Photoshop's Deadly Consequences

by Nick Barreiro

I love Adobe Photoshop. I use Photoshop every day in my work as a video/image forensic analyst. It is a fantastic, powerful piece of software, and the undisputed heavyweight champ of digital image editing applications. Like most powerful tools, Photoshop can be used for good and for evil. We are all familiar with the impact of doctored photographs used for political purposes, and retouched images of supermodels wreaking havoc on young women's self-esteem; however, you have likely never considered the threat posed by the scenario outlined in the following paragraphs. This story illustrates a real and immediate danger to the health of millions of people around the world.

I was recently contacted by Ola M. Kamar, a Biochemistry/Nano-Chemistry Ph.D. candidate at the University of Central Florida, regarding suspicious photographs that appeared in a research paper published by a respected medical scientific journal, Biosensors and Bioelectronics (ISSN: 0956-5663). Ms. Kamar requested forensic image authentication analysis of the photographs because she suspected that the images had been manipulated prior to publication. Ms. Kamar sent me a PDF document containing the research paper, *Cascade of Deoxyribozymes for the Colorimetric Analysis of Drug Resistance in Mycobacterium Tuberculosis*.

The photographs in question appeared on page 9 of the paper. The images depicted multiple sample tubes containing small amounts of liquid, varying in color concentration from bright green to colorless.

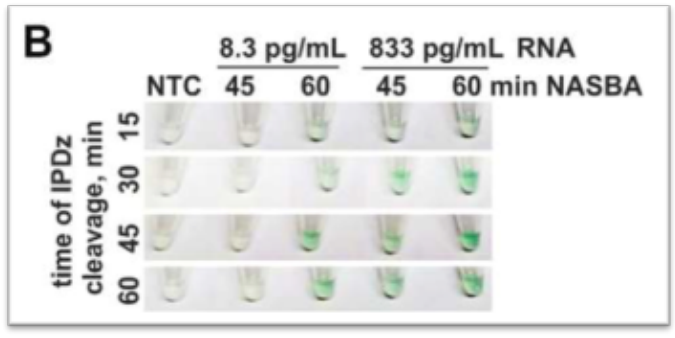


Figure 1: Image from page 9 of Cascade of Deoxyribozymes for the Colorimetric Analysis of Drug Resistance in Mycobacterium Tuberculosis

Ms. Kamar suspected that the bright green color of the liquid in the tubes was manipulated in violation of the journal's guidelines and in violation of the scientific community's trust. The journal's publisher, Elsevier, expressly prohibits image adjustments that result in the distortion of data:

> *Elsevier's policy on manipulation of images*
>
> *Our policy is that no specific feature within an image may be enhanced, obscured, moved, removed, or introduced. Adjustments of brightness, contrast, or color balance are acceptable if and as long as they do not obscure or eliminate any information present in the original. Manipulating images for improved clarity is accepted, but manipulation for other purposes could be seen as scientific ethical abuse and will be dealt with accordingly.*
>
> *- elsevier.com, Artwork and media instructions*

I conducted a preliminary analysis of the image in Figure 1 and observed artifacts consistent with artificially increased contrast and saturation. The intensity of the green color appeared unnatural, and the white background contained a significant amount of visible color noise. There were inconsistencies in the luminance of the shadows cast by the tubes. The shadows on the right side of the image were deep black (RGB 2,3,0) while the shadows on the left were middle gray (RGB 128,128,128). I also conducted Error Level Analysis (ELA) and obtained the results shown below in Figure 2.

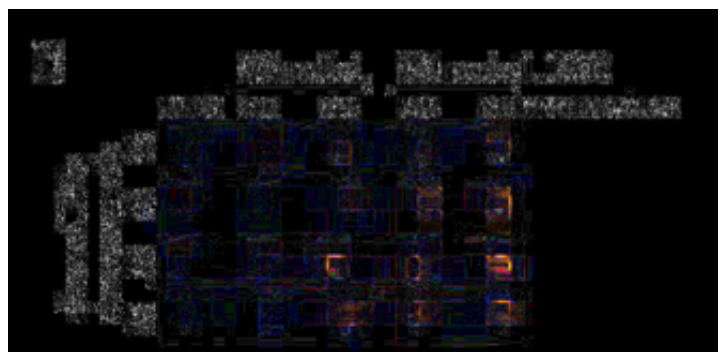


Figure 2: Error Level Analysis of the image in Figure 1

Although ELA is somewhat controversial due to the results requiring some subjective analysis, it often provides a strong visual result that a layperson can recognize with minimal explanation. Like most of the tools I use in forensic work, I never rely solely on ELA to form a conclusion about an image. I always seek corroborating evidence and look at the totality of the circumstances. In this case, the visual evidence and ELA results were consistent and showed strong support for the hypothesis that the images had been manipulated.

I informed Ms. Kamar that her suspicions appeared to be founded and I sent her the ELA results. I explained that I would not be able to quantify the manipulation or write a full forensic report without access to the original unedited images. Ms. Kamar forwarded this information to the journal's editors who then confronted the author of the research paper, Yulia Gerasimova. Ms. Gerasimova responded:

> *I can state that no falsification or fabrication of data took place regarding the results reported in the paper. Figure 2B that your letter is referring to was made in the Adobe Photoshop program to crop the tube areas from original photos (acquired using a smartphone camera) and place the cropped areas from different smartphone images in one file to make one figure. I believe these manipulations are not considered "image falsification". We never engage in data falsification or fabrication in our research practice.*
>
> *- Yulia Gerasimova, via email May 18, 2021*

The editors then requested the original unedited photographs from Ms. Gerasimova. She sent the authentic original JPEG images with the following explanation:

> *The tubes were placed on a white piece of paper, photographed with the camera of an LG Style 4 smartphone and transferred to a desktop computer. The images were open in Adobe Photoshop, cropped to have only the needed tubes, followed by adjustment of brightness/ contrast of the tubes to reflect the lost contrast and/or brightness upon photographing the tubes (the color is brighter when you observe the tubes with the naked eye). Position of the tubes in the images were adjusted whenever needed (up/down to have the tubes on a similar level, and their order was changed whenever needed to correspond to the correct samples as described in capture of Figure 2B). Next, the cropped images from each file were transferred to a new Photoshop document to align the sets of tubes one on top of another, as described*

in the capture of Figure 2B. The combined file was saved as jpg and imported into CorelDraw document to combine panel B with other panels of Figure 2. The CorelDraw file was then exported as jpg file to be submitted to the journal (Fig2-rev.jpg attached).

- Yulia Gerasimova, via email May 19, 2021

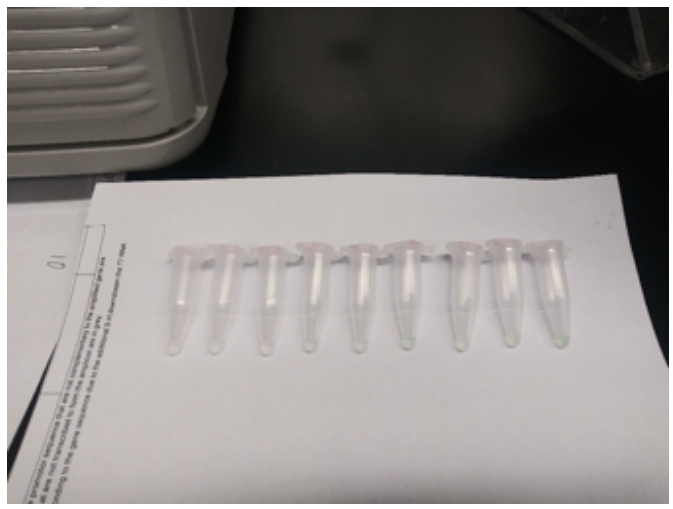


Figure 3: Authentic original JPEG image A

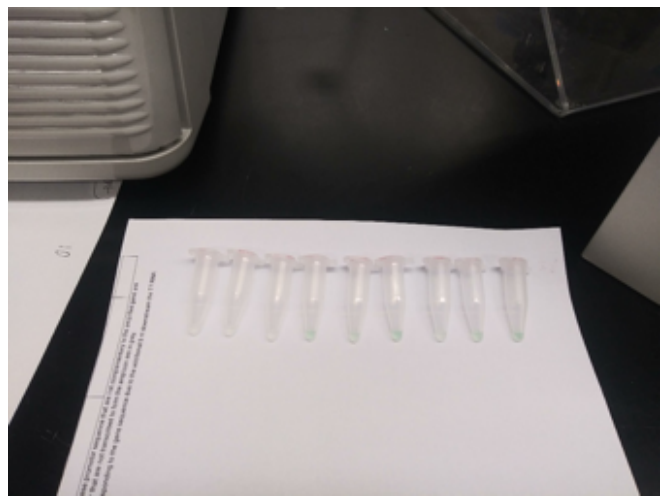


Figure 4: Authentic original JPEG image B

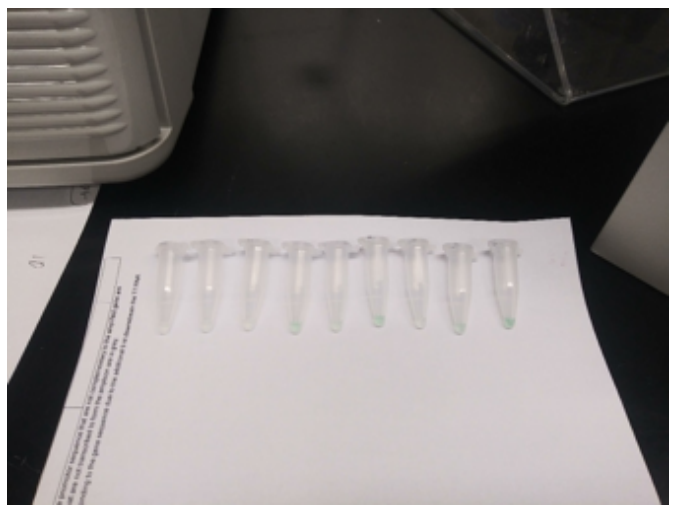


Figure 5: Authentic original JPEG image C

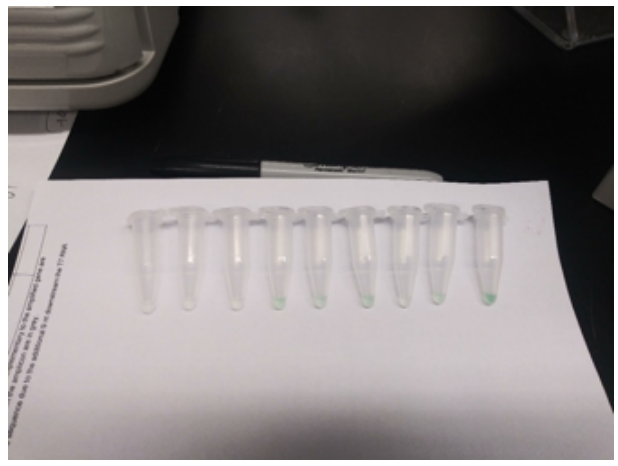


Figure 6: Authentic original JPEG image D

Even an untrained eye can see the published images have significantly more contrast and saturation than the authentic original images.

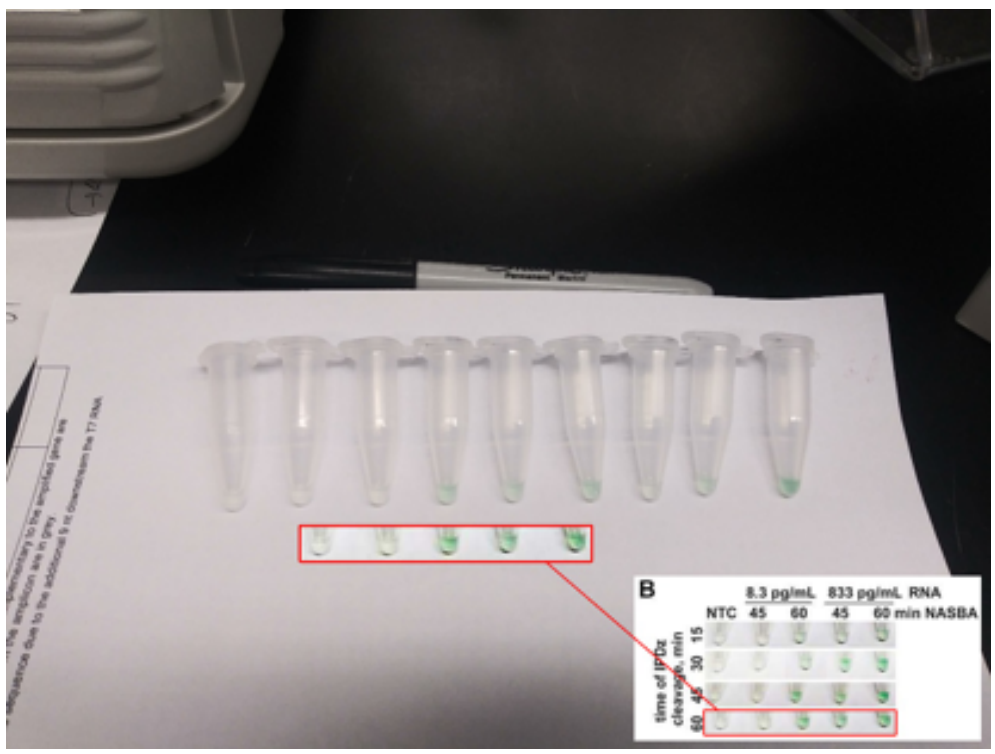


Figure 7: Comparison of authentic original image D with the published image

Ms. Gerasimova's explanation that adjustments were made "to reflect the lost contrast and/or brightness upon photographing the tubes" is refuted by the Sharpie included in the last photograph. The brightness and contrast of the marker accurately represent the gray and black tones of a standard Sharpie.

Below is the same image after I used Adobe Photoshop to adjust the color, brightness, and contrast to match the published image.

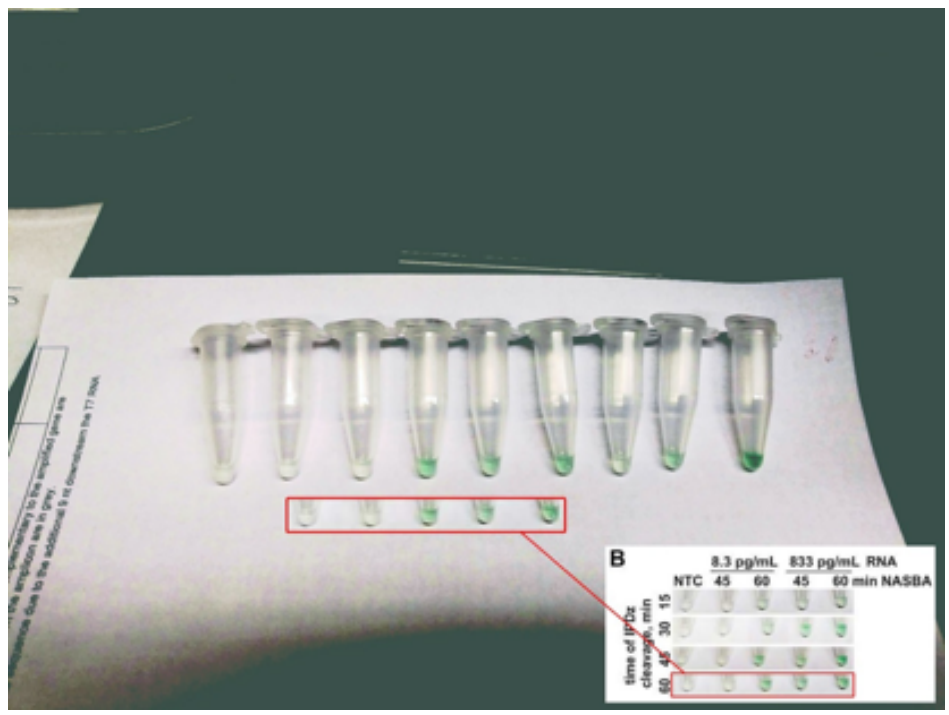


Figure 8: Original JPEG image with color, brightness, and contrast adjustments to match the published image

The adjustments necessary to make the original image match the published image were so extreme that they rendered the Sharpie, as well as all other background details, completely unrecognizable. It is clear that the published image does not represent the reality of what was captured by the camera. To objectively quantify the difference between the original image and the published image, I used Photoshop to generate histograms comparing the tonal range of the liquid in the sample tubes.

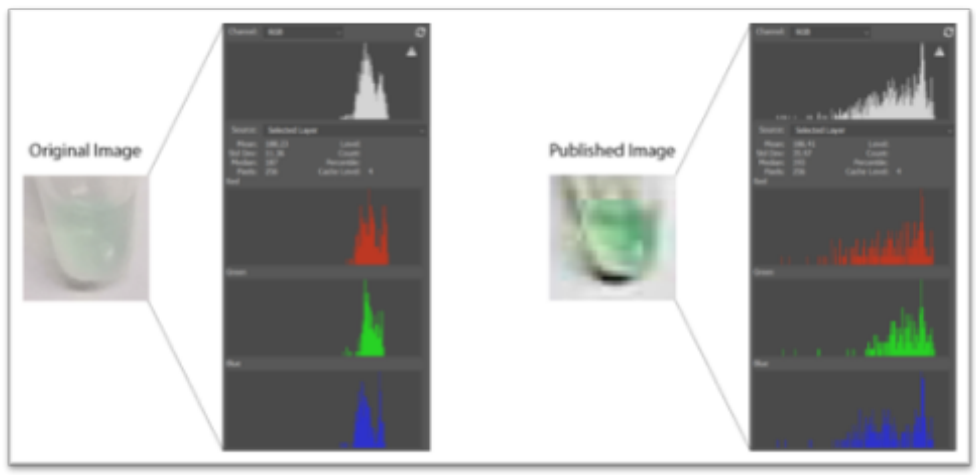
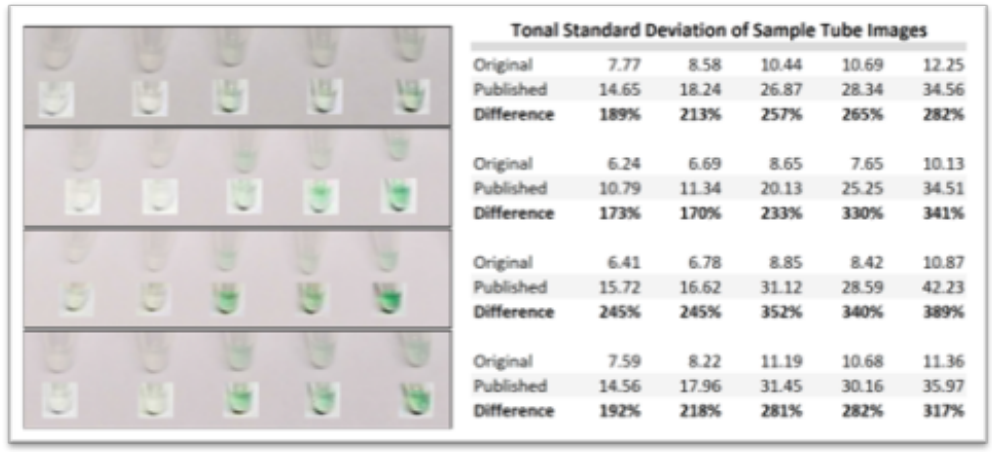


Figure 9: Histograms comparing the tonal ranges of a portion of the original image vs. the published image

The contrast difference is obvious when looking at the images themselves, but the histograms in Figure 9 give an objective measurement of how much additional contrast exists in the published image compared to the original. While the sample from the original image has a tonal standard deviation of 11.36, the published image has more than triple the contrast with a standard deviation of 35.97. The table in Figure 10 shows the tonal standard deviation for all of the sample tubes from Figure 1.



Tonal Standard Deviation of Sample Tube Images

Original	7.77	8.58	10.44	10.69	12.25
Published	14.65	18.24	26.87	28.34	34.56
Difference	**189%**	**213%**	**257%**	**265%**	**282%**
Original	6.24	6.69	8.65	7.65	10.13
Published	10.79	11.34	20.13	25.25	34.51
Difference	**173%**	**170%**	**233%**	**330%**	**341%**
Original	6.41	6.78	8.85	8.42	10.87
Published	15.72	16.62	31.12	28.59	42.23
Difference	**245%**	**245%**	**352%**	**340%**	**389%**
Original	7.59	8.22	11.19	10.68	11.36
Published	14.56	17.96	31.45	30.16	35.97
Difference	**192%**	**218%**	**281%**	**282%**	**317%**

Figure 10: Tonal standard deviation for all of the sample tubes from Figure 1

On average, the difference in contrast between the original images and the published images was 266%, with a maximum of 389%. There were several other clearly enhanced photographs incorporated into the research paper, like those in Figure 11, however the original, unaltered images were not available for comparison purposes.

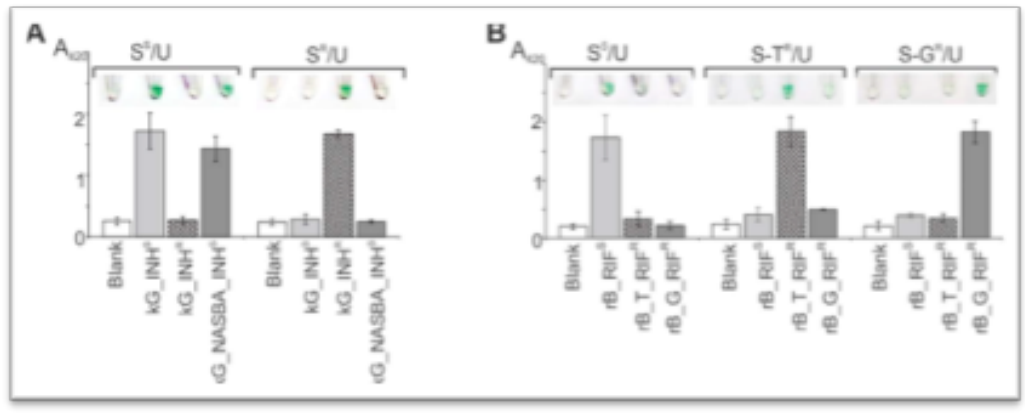


Figure 11: Image from page 7 of *Cascade of Deoxyribozymes for the Colorimetric Analysis of Drug Resistance in Mycobacterium Tuberculosis*

Without question, the images published in *Cascade of Deoxyribozymes for the Colorimetric Analysis of Drug Resistance in Mycobacterium Tuberculosis* were enhanced to exaggerate the results of the study.

A research paper's author has their pride, reputation, and often millions of dollars of grant funding at stake, so the temptation to embellish one's work is understandable, but nonetheless appalling. The scientific community recognizes that this danger exists and is troubled by it. Elsevier, the publisher of the research paper in question, has an article on their website titled Five things every researcher should know about image manipulation. It states that "the manipulation of scientific images is clearly a significant threat to reputable scholarship." The article goes on to say, "Minor adjustment/enhancement of images is acceptable in some cases. Permissible adjustment includes simple magnification of an image, and the addition of relevant arrows and highlights without distortion of the data." There is very

good reason for everyone, not just for the scientific community, to be concerned about distortion of data in scientific research papers.

At the beginning of this article, I stated that this story represents an immediate danger to the health of millions of people around the world. The research paper, *Cascade of Deoxyribozymes for the Colorimetric Analysis of Drug Resistance in Mycobacterium Tuberculosis*, examines a potential new method for detecting tuberculosis, a life-threatening disease. According to the Mayo Clinic, tuberculosis is one of the world's deadly diseases, claiming nearly 4,000 lives each day. Ms. Gerasimova asserted that her method could detect the disease visually, without the use of any instruments. She claimed that a tuberculosis diagnosis could be confirmed or ruled out based on the green color, or lack thereof, in the sample tubes. In a clinical application, a positive test result would almost certainly be interpreted as a negative result due to the exaggerated expectations of color concentration set by the fraudulent images. It is not difficult to see how a false-negative test for patients dying of tuberculosis could have catastrophic consequences.

I am grateful for Ms. Kamar's diligence in her peer review of this research paper and for reaching out to me for assistance with the image analysis. If the manipulated images had remained undetected, misleading conclusions could have resulted in medical misdiagnoses and serious consequences for patients. Until Ms. Kamar contacted me, I had never considered the harm that could be done to the scientific and medical communities by adjusting a few sliders in Adobe Photoshop. It is somewhat ironic that the same tool that allowed Ms. Gerasimova to manipulate the results of her experiment also helped me expose her manipulations. Photoshop's near-magical power to distort reality will always tempt those with malicious intentions, whether in politics, fashion, or science. It is incumbent upon those of us in the forensic community to continue to expose dangerous image manipulation wherever we find it.

Epilogue

After I completed my work on this case, Ms. Kamar identified similar suspicious photographs in a second research paper, Label-Free Pathogen Detection by a Deoxyribozyme Cascade with Visual Signal Readout, authored by Ms. Gerasimova, regarding the diagnosis of Zika virus, published in the journal

Sensors and Actuators B: Chemical (ISSN: 0925-4005) by Elsevier. Upon analysis, it was clear that these images were also enhanced to exaggerate the results of the study.

On the Web:

- https://www.elsevier.com/connect/authors-update/five-things-every-researcher-should-know-about-image-manipulation,
- https://www.elsevier.com/authors/policies-and-guidelines/artwork-and-media-instructions,
- https://www.journals.elsevier.com/biosensors-and-bioelectronics,
- https://www.sciencedirect.com/science/article/abs/pii/S0956566320303791,
- https://www.journals.elsevier.com/sensors-and-actuators-b-chemical,
- https://www.sciencedirect.com/science/article/abs/pii/S0925400518321038,
- https://www.principleforensics.com.

About the Author

Nick Barreiro, AVFA, DIVRT, is a certified Audio Video Forensic Analyst and an FBI-trained member of the Digital Imaging and Video Recovery Team. He is the Chief Forensic Analyst and founder of Principle Forensics, a cutting-edge media forensics laboratory specializing in enhancement and analysis of video, audio, and image evidence. Mr. Barreiro works with attorneys, law enforcement agencies, and corporations involved in civil or criminal matters where recorded evidence plays a key role. This is the first article Mr. Barreiro has written for eForensics magazine.