Study on the perspectives of application of eco-friendly laser biotechnology for environmental protection in Uzbekistan

O Tursunov1,2,3,4*, J W Dobrowolski1, O Khujaev3, N Abduganiev2, O J Nazarova3, and D J Yuldosheva3

1Team of Environmental Engineering and Biotechnology, Faculty of Mining Surveying and Environmental Engineering, AGH University of Science and Technology, 30-059 Krakow, Poland
2Department of Power Supply and Renewable Energy Sources, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 100000 Tashkent, Uzbekistan
3Research Institute of Forestry, 111104 Tashkent, Uzbekistan
4Gulistan State University, 120100 Gulistan, Uzbekistan

*Email: obidtursunov@gmail.com

Abstract. Since few decades, the world is encountering unusual and daunting environmental challenges like global warming, climate change, pollution of the atmosphere and water, an emerging international crisis in water availability, long-term damage to ecosystems and substantial loss of biodiversity, waste production and disposal, damaged aquatic ecosystems, impacts of chemicals use and toxic substance disposal, as well as land degradation and deforestation. Accordingly, Uzbekistan has also been encountering some environmental issues, such as global Aral Sea crisis, soil erosion and desertification, wastewater, air pollution and a growing amount of municipal solid waste. Hence, this paper illustrates the major environmental challenges and risks in Uzbekistan, as well as, the possible application of environmentally friendly laser biotechnology for more efficient and rationale protection of ecosystems and wide-scale reclamation of deteriorated areas. Comprehensive use of laser irradiation can be effectively applied in environmental protection engineering and technologies for sustainable development in selected regions. Laser irradiation or photostimulation is a neoteric area and process of environmental biotechnology. In this process, coherent laser light is employed to optimize the natural processes involved in the bioremediation of xenobiotics or bioaccumulation of metals. Additionally, laser biotechnology could be broadly used for more efficient reclamation of contaminated soil, wastewater treatment, as well as for increasing the growth rate of irradiated plants and their resistance to various macro- and micro pollutants in the air, soil, and water.

1. Introduction

Uzbekistan is in the center of Central Asia, bordered on the south by Kyrgyzstan, Kazakhstan, Tajikistan, and Turkmenistan, and surrounded on the north by Kyrgyzstan, Kazakhstan, Tajikistan, and Turkmenistan. Uzbekistan's total area is around 477,400 km², with scenery ranging from steppe and desert in the west to richer farming along the country's three major rivers as it heads east to the mountainous region. Uzbekistan
boasts a diverse range of natural resources, including oil, natural gas, gold, and silver, and has Central Asia's largest population, with around 31 million people. The bulk of the population is ethnically Uzbek, but there are significant minorities in the country, including Russians, Tatars, Koreans, Kazakhs, Karakalpakians, Tadjiks, and Turkmens [1]. Notwithstanding Uzbekistan's diverse natural environment, decades of Soviet Union environmental neglect have combined with unbalanced economic policies in the Soviet south to make Uzbekistan one of the most serious of the Commonwealth of Independent States' (CIS) many environmental disasters. The widespread use of agrochemicals, the diversion of enormous amounts of irrigation water from the region's two rivers, and the chronic lack of water treatment plants are only a few of the factors that have resulted in widespread health and environmental problems [2]. Figure 1 highlights the overall ecosystem of the Republic of Uzbekistan.

Figure 1. Map of the Ecosystems of Uzbekistan [2]
development. Hence, this study aims to highlight most critical environmental issues which Uzbekistan has been encountering since few decades and possibility of comprehensive application of ecologically-friendly laser biotechnology for environmental protection in Uzbekistan.

2. The Aral Sea Disaster and Environmental Health Crisis

The Aral Sea disaster can be traced back to Soviet Union choices in the 1960s, when every effort was made to boost cotton production, mostly by irrigation. The necessary water was sourced from the Aral Sea's rivers. The Soviet Union's water management had a series of disastrous environmental consequences that impacted the region, particularly the autonomous Republic of Karakalpakistan. Environmental repercussions include a drop in the Aral Sea's volume to less than half its original extent, full ecological degradation, and the virtual extinction of fish. Desertification of vast areas, including the Amu Darya and Syr Darya deltas, is "changing the climate in the region", and has reduced the Sea's proximity to a lifeless desert [8, 9]. Environmental changes have a direct impact on the population. The lack of fish has virtually ruined the region's once-thriving fishing industry, leaving 60,000 people jobless.

![Figure 2. 20th and 21st Century desiccation of the Aral Sea: 1960 – 2020 [10]](image)

The significant loss of inflowing water resulted in massive changes in water level, water chemistry (especially salinity), and the Aral's diversification into a few smaller water bodies (Figure 2). The Small Aral, the Eastern Large Aral, and the Western Large Aral have all emerged as a result of a persistent decline in water level. Solonchaks and soils with takyric surface horizons are salt-affected soils in the southern Aral Sea basin. Surface crusts are present in both types of soils, which cover an area of more than 1,000,000 hectares. The surface crust of very saline Solonchak soils typically has a significant salt concentration. Takyric crusts, which are characterized as heavy-textured surface horizons of regularly flooded soils, have a reduced salinity, and their production is linked to the development of high sodicity when soluble salts are leached. Salt crusts covering areas of the lake bed that became exposed due to desiccation (about 4,000,000 ha total exposed area) are a third type of surface crust [11].
Environmental shifts in the Aral Sea have led to the extinction of fish stocks that historically provided nourishment and employment to nearby human communities, despite the fact that annual fish captures peaked at 44,000 tons in the 1960s. The current eastern and western Aral basins are hypersaline water bodies that have completely eliminated freshwater, brackish water, and marine fish and invertebrate species. Since the 1960s, changes in the Aral Sea's biotic composition have been closely studied and widely reported in Russian-language periodicals [12].

Environmental circumstances, not isolated toxins, undoubtedly have a significant impact on the health of the residents of the area. Pesticide pollution affects residents of the Syr Darya valley and, most likely, the Amu Darya valley far more than residents of the ancient Aral Sea coastline area. High levels of dibenzofurans and dioxins have been found in their bodies as a result of the use of specific pesticides. In Central Asia, water is a precious resource and possibly the most important economic component. The Aral Sea's problems will not be solved in the near future [13]. Nevertheless, with more water left over in the Amu Darya and the Syr Darya, the Aral Sea's area will grow, even if the Aral Sea will likely not restore its former extent in the next generation.

3. Soil Erosion and Desertification

Soil erosion and desertification are one of the major environmental and agricultural problems in the world. Although erosion and desertification have occurred throughout the history of agriculture, it has intensified in recent years [14]. Wind and water erosion take 75 billion metric tons of soil from the earth each year, the majority of which comes from agricultural land [15]. The loss of soil destroys arable land, rendering it unusable in the long run. Non-sustainable farming methods result in the destruction and abandonment of around $12 \times 10^6$ hectares of arable land per year, with only $1.5 \times 10^9$ ha of land being cultivated [16, 17]. Because to lost eroding land and the rise of the world population to about 6 billion people, per capita arable land shortages occur in Africa, Asia, and Europe [14, 18].

Soil erosion and desertification in Uzbekistan lead winds to carry salt and dust hundreds of miles, depositing it on cultivated land and in people's lungs. The history of Resurgence Island as a Soviet Defense Ministry test site poses an extra health risk. Lack of job and health-related concerns have prompted people to migrate from the Aral Sea region, uprooting people and increasing population density in other parts of the country, particularly in the capital city.

4. Water Quality: Causes of Contaminated Water

Water supply and quality are major concerns in Uzbekistan. Indeed, the vast majority of the country's streams are moderately or seriously contaminated, posing a serious threat to human health and deteriorating irrigated land. Industry, agriculture, and human settlements are the main sources of pollution. The distribution of critical water supplies has periodically sparked disputes between Uzbekistan and its downstream neighbors as well as upstream states, causing Uzbekistan to drastically reduce commerce and close its borders on occasion [19].

Monoculture of cotton along Uzbekistan's riverbeds, along with intensive irrigation and pesticide use, has resulted in widespread salinity and impurity throughout the country, as well as a significant reduction in biodiversity. Furthermore, large-scale chemical use for cotton production, inadequate drainage, and ineffective irrigation systems are examples of situations that resulted in a high filtering of salinized and contaminated water back into the soil [4-6]. Chemical fertilizers and insecticides were applied at a rate of twenty to twenty-five kilograms per hectare on average in the Central Asian republics in the early 1990s, compared to three kilograms per hectare for the entire Soviet Union. As a result, the fresh water supply has been contaminated further [7, 8]. Uzbekistan's water has also been harmed by industrial pollution [19]. Concentrations of oil and phenol compounds in the Amu Darya have been found to be significantly over acceptable health levels. Uzbekistan has made significant attempts to increase agricultural diversity and change irrigation practices since independence. However, the economic importance of agriculture, along
with a rise in arable land, means that environmental pressure on the ecosystem and the people who live within it will continue. Pollution of the air has also been caused by poor water management and the widespread use of agricultural pesticides. Salt and dust storms, as well as pesticide and defoliant spraying for the cotton crop, have wreaked havoc on rural air quality.

5. **Air Pollution from Industry**

Factory and automobile emissions are posing an increasing danger to air quality in metropolitan areas. In Uzbekistan, only around half of industry smokestacks have filtering equipment, and none of them can filter gaseous pollutants. Furthermore, a large number of existing filters are damaged or inoperable. Tashkent, Fergana Valey, and Olmaliq all have air pollution levels that are higher than the permissible amounts of nitrogen dioxide and particulates [20]. Heavy metals like nickel, lead, zinc, copper, mercury, and manganese have been identified at high concentrations in Uzbekistan's atmosphere, owing to the combustion of fossil fuels, garbage, and ferrous and nonferrous industries. Heavy metal concentrations were found in particularly high proportions in Toshkent Province and the southern region of Uzbekistan near the Olmaliq Metallurgy Combine.

6. **Municipal Solid Waste Management**

Currently, the global growth of municipal solid waste (MSW) has become the biggest problem in developed and developing countries [21-25]. Uzbekistan is considered as the country with the highest population among other Central Asian countries. According to the State Statistics Committee of the Republic of Uzbekistan, the population of Uzbekistan amounted to 33,724,500 people by October 2019. For these reasons, the amount of solid waste generated is much higher compared to other countries in Central Asia.

![Figure 3. MSW composition in Uzbekistan (2017-2018) [26, 27]](image)

Annually, 35 million cubic meters of household waste and 100 million tons of industrial waste are generated in the republic. Today, 2 billion tons of MSW have accumulated at the landfills [26, 27]. Based
on the results of studies in 2017-2018, Figure 3 shows main composition of MSW in the Republic of Uzbekistan. According to the State Environmental Protection Committee of the Republic of Uzbekistan, modern clusters were launched in 2017 for a full recycling of solid waste: from garbage collection to its processing. In May 2018, the President of Uzbekistan adopted a resolution “Measures to further improve the system of household waste management” [23, 25]. This document is aimed at improving the sanitary and environmental situation in the republic. To date, 183 enterprises are operating for processing the recyclables extracted from MSW. The total processing capacity of enterprises is 894 thousand tons of recyclables per year, of which: 72 polymer processing enterprises, 65 waste paper processing enterprises, 17 rubber and tire processing plants, 6 cullet processing enterprises, 2 oil and textile processing enterprises, 10 metal processing plants, and 11 processing plants for other recyclables.

Apparently, MSW has a negative impact on the environment and human health, as well as pose a threat to environmental safety and public health. Therefore, as in the whole world, Uzbekistan is facing acute issues of safe disposal of solid waste [23, 25]. The issues of safe disposal of solid waste can be resolved by using appropriate advanced and environmentally friendly methods and technologies, such as energy efficient thermolysis, pyrolysis, and gasification [24, 28-35] in integration with green chemistry, nanotechnology and renewable energy, which can reduce the volume of waste efficiently [36, 37].

7. Application of Laser Bio-Technology for Environmental Protection

According to sustainable development principles, laser biotechnology could be applied in environmental engineering technologies [38]. Laser Stimulation can also be utilized to improve the efficiency of wastewater treatment, soil reclamation, bioremediation capabilities, and the growth of energy and food crops.

Dobrowolski pioneered the use of laser stimulation of various plant species, soil bacteria, and fungi in environmental biotechnology in the late twentieth century for the optimization of bioremediation processes, such as the removal of pollutants from sewage and soil reclamation, as well as the increase of biomass production by plants cultivated in polluted soils. Furthermore, laser stimulation allows for the optimization of natural biological processes through better phenotypic expression and adaptation to various contaminants in the natural environment, including more efficient bioremediation of particular elements [38-40].

Bioremediation of extremely hazardous metals using empirically selected wavelength, energy density, and time of irradiation of coherent light is far more efficient than any other approach of contaminated soil remediation. Even when using similar laser biostimulation algorithms, there are significant variances in the bioremediation of Pb, Cd, and Ni, depending on the genotype irradiated and the photonic structure [41]. Not just for diverse industrial zones, but also for areas with high salt levels in the soil or soils degraded by petrochemical toxins, Laser Biotechnology offers a new perspective on reclamation. Furthermore, laser stimulation causes an increase in plant biomass as well as a greater uptake of specific components from contaminated water and soils. Changes in trace element concentrations in plants were also discovered as a result of using a photostimulation algorithm. Increased biomass production of various land and water plants under suboptimal conditions, such as in contaminated areas, could improve low-carbon energy production and sustainable development. New sources of coherent light can be proposed as a cost-effective and best-available technology for bioremediation, as well as biomass and bio-energy generation [42].

Laser biostimulation of inoculums of specific fungi can also aid in the stimulation of mycorrhizal moulds and the adaption of infected seedling roots to contaminated soil. Proper photostimulation of chosen moulds and bacteria inoculums could help speed up the biodegradation of some organic contaminants in water and soil [43-47].

Adaptation of different species of plants (e.g. reed Phragmites australis, duckweed Lemna minor, and willow Salix sp) and water bacteria to suboptimal environmental conditions (e.g. various chemical,
contaminated soil and water) require additional energy. Empirically selected algorithms of irradiation of the above mentioned biological materials with low energy lasers (as sources of coherent light of high energy density) stimulate some enzymes and physiological processes of adaptation useful for more efficient application of plants for bioremediation of metal contaminated soil and wastewater, as well as for biodegradation of xenobiotic pollutants, like polyaromatic hydrocarbons (PAHs) [43, 46, 47]. As a result, laser stimulation is a new branch of environmental biotechnology in which coherent laser light is used to optimize natural processes such as metal bioaccumulation or xenobiotic bioremediation. Laser stimulation can be used to improve the efficiency of sewage treatment bioprocesses, the reclamation of polluted land, enhanced bioremediation capabilities, and the growth rate and resistance of irradiated plants to contaminants in the air, soil, and water.

8. Conclusions
Environmental and ecological security is of pivotal importance for regional sustainable development. This paper highlighted most critical environmental and ecological issues which Uzbekistan has been encountering since few decades. Biotechnology especially, environmentally clean laser bio-technology was proposed as one of the alternative and an effective key method for solving above mentioned environmental and ecological problems. Laser Biotechnology has tremendous potential for unique, efficient, eco-friendly and economically viable options for a more efficient wastewater treatment processes, soil reclamation, improvement of air quality, increase of bioremediation abilities and increase growth of energetic and food crops. Wide-scale application of laser biotechnology would be definitely useful in environmental engineering technologies, in particular for water and soil remediation, also for more efficient production of biological resources.

Acknowledgments
This paper was prepared within the framework of the project F3-2019-1 (2275+3015) “Development of agricultural technology to combat diseases of newly created forests and pastures in the arid part of the Aral Sea” provided by the Ministry of Innovative Development of the Republic of Uzbekistan.

References
[1] Anderson B, Klimov Yu 2012 Uzbekistan: Trade Regime and Recent Trade Developments SSRN 4 2012
[2] Toderich KN, Shuyskaya EV, Ismail S, Gismatullina LG, Radjabov T, Bekchanov BB, Aralova DB 2009 Phytogenic resources of halophytes of Central Asia and their role for rehabilitation of sandy desert degraded rangelands Land Degradation & Development 20 386–396.
[3] Solarin SA, Bello MO 2018 Persistence of policy shocks to an environmental degradation index: the case of ecological footprint in 128 developed and developing countries Ecological Indicators 89 35-44.
[4] Karthe D, Chalov S, Borchardt D 2015 Water resources and their management in central Asia in the early twenty first century: status, challenges and future prospects Environmental Earth Sciences 73(2) 487-499.
[5] Bekturganov Z, Tussupova K, Berndtsson R, Sharapatova N, Aryanazin K, Zhanasova M 2016 Water related health problems in Central Asia- A review Water 8(6) 219.
[6] Duan W, Chen Y, Zou S, Nover D 2019 Managing the water-climate-food nexus for sustainable development in Turkmenistan Journal of Cleaner Production 220 212-224.
[7] Zhang ZY, Abduwuail J, Fengqing J 2015 Heavy metal contamination, sources, and pollution assessment of surface water in the Tianshan Mountains of China Environmental Monitoring and Assessment 187(2) 33.
[8] Jiang L, Jiapaer G, Bao A, Kurban A, Guo H, Zheng G, De Maeyer P 2019 Monitoring the long-term desertification process and assessing the relative roles of its drivers in Central Asia Ecological Indicators 104 195-208.

[9] Wang L, Pang YS 2014 A review of regional ecological security evaluation Applied Mechanics and Materials 178-181 337-344.

[10] Micklin P 2016 The future Aral Sea: hope and despair Environmental Earth Sciences 75 1–15.

[11] Meesa F, Singerb A 2006 Surface crusts on soils/sediments of the southern Aral Sea basin, Uzbekistan Geoderma 136 152-159.

[12] Mardena B, Stappenb GV, Musaevc A, Mirabdullayev I, Joldasovac I, Sorgeloosb P 2012 Assessment of the production potential of an emerging Artemia population in the Aral Sea, Uzbekistan Journal of Marine System 92 42-52.

[13] Erdinger L, Hollert H, Eckl P 2011 An Ecological Disaster Zone with Impact on Human Health: Aral Sea Encyclopedia of Environmental Health, In: Nriagu JO (Eds.), Elsevier, pp. 136-144.

[14] Lal R, Stewart BA 1990 Soil Degradation, Springer, New York.

[15] Myers N 1993 Gala: An Atlas of Planet Management, Anchor and Doubleday, New York.

[16] Buringh P 1989 Availability of Agricultural Land for Crop and Livestock Production Food and Natural Resources In: Pimentel D, Hall GW (Eds.), Academic Press, San Diego, pp. 69-83.

[17] Behnassi M, Shahid SA, D'Silva J 2011 Sustainable Agricultural Development, Springer, Netherlands.

[18] Pimentel D, Harman R, Pacenza M, Pekarsky J, Pimentel M 1994 Natural resources and an optimum human population Population and Environment 15 347-369.

[19] Dorian JP 2006 Central Asia: a major emerging energy player in the 21st century Energy Policy 34(5) 544-555.

[20] Tursunov O 2014 A comparison of catalysts zeolite and calcined dolomite for gas production from pyrolysis of municipal solid waste (MSW) Ecological Engineering 69 237-243.

[21] Adilova M 2006 The problem of primary sorting of household waste Environmental Safety and Civil Initiative 8 10-13.

[22] Tursunov O, Suleimenova B, Kuspangaliyeva B, Inglezakis VJ, Anthony EJ, Sarbassov Y 2020 Characterization of tar generated from the mixture of municipal solid waste and coal pyrolysis at 800 °C Energy Reports 6 147-152.

[23] Adilova M 2006 The problem of primary sorting of household waste Environmental Safety and Civil Initiative 8 10-13.

[24] Wiebers J, Weller CL, Jones DD, Hanna MA 2008 Contemporary issues in thermal gasification of biomass and its application to electricity and fuel production Biomass and Bioenergy 32 573–81.
[30] Zhang L, Xu C, Champagne P 2010 Overview of recent advances in thermo-chemical conversion of biomass Energy Conversion and Management 51 969–82.

[31] Tursunov O, Zubek K, Dobrowolski J, Czerski G, Grzywacz P 2017 Effect of Ni/Al₂O₃-SiO₂ and Ni/Al₂O₃-SiO₂ with K₂O promoter Catalysts on H₂, CO and CH₄ Concentration by CO₂ Gasification of Rosa Multiflora biomass Oil & Gas Science and Technology - Revue d’IFP Energies nouvelles 72 1-16.

[32] Tursunov O, Dobrowolski J, Zubek K, Czerski G, Grzywacz P, Dubert F, Lapczynska-Kordon B, Klima K, Handke B 2018 Kinetic study of the pyrolysis and gasification of Rosa multiflora and Miscanthus giganteus biomasses via thermogravimetric analysis Thermal Science 22 3057-3071.

[33] Anarbaev A, Tursunov O, Kodirov D, Muzafarov S, Babayev A, Sanbetova A, Batirova L, Mirzaev B 2019 Reduction of greenhouse gas emissions from renewable energy technologies in agricultural sectors of Uzbekistan EJS Web of Conferences 135 01035.

[34] Tursunov O, Kustov L, Tilyabaev Z 2019 Catalytic activity of H-ZSM-5 and Cu-HZSM-5 zeolites of medium SiO₂/Al₂O₃ ratio in conversion of n-hexane to aromatics Journal of Petroleum Science and Engineering 180 773-778.

[35] Pasek AD, Kilbergen W, Suwono G, Suwono A 2013 Feasibility of recovering energy from municipal solid waste to generate electricity Journal of Engineering and Technological Sciences 45(3) 241-256.

[36] Sipra AT, Gao N, Sarwar H 2018 Municipal solid waste (MSW) pyrolysis for bio-fuel production: A review of effects of MSW components and catalysts Fuel Processing Technology 175 131–147.

[37] Dobrowolski JW 2000 Perspectives of application laser biotechnology in management of the natural environment Polish Journal of Environmental Studies 10 7-9.

[38] Dobrowolski JW, Wachalewski T, Smyk B, Barabasz W, Rodotlessyckii E 1996 Experiments on the influence of laser light on some biological elements of natural environment Environmental Management and Health 8 136-141.

[39] Dobrowolski JW, Borkowski J, Szymczyk S 1987 Laser stimulation for cummulation of elenium in tomato fruits Photon Emission from Biological Systems In: Jezowska-Trzebiatowska B, Kochel B, Slawinski J, Starek W (Eds.), World Scientific, Singapore, pp. 211-218.

[40] Dobrowolski JW, Noyes J 2012 Photonic structure in nature, Bio nanotechnology Global Perspectives In: Reisner DE (Eds.), CRC Press, Boca Raton, pp. 497-517.

[41] Dobrowolski JW, Mazur R 2012 Laser biotechnology for more efficient bioremediation, protection of aquatic ecosystems and reclamation of contaminated areas Journal of Chemical Technology and Biotechnology 87 1354-1359.

[42] Doborowolski JW, Budak A, Trojanowska D, Rymarczyk M, Macuda J 2012 Laser stimulation of Trichophytonmentagrophytes for the enhancement biodegradation of hydrocarbons Journal of Environmental Engineering and Management 11 173-1788.

[43] Tursunov O, Dobrowolski JW 2015 A brief review of application of Laser Biotechnology as an Efficient Mechanism for the Increase of Biomass for Bio-energy Production via Clean Thermo-Technologies American Journal of Renewable and Sustainable Energy 1(2) 66-71.

[44] Tursunov O, Dobrowolski JW, Klima K, Kordon B, Ryczkowski J, Tylko G, Czerski G 2015 The Influence of Laser Biotechnology on Energetic Value and Chemical Parameters of Rose Multiflora Biomass and Role of Catalysts for bio-energy production from biomass: Case Study in Krakow-Poland World Journal of Environmental Engineering 3(2) 58-66.
[46] Dobrowolski JW, Kobylarczyk J, Tursunov O, Toh SQ 2015 Integration of Local Eco-Innovation with Global Problems of Protection of the Natural Environment and Bio-Based Green Economy, In: Proceedings of the AASRI International Conference on Circuits and Systems, Atlantis Press 9 25-28.

[47] Dobrowolski Dobrowolski JW, Bedla D, Czech T, Gambus F, Gorecka K, Kiszczak W, Kuzniar T, Mazur R, Nowak A, Sliwka M, Tursunov O, Wagner A, Wieczorek J, Swiatek M 2017 Integrated Innovative Biotechnology for Optimization of Environmental Bioprocesses and a Green Economy Optimization and Applicability of Bioprocesses eds Purohit H, Kalia V, Vaidya A, Khardenavis A (Singapore: Springer) chapter 3 pp 27-71.