Thematic Section: Biochemical Research. **Full Paper**
Subsection: Molecular Genetics. *Reference Object Identifier* – ROI: jbc-01/18-55-9-1
The Digital Object Identifier – DOI: 10.37952/ROI-jbc-01/18-55-9-1
Submitted on Jule 12, 2018.

Cytogenetic effect of white phosphorus

© **Anton Z. Mindubaev**,[1]*+ **Edward V. Babynin**,[2] **Dmitry B. Piskunov**,[3]
Ayrat N. Makhiyanov,[3] **Elena K. Badeeva**,[1] **Salima T. Minzanova**,[1]
Lubov G. Mironova,[1] **Akosah Yaw Abayie**,[2] and **Alexandra D. Voloshina**[1]
[1] *Institute of Organic and Physical Chemistry Named after A.E. Arbuzov. Kazan Scientific Center of the Russian Academy of Sciences. Arbuzov St., 8. Kazan, 420088. Republic of Tatarstan. Russia. E-mail: mindubaev@iopc.ru ; mindubaev-az@yandex.ru*
[2] *Kazan (Volga Region) Federal University. University St., 18. Kazan, 420008. Republic of Tatarstan. Russia.*
[3] *Kazan National Research Technological University. Karl Marx St., 68. Kazan, 420015.*

*Supervising author; +Corresponding author

Keywords: white phosphorus, genotoxicity, eukaryotes, chromosomal aberrations, cell cycle, Allium test.

Abstract

Although the utmost toxicity of white phosphorus is well known, its genotoxicity had never been detected prior to our works. Our previous studies demonstrated for the first time the presence of genotoxic properties in white phosphorus. This in no doubt makes white phosphorus even more dangerous to handle. However, our initial studies were carried out on prokaryotes (*Salmonella typhimurium*). Since the genetic apparatus of prokaryotes is differently arranged than in eukaryotes (including humans), the results of the studies on *Salmonella* is not completely transferable to humans. In addition to the gene mutations studied by the Ames test and the SOS-lux test, which have a common nature in all living organisms, there are genomic rearrangements that should be studied in eukaryotes. For this purpose, an Allium test is used on onion rootlets (*Allium cepa* L.). In this work, we present the first report on the negative effect of white phosphorus on the cell cycle of eukaryotes by the Allium test method. It turned out that white phosphorus, even at very low concentrations of 0.01%, exponentially increases the number of chromosomal aberrations.

References

[1] I.S. Belyuchenko. Ecology in terms and concepts. *Ed. Kuban Agricultural University*. Krasnodar. **2000**. P.496. (russian)
[2] I.S. Belyuchenko. Agrolandscapes and problem of protecting its soils. *The North Caucasus Ecological Herald.* **2017**. Vol.13. No.3. P.88-91. (russian)
[3] I.S. Belyuchenko. Production wastes as basis of complex composts. *The North Caucasus Ecological Herald.* **2017**. Vol.13. No.4. P.83-90. (russian)
[4] A.Z. Mindubaev, D.G. Yakhvarov. Biodegradation as a method for waste processing: view on the problem. Part 1. The essence of the method. *Butlerov Communications*. **2013**. Vol.33. No.3. P.1-37. ROI: jbc-01/13-33-3-1
[5] A.Z. Mindubaev, D.G. Yakhvarov. Biodegradation as a method for waste processing: view on the problem. Part 2. Are xenobiotics really xenobiotics? *Butlerov Communications*. **2013**. Vol.34. No.4. P.1-20. ROI: jbc-01/13-34-4-1
[6] A.Z. Mindubaev. Biodegradation of xenobiotics as the self-defense of nature. *Biomolecula*. **2017**. https://biomolecula.ru/articles/biodegradatsiia-ksenobiotikov-kak-samozashchita-prirody. (russian)
[7] Mindubaev. Biodegradation of toxic substances as self-protection of nature. *The North Caucasus Ecological Herald.* **2018**. Vol.14. No.1. P.11-23. (russian)
[8] A.Z. Mindubaev. Who ate the polyethylene? *Nauka i Zhizn*. **2018**. Vol.4. P.32-38. (russian)
[9] A.A. Shubakov, E.A. Mikhailova, Yu.S. Ovodov. The use of microorganisms for the extraction of manganese from aqueous media. *Proceedings of the Komi Science Centre of the Ural Division of the Russian Academy of Sciences.* **2014**. No.1(17). P.16-18. (russian)
[10] I.E. Sharapova, A.V. Garabagiou, A.A. Shubakov. A study of the purification of oil-contaminated aquatic environments by an algo-bacterial-fungal biopreparation in the presence of a sorbent. *Ecology and industry of Russia*. **2013**. No.6. P.32-35. (russian)
[11] I.B. Archegova, F.M. Habibullina, A.A. Shubakov. Optimization of cleaning soil and water objects from oil using biosorbents. *Siberian Journal of Ecology.* **2012**. No.2. P.769-776. (russian)

[12] F.M. Habibullina, I.B. Archegova, A.A. Shubakov, I.E. Sharapova, G.G. Romanov, I.Yu. Chernov, A.I. Taskaev, G.M. Tulyankin, Yu.S. Zhuchikhin, A.N. Koz'minykh. Biosorbent for cleaning reservoirs from petroleum products based on strains of bacteria and yeast fungi. Patent for invention. *RUS 2318736 10.02*.**2006**. (russian)

[13] I.B. Archegova, F.M. Khabibullina, A.A. Shubakova, A.A. Gorbunov. Joint utilization of industrial waste. *Ecology and industry of Russia*. **2008**. No.5. P.22-25. (russian)

[14] G.M. Tulyankin, F.M. Khabibullina, O.M. Gridin, A.A. Shubakov, V.A. Terekhova, Yu.S. Zhuchikhin, A.N. Kozminykh. Ecological basis of the optimized technology for the restoration of oil-contaminated natural objects in the north. Monograph. *Ed. Institute of Biology of the Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences, CJSC "Center for Environmental Initiatives" Press Torf "*Editors: Archegova IB, Taskaev, AI Syktyvkar. **2007**. P.140. (russian)

[15] D.R. Olicón-Hernández, J. González-López, E. Aranda. Overview on the Biochemical Potential of Filamentous Fungi to Degrade Pharmaceutical Compounds. *Front. Microbiol*. **2017**. Vol.8. No.1792. P.1-17.

[16] K.K. Styazhkin, S.V. Petrov, A.S. Tumanov, N.V. Zavyalova, K.A. Vorobiev, V.V. Teterin, I.P. Pogorelsky, A.A. Leshchenko, A.G. Lazykin, V.S. Menukhov. Biopreparation for soil remediation within the zone of protective measures of the chemical weapons destruction facility "Maradykovsky". *Theoretical and applied ecology*. **2013**. Vol.4. P.41-48. (russian)

[17] P. Hugenholtz, B.M. Goebel, N.R. Pace. Impact of Culture-Independent Studies on the Emerging Phylogenetic View of Bacterial Diversity. *Journal of bacteriology*. **1998**. Vol.180. No.18. P.4765-4774.

[18] C. Schmeisser, H. Steele, W.R. Streit. Metagenomics, biotechnology with non-culturable microbes. *Appl Microbiol Biotechnol*. **2007**. Vol.75. No.5. P.955-962.

[19] F. Berini, C. Casciello, G.L. Marcone, F. Marinelli. Metagenomics: novel enzymes from non-culturable microbes. *FEMS Microbiology Letters*. **2017**. Vol.364. No.21.

[20] T. Grinhut, N. Hertkorn, P. Schmitt-Kopplin, Y. Hadar, Y. Chen. Mechanisms of Humic Acids Degradation by White Rot Fungi Explored Using ^{1}H NMR Spectroscopy and FTICR Mass Spectrometry. *Environ. Sci. Technol.* **2011**. Vol.45. No.7. P.2748-2754.

[21] D.J. Arp, L.A. Sayavedra-Soto, N.G. Hommes. Molecular biology and biochemistry of ammonia oxidation by *Nitrosomonas europaea. Arch Microbiol*. **2002**. Vol.178. No.4. P.250-255.

[22] C.-P. Witte. Urea metabolism in plants. *Plant Science*. **2011**. Vol.180. No.3. P.431-438.

[23] H. Basch, K. Mogi, D.G. Musaev, K. Morokuma. Mechanism of the Methane → Methanol Conversion Reaction Catalyzed by Methane Monooxygenase: A Density Functional Study. *J. Am. Chem. Soc.* **1999**. Vol.121. No.31. P.7249-7256.

[24] B.M. Hoffman, D. Lukoyanov, D.R. Dean, L.C. Seefeldt. Nitrogenase: A Draft Mechanism. *Accounts of chemical research*. **2013**. Vol.46. No.2. P.587-595.

[25] B.M. Barney, H.-I. Lee, P.C. Dos Santos, B.M. Hoffman, D.R. Dean, L.C. Seefeldt. Breaking the N2 triple bond: insights into the nitrogenase mechanism. *Dalton Trans.* **2006**. Vol.19. P.2277-2284.

[26] B.M. Barney, J. McClead, D. Lukoyanov, M. Laryukhin, T.-C. Yang, D.R. Dean, B.M. Hoffman, L.C. Seefeldt. Diazene (HN=NH) Is a Substrate for Nitrogenase: Insights into the Pathway of N_2 Reduction. *Biochemistry*. **2007**. Vol.46. P.6784-6794.

[27] T. Klotzbücher, A. Kappler, K.L. Straub, S.B. Haderlein. Biodegradability and groundwater pollutant potential of organic anti-freeze liquids used in borehole heat exchangers. *Geothermics*. **2007**. Vol.36. No.4. P.348-361.

[28] J. Schmid, D. Müller-Hagen, T. Bekel, L. Funk, U. Stahl, V. Sieber, V. Meyer. Transcriptome sequencing and comparative transcriptome analysis of the scleroglucan producer *Sclerotium rolfsii. BMC Genomics*. **2010**. Vol.11. No.329. P.1-16.

[29] V.J. Just, C.E.M. Stevenson, L. Bowater, A. Tanner, D.M. Lawson, S. Bornemann. Closed Conformation of Bacillus subtilis Oxalate Decarboxylase OxdC Provides Evidence for the True Identity of the Active Site. *The journal of biological chemistry*. **2004**. Vol.279. No.19. P.19867-19874.

[30] C.L. Wang, S. Takenaka, S. Murakami, K. Aoki. Isolation of a benzoate-utilizing *Pseudomonas* strain from soil and production of catechol from benzoate by transpositional mutants. *Microbiol. Res*. **2001**. Vol.156. No.2. P.151-158.

[31] T.E. Mattes, A.K. Alexander, N.V. Coleman. Aerobic biodegradation of the chloroethenes: pathways, enzymes, ecology, and evolution. *FEMS Microbiol Rev*. **2010**. Vol.34. No.4. P.445-475.

[32] G. Northcott, D. Jensen, L. Ying, P. Fisher. Degradation rate of sodium fluoroacetate in three New Zealand soils. *Environ Toxicol Chem*. **2014**. Vol.33. No.5. P.1048-1058.

[33] M.R. Hyman, C.L. Page, D.J. Arp. Oxidation of Methyl Fluoride and Dimethyl Ether by Ammonia Monooxygenase in *Nitrosomonas europaea*. *Applied And Environmental Microbiology*. **1994**. Vol.60. No.8. P.3033-3035.
[34] G.V. King. Stability of trifluoromethane in forest soils and methanotrofic cultures. *FEMS Microbiology Ecology*. **1997**. Vol.22. No.2. P.103-109.
[35] P.T. Visscher, C.W. Culbertson, R.S. Oremland. Degradation of trifluoroacetate in oxic and anoxic sediments. *Nature*. **1994**. Vol.369. P.729-731.
[36] S.K. Singh, A. Singh, G.N. Pandey. Methanogenesis of waterhyacinth in the presence of boron compounds. *Renewable Energy*. **1993**. Vol.3. No.1. P.45-47.
[37] G. Mascolo, L. Balest, D. Cassano, G. Laera, A. Lopez, A. Pollice, C. Salerno. Biodegradability of pharmaceutical industrial wastewater and formation of recalcitrant organic compounds during aerobic biological treatment. *Bioresource Technology*. **2010**. Vol.101. No.8. P.2585-2591.
[38] S. Yoshida, K. Hiraga, T. Takehana, I. Taniguchi, H. Yamaji , Y. Maeda , K. Toyohara, K. Miyamoto, Y. Kimura, K Oda. A bacterium that degrades a nd assimilates poly(ethylene terephthalate). *Science*. **2016**. Vol.351. No.6278. P.1196-1199.
[39] D.-W. Liang, T. Zhang, H.H.P. Fang, J. He. Phthalates biodegradation in the environment. *Appl Microbiol Biotechnol*. **2008**. Vol.80. No.2. P.183-198.
[40] H. Hara, L.D. Eltis, J.E. Davies, W.W. Mohn . Transcriptomic Analysis Reveals a Bifurcated Terephthalate Degradation Pathway in *Rhodococcus* sp. Strain RHA1. *Journal of Bacteriology*. **2007**. Vol.189. No.5. P.1641-1647.
[41] H. Hronská, S. Micháliková, M. Rosenberg. Microbial production of specialty C4 dicarboxylic acids from maleic anhydride. *J. Food Nutr. Res*. **2017**. Vol.56. No.3. P.219-231.
[42] W.R. Martin, J.W. Foster. Production of trans-L-epoxysuccinic acid by fungi and its microbiological conversion to *meso*-tartartic acid. *Journal of Bacteriology*. **1955**. Vol.70. No.4. P.405-414.
[43] J. Zeyer, A. Wasserfallen, K.N. Timmis. Microbial Mineralization of Ring-Substituted Anilines through an Ortho-Cleavage Pathway. *Appl. Environ. Microbiol*. **1985**. Vol.50. No.2. P.354-744.
[44] D. Schleheck, F. von Netzer, T. Fleischmann, D. Rentsch, T. Huhn, A.M. Cook, H.-P.E. Kohler. The Missing Link in Linear Alkylbenzenesulfonate Surfactant Degradation: 4-Sulfoacetophenone as a Transient Intermediate in the Degradation of 3-(4-Sulfophenyl)Butyrate *by Comamonas testosteroni* KF-1. *Applied And Environmental Microbiology*. **2010**. Vol.76. No.1. P.196-202.
[45] D.R. Taramasova, A.P. Rakhmatullina, V.M. Voiloshnikov, E.V. Perushkina, E.N. Semenov. Anti-mold compound for water-dispersion polyacrylic paints. *Paintwork materials and their application.* **2018**. No.4. P.14-16. (russian)
[46] P.L.H. McSweeney, M.J. Sousa. Biochemical pathways for the production of flavour compounds in cheeses during ripening: A review. *Lait.* **2000**. Vol.80. P.293-324.
[47] J.F. Bukowski, C.T. Morita, M.B. Brenner. Human γδ T Cells Recognize Alkylamines Derived from Microbes, Edible Plants, and Tea: Implications for Innate Immunity. *Immunity.* **1999**. Vol.11. No.1. P.57-65.
[48] R.J. Bryant, A.M. McClung. Volatile profiles of aromatic and non-aromatic rice cultivars using SPME/GC–MS. *Food Chemistry*. **2011**. Vol.124. No.2. P.501-513.
[49] E. Barbieri, A. M. Gioacchini, A. Zambonelli, L. Bertini, V. Stocchi. Determination of microbial volatile organic compounds from *Staphylococcus pasteuri* against *Tuber borchii* using solid-phase microextraction and gas chromatography/ion trap mass spectrometry. *Rapid Commun. Mass Spectrom*. **2005**. Vol.19. No.22. P.3411-3415.
[50] J. Figueira, H. Câmara, J. Pereira, J.S. Câmara. Evaluation of volatile metabolites as markers in *Lycopersicon esculentum* L. cultivars discrimination by multivariate analysis of headspace solid phase microextraction and mass spectrometry data. *Food Chemistry*. **2014**. Vol.145. P.653-663.
[51] O.S. Sohn, E.S. Fiala, C.C. Conaway, J.H.Weisburger. Metabolism and disposition of morpholine in the at, hamster, and guinea pig. *Toxicol. appl. Pharmacol.* **1982**. Vol.64. No.3. P.486-491.
[52] G. Meister, M. Wechsler. Biodegradation of *N*-methylmorpholine-*N*-oxide. *Biodegradation.* **1998**. Vol.9. No.2. P.91-102.
[53] T.P. McGovern, C.E. Schreck, J. Jackson, M. Beroza. *N*-acylamides and *n*- alkylsulfonamides from heterocyclic amines as repellents for yellow fever mosquitoes. *Mosquito News*. **1975**. Vol.35. No.2. P.204-210.
[54] A.Rimbault, I.P. Niel, H.Virelizier, J.C. Darbordw, G.Leluan. L-Methionine, a Precursor of Trace Methane in Some Proteolytic Clostridia. *Applied and environmental microbiology*. **1988**. Vol.54. No.6. P.1581-1586.

[55] T. Maeda, V. Sanchez-Torres, T.K. Wood. Metabolic engineering to enhance bacterial hydrogen production. *Microbial Biotechnology*. **2008**. Vol.1. No.1. P.30-39.
[56] J. Shan, J. Hu, S.S. Kaplan-Bekaroglu, H. Song, T. Karanfil. The effects of pH, bromide and nitrite on halonitromethane and trihalomethane formation from amino acids and amino sugars. *Chemosphere.* **2012**. Vol.86. No.4. P.323-328.
[57] I. Freuze, S. Brosillon, D. Herman, A. Laplanche, C. Démocrate, J. Cavard. Odorous Products of the Chlorination of Phenylalanine in Water: Formation, Evolution, and Quantification. *Environ. Sci. Technol.* **2004**. Vol.38. No.15. P.4134-4139.
[58] W.M.B. Edmands, N.J. Gooderham, E. Holmes, S.C. Mitchell. S-Methyl-L-cysteine sulphoxide: the Cinderella phytochemical? *Toxicol. Res*. **2013**. Vol.2. P.11-22.
[59] M. Zimmermann, M.A. Fischbach. A Family of Pyrazinone Natural Products from a Conserved Nonribosomal Peptide Synthetase in *Staphylococcus aureus*. *Chemistry & Biology*. **2010**. Vol.17. No.9. P.925-930.
[60] C.-S. Li, C.-Y. An, X.-M. Li, S.-S. Gao, C.-M. Cui, H.-F. Sun, B.-G. Wang. Triazole and Dihydroimidazole Alkaloids from the Marine Sediment-Derived Fungus *Penicillium paneum* SD-44. *J. Nat. Prod.* **2011**. Vol.74. No.5. P.1331-1334.
[61] T. Suami. Synthetic ventures in pseudo-sugar chemistry. *Pure&Appl. Chem*. **1987**. Vol.59. No.11. P.1509-1520.
[62] M.E. Sengül, A. Menzek, E. Sahin, M. Arik, N. Saracoglu. Synthesis of cyclopropane-annulated conduritol derivatives: norcaran-2,3,4,5-tetraoles. *Tetrahedron*. **2008**. Vol.64. No.30-31. P.7289-7294.
[63] P. Sedmera, P. Halada, S. Pospíšil. New carbasugars from *Streptomyces lincolnensis*. *Magn. Reson. Chem*. **2009**. Vol.47. No.6. P.519-522.
[64] Z.J. Witczak, J.M. Culhane. Thiosugars: new perspectives regarding availability and potential biochemical and medicinal applications. *Appl Microbiol Biotechnol*. **2005**. Vol.69. No.3. P.237-244.
[65] E. Sasaki, Y. Ogasawara, H. Liu. A Biosynthetic Pathway for BE-7585A, a 2-Thiosugar-Containing Angucycline-Type Natural Product. *J. Am. Chem. Soc*. **2010**. Vol.132. No.21. P.7405-7417.
[66] G.M. Lacourciere, T.C. Stadtman. Utilization of selenocysteine as a source of selenium for selenophosphate biosynthesis. *Biofactors*. **2001**. Vol.14. No.1-4. P.69-74.
[67] Y. Anan, M. Yoshida, S. Hasegawa, R. Katai, M. Tokumoto, L. Ouerdane R. Łobiński, Y. Ogra. Speciation and identification of tellurium-containing metabolites in garlic. *Allium sativum. Metallomics*. **2013**. Vol.5. No.9. P.1215-1224.
[68] H. Sun, J. Sheng, A.E.A. Hassan, S. Jiang, J. Gan, Z. Huang. Novel RNA base pair with higher specificity using single selenium atom. *Nucleic Acids Research*. **2012**. Vol.40. No.11. P.5171-5179.
[69] L.A. Zettler, M.L. Sogin, D.A. Caron. Phylogenetic relationships between the Acantharea and the Polycystinea: A molecular perspective on Haeckel's Radiolaria. *Proc. Natl. Acad. Sci. USA*. **1997**. Vol.94. No.21. P.11411-11416.
[70] V. Martin-Jézéquel, M. Hildebrand, M.A. Brzezinski. Silicon metabolism in diatoms: implications for growth. *J. Phycol*. **2000**. Vol.36. No.5. P.821-840.
[71] G. Sapriel, M. Quinet, M. Heijde, L. Jourdren,V. Tanty, G. Luo, S.L. Crom, P.J. Lopez. Genome-Wide Transcriptome Analyses of Silicon Metabolism in *Phaeodactylum tricornutum* Reveal the Multilevel Regulation of Silicic Acid Transporters. *PLoS ONE*. **2009**. Vol.4. No.10. P.1-14.
[72] L.-l. Cheng, L.-m. Xiao, W.-X. Chen, J.-d. Wang, F.-b. Che, B. Wu. Identification of compounds characterizing the aroma of oblate-peach fruit during storage by GC-MS. *Journal of Stored Products and Postharvest Research*. **2012**. Vol.3. No.5. P.54-62.
[73] M.P. Heyes, C.Y. Chen, E.O. Major, K. Saito. Different kynurenine pathway enzymes limit quinolinic acid formation by various human cell types. *Biochem. J.* **1997**. Vol.326. No.2. P.351-356.
[74] R.H. Proctor, D.W. Brown, R.D. Plattner, A.E. Desjardins. Co-expression of 15 contiguous genes delineates a fumonisin biosynthetic gene cluster in *Gibberella moniliformis*. *Fungal Genetics and Biology*. **2003**. Vol.38. No.2. P.237-249.
[75] C.C. Velho, D.J. Charles, J.E. Simon. Volatile Fruit Constituents of *Theobroma grandiflorum. Hort Science.* **1991**. Vol.26. No.5. P.608.
[76] H. Cheng. Volatile Flavor Compounds in Yogurt: A Review. *Critical Reviews in Food Science and Nutrition*. **2010**. Vol.50. No.10. P.938-950.
[77] S. Utama, R.B.H. Wills, S. Ben-Yehoshua, C. Kuek. In Vitro Efficacy of Plant Volatiles for Inhibiting the Growth of Fruit and Vegetable Decay Microorganisms. *J. Agric. Food Chem.* **2002**. Vol.50.P.6371-6377.

[78] M. Graupner, H. Xu, R.H. White. Identification of the Gene Encoding Sulfopyruvate Decarboxylase, an Enzyme Involved in Biosynthesis of Coenzyme M. *Journal Of Bacteriology*. **2000**. Vol.182. No.17. P.4862-4867.
[79] M.P. Callahan, K.E. Smith, H. J. Cleaves II, J. Ruzicka, J.C. Stern, D.P. Glavin, C.H. House, J.P. Dworkin. Carbonaceous meteorites contain a wide range of extraterrestrial nucleobases. *PNAS*. **2011**. Vol.108. No.34. P.13995-13998.
[80] M.D. Kirnos, I.Y. Khudyakov, N.I. Alexandrushkina, B. F. Vanyushin. 2-Aminoadenine is an adenine substituting for a base in S-2L cyanophage DNA. *Nature*. **1977**. Vol.270. P.369-370.
[81] J.R.Treberg, W.R. Driedzic. Elevated Levels of Trimethylamine Oxide in Deep-Sea Fish: Evidence for Synthesis and Intertissue Physiological Importance. *Journal of experimental zoology*. **2002**. Vol.293. No.1. P.39-45.
[82] S.M. Weinreb. Some recent advances in the synthesis of polycyclic imidazole-containing marine natural products. *Nat. Prod. Rep.* **2007**. Vol.24. No.5. P.931-948.
[83] R. Graf, S. Anzali, J. Buenger, F. Pfluecker, H. Driller. The multifunctional role of ectoine as a natural cell protectant. *Clinics in Dermatology*. **2008**. Vol.26. No.4. P.326-333.
[84] H. Nakayama, K. Yoshida, H. Ono, Y. Murooka, A. Shinmyo. Ectoine, the Compatible Solute of *Halomonas elongata*, Confers Hyperosmotic Tolerance in Cultured Tobacco Cells. *Plant Physiology*. **2000**. Vol.122. No.4. P.1239-1247.
[85] J. Stefels. Physiological aspects of the production and conversion of DMSP in marine algae and higher plants. *Journal of Sea Research*. **2000**. Vol.43. No.3-4. P.183-197.
[86] D.C. Yoch. Dimethylsulfoniopropionate: Its Sources, Role in the Marine Food Web, and Biological Degradation to Dimethylsulfide. *Applied and environmental microbiology*. **2002**. Vol.68. No.12. P.5804-5815.
[87] U. Lins, M. Farina. Phosphorus-rich granules in uncultured magnetotactic bacteria. *FEMS Microbiology Letters*. **1999**. Vol.172. No.1. P.23-28.
[88] P.A. Lindahl. Acetyl-coenzyme A synthase: the case for a Ni_p^0-based mechanism of catalysis. J *Biol Inorg Chem*. **2004**. Vol.9. No.5. P.516-524.
[89] A. Husen, K.S. Siddiqi. Carbon and fullerene nanomaterials in plant system. *Journal of Nanobiotechnology*. **2014**. Vol.12. No.16. P.1-10.
[90] V.M. Dembitsky, R. Smoum, A.A. Al-Quntar, H. Abu Ali, I. Pergament, M. Srebnik. Natural occurrence of boron-containing compounds in plants, algae and microorganisms. *Plant Science*. **2002**. Vol.163. No.5. P.931- 942.
[91] S.I. Elshahawi, A.E. Trindade-Silva, A. Hanora, A.W. Han, M.S. Flores, V. Vizzoni, C.G. Schrago, C.A. Soares, G.P. Concepcion, D.L. Distel, E.W. Schmidt, M.G. Haygood. Boronated tartrolon antibiotic produced by symbiotic cellulose-degrading bacteria in shipworm gills. *PNAS*. **2013**. Vol.10. No.4. P.E295-E304.
[92] R.D. Scavetta, C.D. Thomas, M.A. Walsh, S. Szegedi, A. Joachimiak, R.I. Gumport, M.E.A. Churchill. Structure of **Rsr**I methyltransferase, a member of the **N**6-adenine β class of DNA methyltransferases. *Nucleic Acids Res*. **2000**. Vol.28. No.20. P.3950-3961.
[93] A. Bird. DNA methylation patterns and epigenetic memory. *Genes & Development*. **2002**. Vol.16. No.1. P.6-21.
[94] J.C. Spain, S.F. Nishino, B. Witholt, L.-S. Tan, W.A. Duetz. Production of 6-Phenylacetylene Picolinic Acid from Diphenylacetylene by a Toluene-Degrading *Acinetobacter* Strain. *Applied And Environmental Microbiology*. **2003**. Vol.69. No.7. P.4037-4042.
[95] G. Chotani, T. Dodge, A. Hsu, M. Kumar, R. LaDuca, D. Trimbur, W. Weyler, K. Sanford. The commercial production of chemicals using pathway engineering. *Biochimica et Biophysica Acta*. **2000**. Vol.1543. P.434-455.
[96] M.B. Davies, J. Austin, D.A. Partridge. Vitamin C: Its Chemistry and Biochemistry. *M: Mir*. **1999**. 176p.
[97] K. Bosecker. Bioleaching: metal solubilization by microorganisms. *FEMS microbiology reviews*. **1997**. Vol.20. No.3-4. P.591-604.
[98] H.R. Watling. The bioleaching of nickel-copper sulfides. *Hydrometallurgy*. **2008**. Vol.91. No.1-4. P.70-88.
[99] Mindubaev A.Z., Yakhvarov D.G. Phosphorus: properties and application. *Butlerov Communications*. **2014**. Vol.39. No.7. P.1-24. ROI: jbc-01/14-39-7-1
[100] A.V. Kasatkin, N.M. Vatutin, V.V. Koltunov, S.E. Malinin. Features of phosphorus-containing ammunition for special purposes and methods for their utilization. *Herald of the Technological University*. **2017**. Vol.20. No.5. P.39-43. (russian)

[101] A.V. Kasatkin, N.M. Vatutin, V.V. Koltunov, I.A. Kuznetsova, E.M. Vasilevskaya. On the development of a method for converting phosphorus from yellow to red phase directly inside smoke ammunition chamber. *Izvestiya TulGU. Technical science*. **2017**. Vol.11. Part3. P.9-22. (russian)

[102] A.I. Kal'noy, S.V. Tarasov, F.A. Katunin, S.I. Strelnikov. Analysis of the use of masking veils (smoke screens) in military operations. *Nauka I voennoaya bezopasnost*. **2017**. No.4 (11). P.13-20. (russian)

[103] F.C. Hawthorn. Structure and chemistry of phosphate minerals. *Mineralogical Magazine*. **1998**. Vol.62. No.2. P.141-164.

[104] S.J. Van. Kauwenbergh. World Phosphate Rock Reserves and Resources. *International Fertilizer Development Center (IFDC). Alabama*. **2010**. 49p.

[105] C.W. Forsberg, R.G. Meidinger, M. Liu, M. Cottrill, S. Golovan, J.P. Phillips. Integration, stability and expression of the *E. coli* phytase transgene in the Cassie line of Yorkshire Enviropig. *Transgenic Res*. **2013**. Vol.22. No.2. P.379-389.

[106] A. Panchin. The sum of biotechnology. Guide to combating myths about genetic modification of plants, animals and humans. *Moscow: publishing house ACT: CORPUS.* **2016**. P.432. (russian)

[107] I. Nikolaidis, S. Favini-Stabile, A. Dessen. Resistance to antibiotics targeted to the bacterial cell wall. *Protein science*. **2014**. Vol.23. No.3. P.243-259.

[108] A.Z. Mindubaev, Y.A. Akosah, F.K. Alimova, D.M.Afordoanyi, R.M. Kagirov, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. On the White Phosphorus Degradation by Wastewater Mud. *Uchenye Zapiski Kazanskogo Universiteta. Seriya Estestvennye Nauki*. **2011**. Vol.153. No.2. P.110-119.

[109] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe, C. Bolormaa, A.D. Voloshina, N.V. Kulik, S. T. Minzanova, L.G. Mironova, D.G. Yakhvarov. The possibility for anaerobic detoxication of white phosphorus. *Butlerov Communications*. **2013**. Vol.33. No.1. P.22-34. ROI: jbc-01/13-33-1-22

[110] A.Z. Mindubaev, A.D. Voloshina, D.G. Yakhvarov. Biological degradation of white phosphorus: feasibility and prospects. *Butlerov Communications*. **2013**. Vol.33. No.2. P.1-17. ROI: jbc-01/13-33-2-1

[111] A.Z. Mindubaev, A.D. Voloshina, N.V. Kulik, S.T. Minzanova, L.G. Mironova, D.G. Yahvarov, F.K. Alimova, S.C. Ahossiyenagbe, A.C. Bolormaa. Possibility of anaerobic biodegradation of white phosphorus. *The North Caucasus Ecological Herald.* **2013**. Vol.9. No.2. P.4-15.

[112] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe,S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. New confirmation for white phosphorus biodegradation. *Butlerov Communications*. **2013**. Vol.36. No.10. P.1-12. ROI: jbc-01/13-36-10-1

[113] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe, C. Bolormaa, A.D. Voloshina, N.V. Kulik, S. T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Microbial metabolism of the white phosphorus. *Butlerov Communications*. **2013**. Vol.36. No.12. P.34-52. ROI: jbc-01/13-36-12-34

[114] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe,S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Relationship between microbial metabolism and rate of destruction of white phosphorus in sewage sludge. *The North Caucasus Ecological Herald.* **2014**. Vol.10. No.1. P.88-96.

[115] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, S. T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Metabolites and tolerant microflora in substrates with white phosphorus 0.1%. *Butlerov Communications*. **2014**. Vol.37. No.3. P.67-78. ROI: jbc-01/14-37-3-67

[116] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe, E.V. Gorbachuk, S. T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Metabolic pathway of white phosphorus. *The North Caucasus Ecological Herald.* **2014**. Vol.10. No.3. P.36-46.

[117] C. Bolormaa, K.A. Saparmyradov, F.K. Alimova, A.Z. Mindubaev. Comparison of phytotoxicity indices, fungicidal and bactericidal activity of *Streptomices* from different habitats. *Butlerov Communications*. **2014**. Vol.38. No.6. P.147-152. ROI: jbc-01/14-38-6-147

[118] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe, C. Bolormaa, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, L.G. Mironova, A.V. Pankova, D.G. Yakhvarov. Decontamination of industrial waste water containing white phosphorus, using SALT microflora. *Ecology and Safety Journal*. **2014**. No.1-2. P.68-72.

[119] A.Z. Mindubaev, F.K. Alimova, S.C. Ahossiyenagbe, E.V. Gorbachuk, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Resistant microflora in substrata with phosphorus content 0.1% by mass, and its cultivation in artificial media. *The North Caucasus Ecological Herald.* **2014**. Vol.10. No.4. P.66-74.

[120] A.Z. Mindubaev, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, S.C. Ahossiyenagbe, F.K. Alimova, S.T. Minzanova, L.G. Mironova, A.V. Pankova, C. Bolormaa, K.A. Saparmyradov, D.G. Yakhvarov. White phosphorus as a new object of biological destruction. *Butlerov Communications*. **2014**. Vol.40. No.12. P.1-26. ROI: jbc-01/14-40-12-1

[121] A.Z. Mindubaev, F.K. Alimova, D.G. Yakhvarov, C. Bolormaa, K.A. Saparmyradov. Comparison of phytotoxicity, fungicidal and bactericidal activity of *Streptomices* from different biotopes. Determination of species rank for strain A8. *The North Caucasus Ecological Herald.* **2015**. Vol.11. No.1. P.51-58.
[122] A.Z. Mindubaev, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, F.K. Alimova, S.T. Minzanova, L.G. Mironova, K.A. Saparmyradov, K.R. Khayarov, D.G. Yakhvarov. The inclusion white phosphorus in the natural cycle of matter. Cultivation of resistant microorganisms. *Butlerov Communications*. **2015**. Vol.41. No.3. P.54-81. DOI: 10.37952/ROI-jbc-01/15-41-3-54
[123] A.Z. Mindubaev, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, S.T. Minzanova, L.G. Mironova, F.K. Alimova, K.A. Saparmyradov, D.G. Yakhvarov. Increase of resistance to white phosphorus in microorganisms as a result of directed selection: biochemical analysis of *streptomyces* sp. A8 strain. *The North Caucasus Ecological Herald.* **2015**. Vol.11. No.3. P.10-18.
[124] A.Z. Mindubaev, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, Alimova, K.A. Saparmyradov, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Ecotoxicants white phosphorus as phosphoric fertilizing for microorganisms. *Ecology and Safety Journal*. **2015**. No.1-2. P.46-51.
[125] A.Z. Mindubaev, S.T. Minzanova, L.G. Mironova, F.K. Alimova, D.E. Belostotskiy, D.G. Yakhvarov**.** The effect of the amaranth phytomass on the white phosphorus biodegradation rate. *The North Caucasus Ecological Herald.* **2015**. Vol.11. No.4. P.73-79.
[126] A.Z. Mindubaev, A.D. Voloshina, E.V. Gorbachuk, S. Z. Validov, N.V. Kulik, F.K. Alimova, S.T. Minzanova, L.G. Mironova, D.E. Belostotskiy, K.A. Saparmyradov, R.I. Tukhbatova, D.G. Yakhvarov**.** Adaptation of microorganisms to white phosphorus as a result of directed selection. Genetic identification of sustainable *Aspergillus* and metabolic profiling of *Streptomyces* A8. *Butlerov Communications*. **2015**. Vol.44. No.12. P.1-28. DOI: 10.37952/ROI-jbc-01/15-44-12-1
[127] A.Z. Mindubaev, S.Z. Validov, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik**,** F.K. Alimova**,** S.T. Minzanova**,** R.I. Tukhbatova*,* L.G. Mironova**,** D.G. Ya**k**hvarov. Identification of resistant to white phosphorus *Aspergillus***.** *The North Caucasus Ecological Herald.* **2016**. Vol.12. No.1. P.70-75.
[128] A.Z. Mindubaev. Biodegradation of white phosphorus: How a poison became a fertilizer. *Biomolecula*. **2016**. http://biomolecula.ru/content/1932
[129] A.Z. Mindubaev, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, S.T. Minzanova, L G. Mironova, F.K. Alimova, D.G. Yakhvarov. The detoxication of white phosphorus containing wastewaters, by microflora. *Russian Journal of Applied Ecology*. **2015**. No.3. P.42-47.
[130] A.Z. Mindubaev, A.D. Voloshina, S. Z. Validov, N.V. Kulik, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov, A.Y. Akkizov. *Aspergillus niger* AM1 culture growth in medium with two phosphorus sources. The validity of the definition "biodegradation" with respect to white phosphorus. *Butlerov Communications*. **2016**. Vol.46. No.5. P.1-20. DOI: 10.37952/ROI-jbc-01/16-46-5-1
[131] A.Z. Mindubaev, A.D. Voloshina, S.T. Minzanova. Growth of bacterial culture in a medium with potassium phosphite as a sole source of phosphorus. *The North Caucasus Ecological Herald.* **2016**. Vol.12. No.3. P.81-84.
[132] A.Z. Mindubaev, K.A. Saparmyradov, E.V. Gorbachuk, A.V. Pankova. Selection of microorganisms for resistance to white phosphorus. *Russian Journal of Applied Ecology*. **2016**. No.2. P.42-46.
[133] A.Z. Mindubaev, F.K. Alimova, A.D. Voloshina, E.V. Gorbachuk, N.V. Kulik, S.T. Minzanova, R.I. Tukhbatova, D.G. Yakhvarov. Method for detoxification of white phosphorus using microorganism strain *Trichoderma asperellum* VKPM F-1087. *Patent RF No 2603259 from 1.11.2016. Bul. 33. Reciprocity date 28. 07. 2015. Registration number 2015131380 (048333). The decision to grant a patent on 29. 08.* **2016**.
[134] A.Z. Mindubaev, E.V. Babynin, A.D. Voloshina, S.Z. Validov, N.V. Kulik, S.T. Minzanova, L.G. Mironova, A.Y. Akkizov, D.G. Yakhvarov. Evaluation of white phosphorus genotoxicity. Growth of bacterial culture in a medium with potassium phosphite as a sole source of phosphorus. *Butlerov Communications*. **2016**. Vol.47. No.7. P.1-20. DOI: 10.37952/ROI-jbc-01/16-47-7-1
[135] A.Z. Mindubaev, A.D. Voloshina., N.V. Kulik, Sh.Z. Validov, E.V. Babynin, K.A. Saparmyradov, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Selection of cultures of microorganisms for resistance to white phosphorus and their identification. *Journal of Ecology and Industrial Safety*. **2016**. No.2. P.22-27.
[136] A.Z. Mindubaev, K.A. Saparmyradov, F.K. Alimova. Comparison of antagonistic properties of *Streptomyces* from different biotopes. *Russian Journal of Applied Ecology*. **2016**. No.3. P.28-32.
[137] A.Z. Mindubaev, A.D. Voloshina, S.T. Minzanova. Possibility of decontamination of decontamination by using white phosphorus. *The North Caucasus Ecological Herald.* **2016**. Vol.12. No.4. P.63-70.

[138] A.Z. Mindubaev, E.V. Babynin, A.D. Voloshina, I.F. Sakhapov, N.V. Kulik, S.Z. Validov, S.T. Minzanova, L.G. Mironova, A.Y. Akkizov, D.G. Yakhvarov. Genotoxicity of white phosphorus. *Butlerov Communications*. **2017**. Vol.49. No.1. P.1-20. DOI: 10.37952/ROI-jbc-01/17-49-1-1

[139] A.Z. Mindubaev, A.D. Voloshina, S.Z. Validov. *Aspergillus niger* AM1 culture growth in medium with two phosphorus sources effectiveness of white phosphorus sterilization with acetone. *The North Caucasus Ecological Herald.* **2017**. Vol.13. No.1. P.47-54.

[140] A.Z. Mindubaev, A.D. Voloshina, S. Z. Validov, N.V. Kulik, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov, A.Y. Akkizov. *Aspergillus niger* AM1 culture growth in medium with two phosphorus sources. The validity of the definition "biodegradation" with respect to white phosphorus. *Butlerov Communications*. **2016**. Vol.46. No.5. P.1-20. DOI: 10.37952/ROI-jbc-01/16-46-5-1

[141] A.Z. Mindubaev. Biodegradation of white phosphorus: How a poison became a fertilizer. 2016 A.E. Arbuzova IOPC Yearbook. *Kazan, KPhTI, KazNC of the Russian Academy of Sciences*. **2017**. P.93-105. (russian)

[142] A.Z. Mindubaev, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. The effect of the amaranth green mass on the white phosphorus degradation rate. *Russian Journal of Applied Ecology*. **2017**. No.1. P.50-54.

[143] A.Z. Mindubaev, A.D. Voloshina, Sh.Z. Validov, D.G. Yakhvarov. Biodegradation of white phosphorus. *Priroda*. **2017**. No.5. P.29-43. (russian)

[144] A.Z. Mindubaev, Sh.Z. Validov, E.V. Babynin. Research of white phosphorus genotoxicity. *The North Caucasus Ecological Herald.* **2017**. Vol.13. No.2. P.38-44.

[145] A.Z. Mindubaev, A.D. Voloshina, N.V. Kulik, K.A. Saparmyradov, Kh.R. Khayarov, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Anaerobic detoxication of white phosphorus by microorganisms in sewage sediments. *Chemical safety.* **2017**. Vol.1. No.1. P.177-192.

[146] A.Z. Mindubaev, A.D. Voloshina, E.V. Gorbachuk, S.Z. Validov, N.V. Kulik, F.K. Alimova, S.T. Minzanova, L.G. Mironova, D.E. Belostotsky, K.A. Saparmyradov, R.I. Tukhbatova, D.G. Yakhvarov. Adaptation of microorganisms to white phosphorus as a result of directed selection. Genetic identification of sustainable *Aspergillus* and metabolic profiling of *Streptomyces* A8. *Butlerov Communications.* **2015**. Vol.44. No.12. P.1-28. DOI: 10.37952/ROI-jbc-01/15-44-12-1

[147] A.Z. Mindubaev, E.V. Babynin, S.Z. Validov, A.D.Voloshina, N.V. Kulik, S.T. Minzanova, L.G. Mironova, A.Y. Akkizov, D.G. Yakhvarov. Evaluation of white phosphorus genotoxicity. Growth of bacterial culture in a medium with potassium phosphite as a sole source of phosphorus. *Butlerov Communications.* **2016**. Vol.47. No.7. P.1-20. DOI: 10.37952/ROI-jbc-01/16-47-7-1

[148] A.Z. Mindubaev, E.V. Babynin, A.D. Voloshina, I.F. Sakhapov, N.V. Kulik, S.Z. Validov, S.T. Minzanova, L.G. Mironova, A.Y. Akkizov, D.G. Yakhvarov. Genotoxicity of white phosphorus. *Butlerov Communications.* **2017**. Vol.49. No.1. P.1-20. DOI: 10.37952/ROI-jbc-01/17-49-1-1

[149] A.Z. Mindubaev, A.D. Voloshina, D.G. Yakhvarov. Biological degradation of white phosphorus: feasibility and prospects. *Butlerov Communications*. **2013**. Vol.33. No.2. P.1-17. ROI: jbc-02/13-33-2-1

[150] A.Z. Mindubaev, E.V. Babynin, A.D. Voloshina, I.F. Sakhapov, D.G. Yakhvarov. Study of the white phosphorus genotoxicity. *Russian Journal of Applied Ecology*. **2017**. No.2. P.42-46. (russian)

[151] A.Z. Mindubaev, A.D. Voloshina, Kh.R. Khayarov, I.F. Sakhapov, E.K. Badeeva, A.S. Strobykina, Sh.Z. Validov, V.M. Babaev, S.T. Minzanova, L.G. Mironova, A.Y. Abaye, D. G. Yakhvarov. Dynamics of white phosphorus transformation by a culture of black aspergill. *Butlerov Communications*. **2017**. Vol.51. No.8. P.1-26. DOI: 10.37952/ROI-jbc-01/17-51-8-1

[152] A.Z. Mindubaev E.V. Babynin, A.D. Voloshina. Estimation of mutagenic and antimutagenic properties of white phosphorus using SOS-lux test. *The North Caucasus Ecological Herald.* **2017**. Vol.13. No.4. P.40-45. (russian)

[153] A.Z. Mindubaev, A.D. Voloshina, E.V. Babynin, E.K. Badeeva, Kh.R. Khayarov, S.T. Minzanova, D.G. Yakhvarov. Microbiological degradation of white phosphorus. *Ecology and Industry of Russia.* **2018**. Vol.22. Iss.1. P.33-37. (russian)

[154] A.Z. Mindubaev, A.D. Voloshina, N.V. Kulik, K.A. Saparmyradov, Kh.R. Khayarov, S.T. Minzanova, L G. Mironova, D.G. Yakhvarov. Involving white phosphorus into natural cycle of biogenic elements. *Chemical safety.* **2017**. Vol.1. No.2. P.205-220. (russian)

[155] A.Z. Mindubaev, A.D. Voloshina, E.V. Babynin, Sh.Z. Validov, K.A. Saparmyradov, Kh.R. Khayarov, E.K. Badeeva, S.T. Minzanova, L.G. Mironova, Y.A. Akosah, D.G. Yakhvarov. Neutralization of white phosphorus by means of microbiological decomposition. *Butlerov Communications*. **2017**. Vol.52. No.12. P.87-118. DOI: 10.37952/ROI-jbc-01/17-52-12-87

[156] A.Z. Mindubaev, A.Y. Abayie, D.G. Yakhvarov. Phosphine oxide as a prospective intermediate of biological processes. *Butlerov Communications*. **2018**. Vol.53. No.3. P.1-34. DOI: 10.37952/ROI-jbc-01/18-53-3-1
[157] A.Z. Mindubaev, A.D. Voloshina, N.V. Kulik, I.F. Sakhapov, Sh.Z. Validov, D.G. Yakhvarov. Mold fungus *aspergill* growth in medium with white phosphorus and phosphate. Sterilization samples of white phosphorus. *Russian Journal of Applied Ecology*. **2017**. No.3. P.37-40. (russian)
[158] A.Z. Mindubaev, E.V. Babynin, A.D. Voloshina, S.T. Minzanova, E.K. Badeeva. About the genotoxicity of white phosphorus. *Proceedings of the International Scientific Ecological Conference "Ecological problems of agrolandscape development and ways to increase their productivity"*, Krasnodar. **2018**. P.292-295 (russian)
[159] A.Z. Mindubaev, A.D. Voloshina, E.K. Badeeva, Kh.R. Khayarov, D.G. Yakhvarov. Oxidation of white phosphorus by a black aspergill. Appearance of a mutant culture *Aspergillus niger* AM1. *Russian Journal of Applied Ecology*. **2018**. No.1. P.28-31. (russian)
[160] A.Z. Mindubaev, Y.A. Akosah, E.V. Babynin, D.G. Yakhvarov. The appearance of a mutant A. niger AM1 culture, more adapted to white phosphorus than an ancestral strain. *Materials of the VII All-Russian Conference with international participation "Topical issues of chemical technology and environmental protection"*. Cheboksary. **2018**. P.66-67. (russian)
[161] A.Z. Mindubaev, E.V. Babynin, A.D. Voloshina, E.K. Badeeva, S.T. Minzanova, G.G. Kabirova, R.K. Shaikhutdinov, A.A. Sinitsyna, A.A. Sharipov A.N. Makhyanov, D.B. Piskunov, D.K. Rejepov, S.M. Ozerskaya. Resistance of black aspergillus cultures to white phosphorus. Its effect on the cell cycle. *Collection of articles of the 13th All-Russian Scientific and Practical Conference with International Participation "Ecology of the Motherland: Problems and Ways to Solve Them -2018"*, Kirov. **2018**. Book 2. P.74-78. (russian)
[162] A.Z. Mindubaev, A.D. Voloshina, E.V. Babynin, D.G. Yakhvarov. Microorganism, neutralizing white phosphorus. *Collection of materials of the 71st All-Russian school-conference of young scientists with international participation "Biosystems: organization, behavior, management"*. Nizhny Novgorod. **2018**. P.153. (russian)
[163] Y.A. Akosah, A.Z. Mindubaev, E.V. Babynin, E.K. Badeev. The emergence of a mutant *A. niger* culture, more resistant to white phosphorus. *Collection of theses of the 22nd International Pushchino School-Conference of Young Scientists "Biology - Science of the XXI Century"*. Pushchino. **2018**. P.273. (russian)
[164] A.Z. Mindubaev, D.G. Yakhvarov. Biological neutralization of white and yellow phosphorus. *Collection of materials of the XIX International Scientific Conference "Chemistry and Chemical Engineering in XXI century" dedicated to Professor L.P. Kulyov.* Tomsk. **2018**. P.451. (russian)
[165] A.Z. Mindubaev, E.V. Babynin, G.G. Kabirova, R.K. Shaikhutdinov, A.A. Sinitsina, A.A. Sharipov, A.N. Makhiyanov, D.B. Piskunov, D.K. Rejepov, A.D. Voloshina, E.K. Badeeva, Y.A. Akosah, S.M. Ozerskaya. Resistance of *Aspergillus niger* to white phosphorus. The mitotoxic effect of P4. *Proceedings of the 18th International Symposium "Energy Resource Efficiency and Energy Saving",* Kazan. **2018**. P.91-94. (russian)
[166] A.Z. Mindubaev, A.D. Voloshina, N.V. Kulik, K.A. Saparmyradov, S.T. Minzanova, L.G. Mironova, Kh.R. Khayarov, D.G. Yakhvarov. Resistance of fungi and streptomycetes to white phosphorus. *Collection of articles of the IV International scientific and practical conference of students, undergraduates, graduate students, scientists and employees of IT companies "Transboundary cooperation in the field of environmental safety and environmental protection"*, Gomel, Belarus. **2018**. P.248-253. (russian)
[167] A.Z. Mindubaev, A.D. Voloshina, K.A. Saparmyradov, S.T. Minzanova, L.G. Mironova, Kh.R. Khayarov, D.G. Yakhvarov. Microbial detoxification of white phosphorus, a dangerous river pollutant. *Collection of articles of the 2nd International Ecological Conference "Ecology of river landscapes"*. Krasnodar. **2017**. P.139-150. (russian)
[168] A.Z. Mindubaev, A.D. Voloshina, E.V. Babynin. Resistance of microorganisms to white phosphorus. *Abstract book International Scientific Conference PLAMIC2018 «Plants and microbes: the future of biotechnology» Russia, Ufa*. **2018**. P.194. (russian)
[169] A.S. Strobykina, I.F. Sakhapov, Y.A. Akosah. Microbial resistance to white phosphorus – A toxic and genotoxic pollutant. *Collection of scientific works of the III Republican Youth Ecological Scientific Conference*. Kazan. **2018**. P.99-108. (russian)
[170] A.Z. Mindubaev, Voloshina A.D, Kulik N.V., Saparmyradov K.A., Minzanova S.T, Mironova L.G, Khayarov Kh.R. Resistance to white phosphorus of fungi and streptomycetes. *Biomics*. **2018**. Vol.10. No. 2. P. 214- 219. DOI: 10.31301/2221-6197.bmcs.2018-31 (russian)

[171] A.Z. Mindubaev, A.D. Voloshina, N.V. Kulik, Sh.Z. Validov, K.A. Saparmyradov, S.T. Minzanova, L.G. Mironova, D.G. Yakhvarov. Effect of selection upon resistance of microorganisms to white phosphorus. *Chemical safety*. **2018**. Vol.2. No.1. P.191-205. (russian)

[172] A.Z. Mindubaev, A.D. Voloshina, K.A. Saparmyradov, S.T. Minzanova, Kh.R. Khayarov. Microbial detoxification of white phosphorus, a dangerous soil pollutant. *Collection of the 4th All-Russian Scientific Conference "Chemical and Biological Pollution of Soils"* Pushchino. **2018**. P.189-192. (russian)

[173] A.Z. Mindubaev, A.D. Voloshina, E.V. Babynin, Sh.Z. Validov, K.A. Saparmyradov, Kh.R. Khayarov, E.K. Badeeva, S.T. Minzanova, L.G. Mironova, Y.A. Akosah, D.G. Yakhvarov. Neutralization of white phosphorus by means of microbiological decomposition. *Butlerov Communications*. **2017**. Vol.52. No.12. P.87-118. DOI: 10.37952/ROI-jbc-01/17-52-12-87

[174] A.Z. Mindubaev, E.V. Babynin, A.D. Voloshina, E.K. Badeeva, S.T. Minzanova, G.G. Kabirova, R.K. Shaikhutdinov, A.A. Sinitsyna. Resistance of *Aspergillus niger* strains to white phosphorus. *Collection of scientific works of the 6th All-Russian Conference with international participation "Chemistry and Modernity"*. Cheboksary. **2018**. P.57-60. (russian)

[175] V.B. Ivanov. Cellular bases for plant growth. *Moscow: Nauka*. **1974**. P.231. (russian)

[176] G. Shamim, S.K. Ranjan 2, D.M. Pandey, R. Ramani. Biochemistry and biosynthesis of insect pigments. *Eur. J. Entomol*. **2014**. Vol.111. No.2. P.149-164.

[177] H. Beecken, E.-M. Gottschalk, U. v Gizycki, H. Krämer, D. Maassen, H.-G. Matthies, H. Musso, C. Rathjen, U. Zdhorszky. Orcein and Litmus. *Biotechnic & Histochemistry*. **2003**. Vol.78. No.6. P.289-302.

[178] G. Fiskesjo. Allium test for screening chemical evaluation of cytological parameters / in W. Wang, J.W. Gorsuch, J.S. Hughes. *Plants for Environmental Studies. 6005 J.S. (Eds), New York, NY:CRC Lewis Publishers*. **1997**. P.307-333.

[179] I.M. Prokhorov, M.I. Kovaleva, A.N. Fomichev. Genetic toxicology: laboratory practicum. P.G. Demidov Yaroslavl State University. *Yaroslavl*. **2005**. P.132. (russian)

[180] B.M. Cossairt, N.A. Piro, C.C. Cummins. Early-Transition-Metal-Mediated Activation and Transformation of White Phosphorus. *Chem. Rev*. **2010**. Vol.110. No.7. P.4164-4177.

[181] R.M. Kagirov, A.V. Voloshin, I.Kh. Rizvanov, O.G. Sinyashin, D.G. Yakhvarov. Activation and transformation of white phosphorus by palladium (ii) complexes. *Russian Chemical Bulletin*. **2010**. Vol.59. No.6. P.1116 -1118.

[182] Green, W. Stout, D. Taylor. Biological Science: in 3 vol. *Tr. From Eng. Edited by R. Soper*. *Moscow: Mir*. **1993**. Vol.3. 376p.

[183] K. Lamsal, B.K. Ghimire, P. Sharma, A.K. Ghimiray, S.W. Kim, C.Y. Yu, I.M. Chung, Y.S. Lee, J.-S. Kim, S.R. Shakya. Genotoxicity evaluation of the insecticide ethion in root of *Allium cepa* L. *Afr. J. Biotechnol*. **2010**. Vol.9. No.27. P.4204-4210.

[184] N. Green, W. Stout, D. Taylor. Biological Science: in 3 vol. *Tr. From Eng. Edited by R. Soper*. *Moscow: Mir*. **1993**. Vol. 1. 368 p.

[185] A. Vandecandelaere, S.R. Martin, Y. Engelborghs. Response of microtubules to the addition of colchicine and tubulin–colchicine: evaluation of models for the interaction of drugs with microtubules. *Biochem. J*. **1997**. Vol.323. No.1. P.189-196.

[186] R. Bentley. A fresh look at natural tropolonoids. *Nat Prod Rep*. **2008**. Vol.25. No.1. P.118-138.