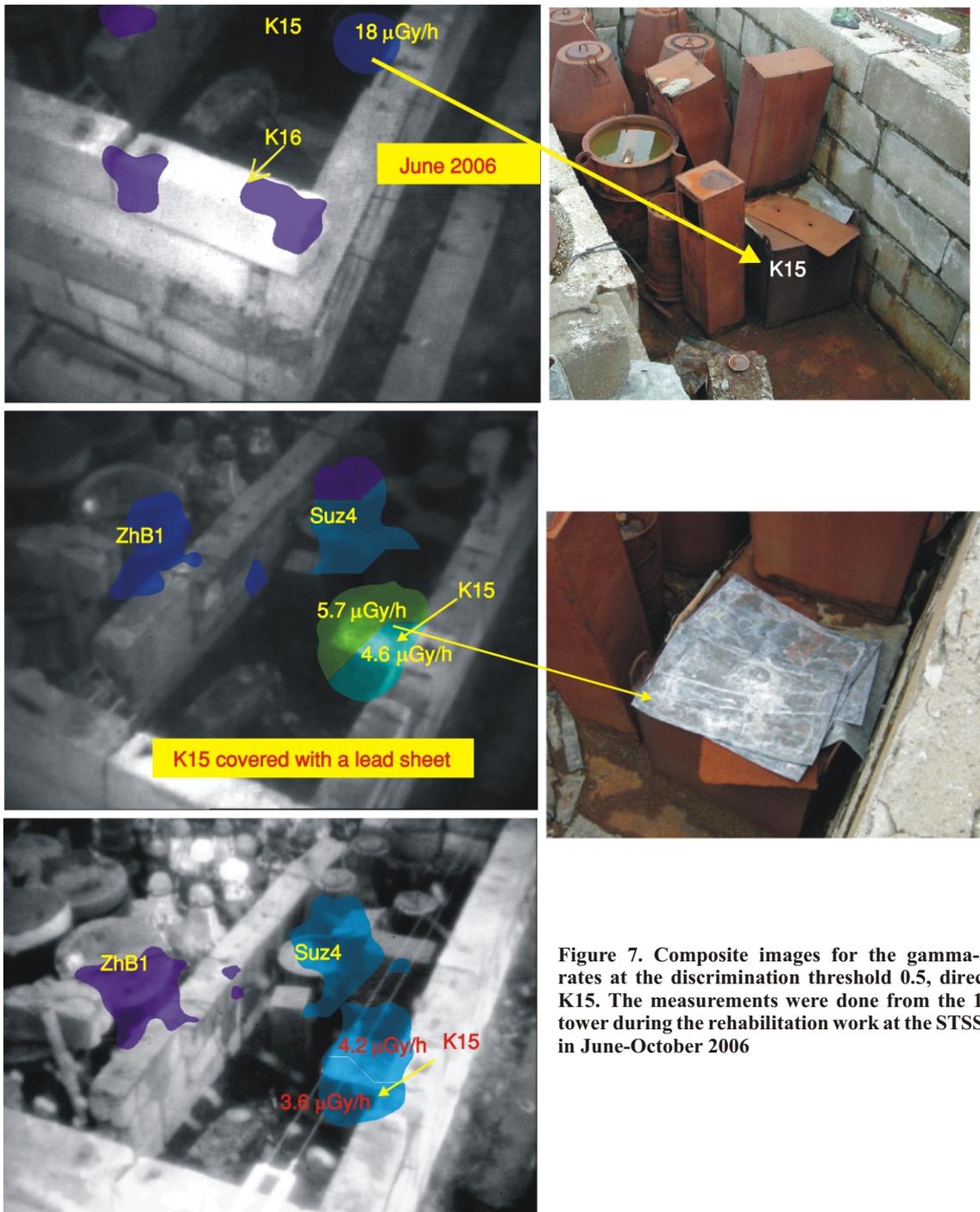


Figure 7. Composite images for the gamma-dose rates at the discrimination threshold 0.5, direction K15. The measurements were done from the 10 m tower during the rehabilitation work at the STSSRW in June-October 2006

measure because of the presence of many sources of different dose rates at the STSSRW. After the rehabilitation work on neutralization of the most dangerous objects, the gamma-visor will detect the next intense ones, *etc.* That was how the container 35 (fig. 5) was detected. Unfortunately, the correlation of the gamma-visor data and the real ADR at the studied source has not been drawn yet. This correlation must exist for the point sources. However, it requires an experimental confirmation.

All the obtained data agree qualitatively with the dosimetry data [2] and describe the radiological

situation at the STSSRW well enough. These data allow planning the rehabilitation work and fulfilling proper monitoring during the work.

## CONCLUSIONS

The assemblage and installation of the gamma-visor Cartogam with the mechanical positioning block on the top of the telescopic tower close to the STSSRW allowed the registration of  $\gamma$ -radiation from the individual sources from the same position in differ-

ent periods of time. As a result, a technique of the remote monitoring of the radiation situation at the STSSRW during the rehabilitation work was elaborated.

The search of the main  $\gamma$ -radiation sources at the STSSRW was carried out using the gamma-visor Cartogam equipped with the special software GammaView 4.03. The relative ADRs for different  $\gamma$ -sources before and after the rehabilitation work were measured. It allowed a qualitative and quantitative analysis of the effectiveness of the rehabilitation work at the STSSRW in 2006.

– It was found that after the partial closure of TK113 and K15 by lead sheets in June 2006, their ADRs decreased about twice. After the extra protection of the upper part of TK113 by lead balls in September 2006, its ADR decreased twice more.

– After the removal of the active rod from K10 to the container 55 in June 2006, the ADR from K10 dropped to the STSSRW background level. The ADR from the container 55 also remained at the background level.

– Reduction of the general background radiation at the STSSRW due to the closure of TK113 and K15

and removal of the active rod from K10 during the rehabilitation work revealed a new  $\gamma$ -source – container 35.

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## ЛОКАЛИЗАЦИЈА ИЗВОРА ГАМА ЗРАЧЕЊА ПОМОЋУ ГАМА ВИЗИРА

Приказана је потрага за главним изворима гама зрачења на простору привременог одлагалишта чврстог радиоактивног отпада. За неке гама изворе, пре и после поступка рехабилитације, измерене су релативне јачине апсорбованих доза. Успешност поступка рехабилитације у периоду 2006–2007. година процењена је квалитативно и квантитативно. Слабљење основног нивоа зрачења на простору привременог одлагалишта чврстог радиоактивног отпада, омогућило је локализацију нових гама извора по спроведеном обнављању.

*Кључне речи: Картограм – гама визир, јачина дозе, радиоактивни отпад*