

The impact of terahertz radiation on living systems

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Key words: terahertz radiation, *E. coli*, *Geobacillus icigianus*, HESc, transcriptomics, proteomics

Motivation and Aim: Nowadays terahertz (THz) frequency range is widely used, especially in the fields of security inspection and medical diagnostics. THz radiation is a non-ionizing radiation with a quantum energy of ~ 0.01 eV, corresponding to the vibrational energies of hydrogen bonds that form the supramolecular structures. It was shown that THz radiation transfers biopolymers to gaseous phase as single nanoparticles, retaining their primary structure. Since it is not extensively presented in the natural habitats, the emergence of such an intense source of this radiation requires the study of the possible effects of THz radiation on living organisms.

Methods and Algorithms: The Novosibirsk free electron laser generates THz radiation in a range of wavelengths from 50 to 240 microns with the peak of 1 MW powers. Proteomic and transcriptomic analysis were performed on various model organisms including human embryonic stem cells and *E. coli* strains with previously developed genosensors pGlnA-GFP, pMatA-TurboGFP, pSafA-TurboGFP, and pChbB-TurboYFP.

Results: Various results on proteomic and transcriptomic responses to THz radiation were obtained. Using MALDI-TOF mass spectrometry it was shown, that radiation near 2.2 THz induce the nondestructive ablation of lysozyme. Bioinformatic analysis indicated that both bacterial and human cells develop a complex response including changes in gene expression and protein production. About 2 % of *E. coli* proteome is affected by THz radiation varying gene expression level of *tdcABCDEFGR*, *matA-F*, *yjjQ*, *dicABCF*, *FtsZ*, *minCDE*, *sfmACDHF*, *yjbEFGH*, and *gfcA* genes, including the induction amyloid biosynthesis through *csg* operon genes. Moreover, THz radiation was shown to cause abnormal morphology of bacterial cells. The study of 2.3 THz irradiation effect on human embryonic stem cells showed no DNA damage, formation of γ H2AX foci, structural chromosomal aberrations, no changes in mitotic index nor morphology, although transcriptional study showed that approximately 1 % of genes expression level was increased, including 15 functional gene classes mostly related to mitochondria.

Conclusion: Application of various electromagnetic radiation spectrum range equipment is one of the most critical anthropogenic impact on the environment factors, with also being a source of environmental pollution. The results of the work allow us to state that non-ionizing THz radiation cannot cause mutational events in biological systems, but it affects the metabolic activity and expression of both individual genes and gene cascades. We are currently continuing experiments with thermotolerant bacteria in the hope of understanding the difference in the response of their genome to THz radiation.

Acknowledgements: This research was funded by the Ministry of Science and Higher Education of the Russian Federation, project No. 075-15-2019-1662 [Laboratory of Molecular Biotechnologies and Kurchatov Genomic Center, Federal Research Center ICG SB RAS, Novosibirsk]. We also have support by Ministry of Science and Higher Education grant No. FWNR-2022-0022 at the Federal Research Center ICG SB RAS.

References

1. Peltek S.E. et al. Novosibirsk FEL terahertz emission for biological application (plenary). 2nd International THz-Bio Workshop 2011.01.19-20, Seul National University, Seoul, Korea. 2011;37.
2. Bogomazova A., Vassina E., Goryachkovskaya T. et al. No DNA damage response and negligible genome-wide transcriptional changes in human embryonic stem cells exposed to terahertz radiation. *Sci Rep.* 2015;5:7749. doi: 10.1038/srep07749.
3. Serdyukov D.S., Goryachkovskaya T.N., ..., Peltek S.E. Study on the effects of terahertz radiation on gene networks of *Escherichia coli* by means of fluorescent biosensors. *Biomed Opt Express.* 2020;11(9):5258-5273. doi: 10.1364/BOE.400432.
4. Peltek S., Meshcheryakova I., Kiseleva E. et al. *E. coli* aggregation and impaired cell division after terahertz irradiation. *Sci Rep.* 2021;11:20464. doi: 10.1038/s41598-021-99665-3.