Abstracts of the papers

enclosed with the application for Assoc. Prof. of Assis. Prof. Dr. Rayka Kirilova Vladova

1. Vaklieva-Bancheva, N., **Vladova, R.**, Kirilova, E., "Analysis of energy efficiency of heat integration framework of ATAD wastewater treatment plant under uncertainties". *Reports Awarded with Best Paper Cristal Prize. 56-th Annual Science Conference of Angel Kanchev University of Ruse "Industry 4.0. Business Environment. Quality of Life"*, 2017, ISBN:978-954-712-733-3, 44-49, https://conf.uni-ruse.bg/bg/docs/cp17/bp/bp-6.pdf

The aim of the study is to develop an approach for analysis of energy efficiency of heat integrated Autothermal Thermophilic Aerobic Digestion system for wastewater treatment operating under uncertainties. The approach involves formulation of an optimization model of heat integration of the processes with one heat storage tank. The model is solved at all possible combinations of lower and upper boundaries of the stochastic parameters of ATAD system to determine the maximal temperature achieved at the end of the integration process. Based on the analysis conducted, the efficiency boundaries of the proposed heat integration framework are determined.

2. Vaklieva-Bancheva, N., **Vladova, R.**, Kirilova, E., "Mathematical model of energy integration of the processes in ATAD system operating under uncertainties". *Proceedings of 56-th Annual Science Conference of Angel Kanchev University of Ruse "Industry 4.0. Business Environment. Quality of Life*", 56, Book 1.2. Thermotechnics. Hydro- and Pneumotechnics. Ecology and Environmental protection, 2017, 120-124, https://conf.uni-ruse.bg/bg/docs/cp17/1.2/1.2-23.pdf

This study proposes an approach for energy integration of processes in Autothermal Thermophilic Aerobic Digestion (ATAD) system for wastewater treatment for the purpose of their energy efficiency and sustainability improvement.

The idea for that came from the fact that the ATAD systems have a sufficient energy potential which can be used for reducing the depth of the thermal shock that occurs in first bioreactors stages due to uncertainties regarding to the quantities, composition and temperatures of the incoming into the system raw sludge.

To reduce the impact of the stochastic parameters and to ensure efficient using of the waste heat for the sustainable operation of the ATAD system, a mathematical model of energy integration scheme with two heat storage tanks is proposed which will be suitable to be involved in a stochastic optimization framework.

3. Vaklieva-Bancheva, N., **Vladova, R.**, Kirilova, E., "Mathematical modeling of energy integrated ATAD system for their sustainability improvement". *International Scientific Journal Industry* 4.0, Year II, Issue 4, Scientific Technical Union of Mechanical Engineering "Industry 4.0.", 2017, ISSN:2543-8582, 81-83,

https://old.iche.bas.bg/WWW_Project_NGV/NGV_WWW/bulgarian/Publication_Project/Industry_Borobetz.pdf

Autothermal Thermophilic Aerobic Digestion (ATAD) is a technology for municipal waste water treatment where Class A Biosolids is produced. ATAD systems characteristic with the simplicity of the process, the higher reaction rate and smaller bioreactors. Systematic observations carried out on conventional ATAD systems have shown that their major disadvantage is the thermal shock that occurs in first bioreactors stages due to uncertainties regarding to the quantities, composition and temperatures of the incoming into the system raw sludge. This study focuses on opportunities for the thermal shock reduction in conventional ATAD system through recovery the heat from the effluent stream. It can lead to substantial savings of the time required for operating temperature recovery and quicker bio-degradation. To reduce the impact of the stochastic parameters and to ensure efficient using of the waste heat for the sustainable operation of the ATAD system, two mathematical models of energy integration with one and two heat storage tanks are proposed which will be suitable to be involved in a stochastic optimization framework.

4. Kirilova, E., Vaklieva-Bancheva, N., **Vladova, R**., "Environmental impact assessments of CO_2 emissions of pollutants produced using different transportation fleets for "green" supply chain design". *Proceeding of 57th Annual Science Conference of Angel Kanchev University of Ruse and Union of Scientists – Ruse*, Volume 57, book 10.2. Biotechnologies and food technologies, 2018, ISSN:ISSN 1311-3321 (print), ISSN 2603-4123 (on-line), 16-22, https://ibn.idsi.md/sites/default/files/imag_file/PROCEEDINGS-Vol.-57-book-10.2.-2018686955230589523718 5.pdf

This study represents a continuation of the optimization approach for short-term design of "green" products portfolio of three echelon "green" supply chain (GSC) of the production complex from the dairy industry. The approach takes into consideration three main subjects - products manufacturing, SC management and environmental impact. The latter involves environmental impact assessments of wastes produced along the chain and released in air and water. They are evaluated in terms of costs such as the best trade-off between environmental and economic performance of the designed green products portfolio to be achieved. The approach is extended by including additional environmental impact assessments for the CO_2 emissions produced during transportation of raw material and products when fleets with different payload capacity and fuel engines are used. The latter aims to show how this factor influences designing the optimal environmental dairy products portfolio and they can be used in the decision-making process.

5. **Vladova, R**., Kirilova, E., Vaklieva-Bancheva, N., "An approach for reduction of computational complexity of a two-stage stochastic optimization problem for capturing parameters uncertainty in an ATAD system". 50, Special Issue K, *Bulgarian Chemical Communications*, 2018, ISSN:0324-1130, 100-105. http://www.bcc.bas.bg/bcc_volumes/Volume_50_Special_K_2018/BCC-50-K-2018-100-105-Vladova.pdf

An approach for reduction of the computational complexity of a two-stage stochastic optimization problem for capturing parameters uncertainty in a conventional ATAD system is proposed in this study. The main aim is to find the boundary values of the variables of the first stage of the approach which will result in solutions into the boundaries of the stochastic space. The boundaries of variation of the first stage variables determine the variation of the parameters of the main equipment (heat exchangers surfaces and operating volumes of heat storage tank) which are affected by the change in stochastic parameters. The computational complexity is reduced as in any scenario vertex in the stochastic space a deterministic optimization problem is formulated and solved. As an optimization criterion, the minimum capital costs for purchase of heat exchangers and heat storage tank are used. For the purpose of the study, data from measurements in a real ATAD system were used. As a result of the deterministic optimization problems solution, the values of the parameters of main equipment corresponding to the minimum capital costs are determined. Based on these values the lower and the upper boundaries of the variables of the first stage of the approach are determined.

6. **Vladova, R**., Vaklieva-Bancheva, N., Kirilova, E., "Improving the energy efficiency of the ATAD system through redesign using integration superstructure". *Chemical Engineering Transactions,* Volume 70, 2018, ISSN:2283-9216; ISBN:978-88-95608-67-9, DOI:10.3303/CET1870171, 1021-1026. **SJR (Scopus): 0.273, Q3,** https://www.aidic.it/cet/18/70/171.pdf

The aim of this study is application of an approach for solution of two-stage stochastic optimization problem for design of heat-integrated Autothermal Thermophilic Aerobic Digestion (ATAD) bioreactors system for municipal wastewater treatment operating under uncertainties. It incorporates in a common superstructure of two models of heat integration with one heat storage tank and two heat storage tanks for storing the heat used for preheating the incoming into the ATAD system cold raw sludge. On the first stage of the approach heat exchanger networks areas and the volumes of the heat storage tanks are determined. On the second stage - the flows rates represented by respective heating and cooling times are determined. As an optimization criterion - the annual capital costs for needed for the purpose of redesign of the ATAD system equipment as heat exchangers, heat storage tanks and pumps is determined as well as operating costs related with energy consumption of used pumps. The optimization problem is solved using genetic algorithm. Implementation of the proposed approach results in reduction of the depth of the thermal shock and achievement of sustainability improvement of the ATAD system.

7. **Rayka Kirilova Vladova**, Natasha Grigorova Vaklieva-Bancheva., "Assessment of the Quality of the Treated Wastewater in Relation to the Amount of Electricity Consumed in WWTP". *Proceeding of University of Ruse*, 58, 10.2, 2019, ISSN:1311-3321, 88-93, https://conf.uni-ruse.bg/bg/docs/cp19/10.2/10.2-16.pdf

In recent years, environmental impact measures regarding the quality of treated wastewater have become increasingly stringent. This requires development and application of new technologies for the removal of the biological and chemical pollutants. However, realization of most of them is related to the large energy consumption. In order to improve their energy

efficiency all flows and processes in the wastewater treatment plants should be estimated. The purpose of this study is to provide information about the amounts of the wastewater treated on the territory of two municipal wastewater treatment plants in Southwestern Bulgaria, as well as their energy consumption per m^3 of treated wastewater. Moreover, an analysis of the raw and the treated wastewater in respect of BOD, COD, total content of N and P has been conducted. The amounts of energy consumed at each stage of the wastewater treatment plants have calculated. It has been found that the processes of biological wastewater treatment aeration have the greatest energy consumption.

8. Vaklieva-Bancheva, N., **Vladova, R.**, Kirilova, E., "Methodology for energy efficiency and sustainability improvement of batch production systems on the example of Autothermal Thermophilic Aerobic Digestion systems", *Journal of Ecological Engineering*, 20, 9, (2019), DOI:https://doi.org/10.12911/22998993/112501, 103-115, https://www.jeeng.net/Methodology-for-Energy-Efficiency-and-Sustainability-Improvement-of-Batch-Production,112501,0,2.html

The present study proposes a methodology for energy efficiency and sustainability improvement of the operating conditions of batch production systems. The methodology involves applying a conventional system for municipal wastewater treatment using the process of Autothermal Thermophilic Aerobic Digestion (ATAD) of sludge. Its sustainable operation is essential for the quality of the treated sludge and the reduction of environmental impact. An analysis of the possibilities for energy integration of processes in ATAD systems was performed. The structures for indirect energy integration of processes using storage tanks and mathematical models for describing energy integration for the studied object were proposed. The models are included within a two-stage stochastic optimization problem together with constraints on the physical, technical and technological feasibility of the integration frameworks and temperature constraints with an optimization criterion minimum redesign cost. The obtained results show significant energy savings as a result of energy integration and sustainability to temperature conditions in bioreactors.

9. Vaklieva-Bancheva, N., **Vladova, R.**, Kirilova, E., "Simulation of heat-integrated Autothermal Thermophilic Aerobic Digestion system operating under uncertainties through Artificial Neural Networks". *Chemical Engineering Transactions*, 76, Italian Association of Chemical Engineering, 2019, DOI: https://doi.org/10.3303/CET1976055, 325-330-330, https://www.aidic.it/cet/19/76/055.pdf

The aim of the study is verification of a stochastic optimization approach for redesign of heat-integrated two-stage Autothermal Thermophilic Aerobic Digestion (ATAD) bioreactors system for municipal wastewater treatment operating under uncertainties. It was implemented through simulation of the ATAD system operation using feed-forward Artificial Neural Networks (ANN) for bioreactors modelling of the both stages and heat integration model of ATAD system with one heat storage tank. For the simulation purpose the design parameters values of the heat integration equipment associated with the obtained optimal solution of the stochastic approach were used. The ANN models were applied for prediction of the thermal shock occurred in the first bioreactor stage at incoming of each new portion of raw sludge, the expected temperature

of the sludge at the end of the process and the volatile solids reduction at constant parameters of the inlet flows. They were included in two sequentially linked modules for simulation of the bioreactors operation. An appropriate data transfer between the modules, simulating the bioreactors and the Heat Integration module was provided. The simulation was carried out for two 15 d winter and summer periods. The simulation results have shown that applying the heat-integration of the process can lead to an increase in the temperatures of the inlet raw sludge about 6-8 °C and a decrease in the depth of thermal shock in both bioreactors about 5-7 °C. It also can provide higher and sustainable temperatures of the hot treated sludge at the end of the process which get much closer to the optimal of 55 °C for the first bioreactor and 65 °C for the second bioreactor and higher volatile solids reduction in both bioreactors about 1.5 wt.%.

10. **Vladova, R.**, Vaklieva-Bancheva, N., Kirilova, E., "Application of flexibility index approach for sustainable operation of heat-integrated Autothermal Thermophilic Aerobic Digestion system". *Chemical Engineering Transactions*, 76, 2019, DOI:https://doi.org/10.3303/CET1976056, 331-336. https://www.aidic.it/cet/19/76/056.pdf

The present study proposes a decision-making approach based on flexibility index calculation of already obtained solutions of a stochastic multi-scenario optimization model for redesign of heat-integrated two-stage Autothermal Thermophilic Aerobic Digestion (ATAD) bioreactors system for municipal wastewater treatment operating under uncertainties. Obtained solutions with minimal costs for redesign were presented in Vladova et al. (2018). Aiming to find the solution which provides sustainable operation of the heat-integrated ATAD system within the widest range of variation of its uncertain parameters, the Flexibility Index (FI) approach should be applied. A fast approach for evaluation of the flexibility index by presenting it as an inscribed a hyper-rectangle in the scaled hyper-space of variation of the uncertain parameters so as to ensure no violation of the process feasibility constraints is proposed. An optimization problem for determining the maximal flexibility index is formulated and solved for each solution obtained in Vladova et al. (2018). Decision making is carried out to choose most sustainable solutions for redesigned ATAD system. Analyzing the results obtained, it can be concluded that not always the solutions with the minimal annual costs for redesigning provide the sustainable operation of the ATAD system.

11. Kirilova, E., Vaklieva-Bancheva, N., **Vladova, R.,** Petrova, T. "Optimal products portfolio design of a sustainable supply chain using different recipes for dairy products production". *Chemical Engineering Transactions*, 81, Italian Association of Chemical Engineering, 2020, ISSN:2283-9216, DOI:https://doi.org/10.3303/CET2081011, 61-66, https://www.aidic.it/cet/20/81/011.pdf

This study proposes a deterministic optimization approach for products portfolio design of a Sustainable Supply Chain (SSC) comprising suppliers, plants and markets for production of dairy products using different recipes. It includes three interconnected models of the recipes used for the production of the dairy products, the SC design and the SC environmental impact. The latter is assessed in terms of wastewater and CO_2 emissions associated with the dairy production and the transportation. The models are included in an optimization working frame

along environmental and economic criteria. The proposed approach has been implemented on a case study from Bulgaria – for production of two types of curd at two recipes using two types of milk. Optimization problems have been formulated in terms of MINLP. They are solved at different imposed environmental pollution taxes on the dairies regarding both wastewater and CO_2 emissions. The optimal SC products portfolio for the production of the planned products is obtained satisfying the best trade-off between environmental and economic criteria.

12. Kirilova, E., **Vladova, R.**, Petrova, T., Vaklieva-Bancheva, N., "A sustainable dairy supply chain design taking into account the impact of production recipes and CO_2 emissions from the transportation". *Proceedings of 4th South East European Conference on Sustainable Development of Energy, Water and Environment System – SDEWES*, 2020, Sarajevo, Bosna and Herzegovina, DOI: Paper ID: SEE.SDEWES2020.0194, Archival paper

This study proposes an approach for optimal product portfolio design of a sustainable supply chain for dairy products. It uses two recipes. The approach includes mathematical models of recipes, supply chain design and supply chain environmental impact. The latter is assessed in terms of wastewater and CO_2 emissions associated with dairy production and the transportation of raw materials and products. Additional environmental impact assessments for the CO2 emissions produced during the transportation of raw materials and products when vehicles with different payload capacity and fuel engines are used. Multi-objective optimization problems are formulated with environmental and economic criterion defined in terms of costs. The approach was implemented on a case study from Bulgaria for the production of two types of dairy products, based on two recipes and using two different raw materials. The obtained results have clearly shown the influence of the choice of the types of production recipe and the vehicles used on the sustainable product portfolio design.

13. Kirilova, E., **Vladova, R.**, Vaklieva-Bancheva, N., "Heat integration of two-stage autothermal thermophilic aerobic digestion system for reducing the impact of uncertainty", *Energy*, 118329, 208, Elsevier, (2020), DOI:https://doi.org/10.1016/j.energy.2020.118329, https://ideas.repec.org/a/eee/energy/v208y2020ics0360544220314365.html

The operation of Autothermal Thermophilic Aerobic Digestion (ATAD) wastewater treatment systems is subjected to daily uncertainties regarding the parameters of the inlet streams, which lead to prolongation of the process and increase the energy consumption. This, together with the heat loss in the environment from the product tank, makes the ATAD system energy inefficient. Heat integration plays an important role in improving the sustainability of ATAD systems. In this study an approach for optimal redesign of heat integrated two-stage ATAD system operating under uncertainties is presented. It includes a two-stage stochastic optimization model for heat integration with an optimization criterion - the annual capital cost for redesign of the heat integrated system and its operating costs. Artificial Neural Network (ANN) models of the bioreactors are used for simulation of the system operation. They are combined with the heat integration model for the obtained with the stochastic approach values of design parameters of the heat integration equipment. The simulation results show a thermal

shock reduction of 5–6 °C, an increase of the inlet sludge temperature of 8–10 °C, achievement of close to normal operating temperatures in the ATAD system and reduction of solids in both bioreactors by about 2 wt%.

14. **Райка Владова**. Глава 7. Устойчиви системи за автотермално термофилно аеробно пречистване на утайки в битови отпадъчни води. "Устойчиви процеси, устойчиви системи, устойчива околна среда". Под редакцията на проф. д-р Н. Ваклиева-Банчева. *Издателство на БАН "Проф. Марин Дринов".,* 2020, ISBN:978-619-245-056-4, 185-215

In recent years, the environmental protection issues has attracted more and more public attention, which necessitates changes in legal and regulatory documents in the countries of the European Union, as well as on a global scale. One of these directions is reducing the amount of sludge deposited as a result of the treated domestic wastewater in the city treatment plants. Globally, the most significant regulation governing the production and management of biosolids is the United States Environmental Protection Agency (USEPA) 40 CFR Rule 503 (USEPA 1993). In the European Union, such a regulation is EC Directive 91/271/EEC (on urban wastewater), and secondary treatment is required for population equivalents of over 2,000 people. All this necessitates the development of new sustainable technologies and methods to meet environmental standards.

The main methods used to reduce and stabilize sludge in sewage treatment plants are anaerobic and aerobic. Anaerobic treatment is one of the oldest and most universal methods of urban wastewater treatment. Suitable for large agglomerates where a significant part of the methane can be utilized. Aerobic digestion is more suitable for medium and small treatment plants where anaerobic treatment is no longer economically viable. An example of such a technology is the Autothermal Thermophilic Aerobic Digestion (ATAD), where the end product is biofertilizer class A, which can be used for direct fertilization of agricultural areas.

This technology involves biodegradation (stabilization) of biomass with subsequent pasteurization. The process takes place in a batch mode of operation in two serially connected bioreactors, where the sludge is treated at different operating temperatures. The reduction of organic matter and the removal of pathogenic microorganisms are carried out with the help of thermophilic aerobic microorganisms having an exothermic metabolism. As a result of the biochemical oxidation of the organic substance, energy is released in the form of heat, which leads to an increase in the operating temperatures in the reactors, and hence to the killing of pathogenic microorganisms. In the first bioreactor, sludge stabilization takes place, with the best stabilization occurring at temperatures around 55 °C. While higher temperatures are required for pasteurization of organic matter, around 65 °C, this is also the desired operating temperature for the second stage reactors.

ATAD processes are temperature unstable. They are significantly affected by the change in the quantities, composition and temperatures of the incoming wastewater. The daily partial loading of the first bioreactor with raw sludge causes a sharp drop in the temperature in the bioreactor and induces a thermal shock (TSk) to the thermophilic microorganisms in the bioreactor. This, in turn, leads to a drop in the operating temperature in the first bioreactor, lengthening the

degradation process, increasing energy costs for aeration and stirring, and sometimes there is also a need for external heating of the system, because increasing the temperature by 1 degree costs thermophilic microorganisms about 2 hours of work. Therefore, reducing the operating time of thermophilic microorganisms in the mesophilic temperature range and pushing the temperature conditions into the thermophilic range would lead to more sustainable operating temperatures and increase the reaction rate of the process. All this would increase the energy efficiency of sludge treatment systems. To achieve them, the methodologies described in Chapters 3–6 are applied. The aim is to improve the energy efficiency of the batch system and to create sustainable operating temperatures through the energy integration of the processes in an ATAD system in the conditions of stochastically changing parameters of the relevant flows and to verify the obtained solutions using ANN modeling methods of the bioreactors.

15. Ivanov, B., Nikolova, D., Kirilova, E., Vaklieva-Bancheva, N., **Vladova, R**. "Optimal design of sustainable biodiesel supply chain using dairy waste scum as a feedstock generated from dairy supply chain". *Chemical Engineering Transactions*, 88, Italian Association of Chemical Engineering, 2021, ISSN:2283-9216, DOI:10.3303/CET2188096, 577-582, https://www.cetjournal.it/cet/21/88/096.pdf

The rapid depletion of fossil fuels and the increased environmental impact of their combustion make it necessary to find cleaner and more sustainable energy resources. Over the last decades, biodiesel has been introduced as an alternative because of its advantages over fossil fuels. However, the high production cost of biodiesel is one of the main obstacles to achieving its commercial viability. One way to improve the efficiency and sustainability of this process is to use Dairy Waste Scum (DWS), which is a waste product from the dairy industry as a feedstock. Selection of the feedstock used is only a part of the strategy to increase the sustainability of this type of production. The most effective way to achieve this is by optimising the activities across the supply chains (SCs). In addition, the sustainability of the biodiesel production process using DWS may be influenced by design of optimal product portfolio of the considered dairy SC. This study proposes an approach for optimal design of a sustainable combined dairy and biodiesel/diesel SC using dairy waste scum as a feedstock, generated from dairy SC. It is based on defining mixed integer linear programming (MILP) model of the optimal design of the considered combined SC. The latter includes economic and environmental assessments. The first one is defined as an optimization criterion while the second one is defined as a constraint. The model takes into account key SC activities such as infrastructure compatibility; the production of the dairy products; milk, dairy products and DWS transportation between the regions, carbon taxes, related with all SC activities. The environmental and economic performance of the combined dairy and biodiesel/diesel SC is assessed by the annual operating costs for the combined SC design and greenhouse gas (GHG) emissions of pollutants associated with its operation. The developed approach was implemented on a real case study from Bulgaria. The analysis of the environmental results shown that the total GHG emissions generated by the operation of the SC for all time intervals are mainly due to the production of the products in dairies and utilization of unused DWS for production of biodiesel.

16. Kirilova, E., Vaklieva-Bancheva, N., Petrova, T., **Vladova, R**., Varbanov, P., "A MINLP model to optimal design of a sustainable dairy supply chain taking into account

preferences of the network actors". *Chemical Engineering Transactions*, 88, Italian, Association of Chemical Engineering, 2021, ISSN:2283-9216, DOI:10.3303/CET2188174, 1045-1050**,** https://www.cetjournal.it/cet/21/88/174.pdf

The increase of pollutants generated in the production of dairy products, the increase of the production costs and emerging social problems requires the development of approaches for resilience improvement of the considered product productions. An effective way to achieve this is by optimising all activities across the supply chain: from milk suppliers through the production itself to end-users meeting environmental, economic and social criteria. The other important aspect of solving this type of problems is taking into account the preferences of all actors in the network. The present study proposes a mixed-integer non-linear programming (MINLP) model for the optimal design of a sustainable dairy supply chain (SC) for the production of different dairy products satisfying the preferences of all actors of the network - milk suppliers, dairies and markets. The approach includes models for the production of dairy products along with the economic, environmental and social impact of the considered SC. Three optimization problems are defined and solved at different optimisation criteria representing the preferences of all actors in the SC. The first solution results in the supply of 162,022 kg of two types of milk for the production of 61,758 kg of low and high-fat content products. The latter exceeds the market demands. This is the solution with the largest economic and social costs and lowest production profit of 118,008 BGN. The second solution is related to the production of 60,023 kg of both products. This is the solution with the lowest economic costs and largest production profit of 143,809 BGN. In solution 3, full satisfaction of market requirements was achieved. It is related to the supply of 132,146 kg of both types of milk for the production of 60,057 kg of both products.

17. Kirilova, E., **Vladova, R**., Vaklieva-Bancheva, N., "Chapter 28 - Multiscenario Approach for Capturing Uncertainties in Energy-Integrated Autothermal Thermophilic Aerobic Digestion Systems", *Soft Computing Techniques in Solid Waste and Wastewater Management*. Edited by Rama Rao Karri, Elsevier, USA, 2021, ISBN:978-0-12-824463-0, DOI:https://doi.org/10.1016/C2020-0-01696-8, 20, 469-489, https://www.sciencedirect.com/science/article/pii/B9780128244630000070

Autothermal Thermophilic Aerobic Digestion (ATAD) is a process for domestic wastewater treatment that produces class A biosolids—used as a fertilizer in agriculture. It carries out in parallel series of semibatch bioreactors at different operating temperatures. The process has a number of advantages, but its significant disadvantage is the presence of thermal shock (TSk) on thermophilic microorganisms when raw sludge incomes the system. The latter leads to an increase in the time required for restoring the normal operating temperatures in the system, and hence, the energy consumption for aeration and mixing. This phenomenon is also influenced by the uncertain stream parameters of the incoming raw sludge. One way to improve energy efficiency and sustainability is the application of heat integration to the ATAD process. This chapter presents an engineering approach for an optimal design of a heat-integrated ATAD system operating under uncertainties. It includes a superstructure of heat integration models with one and two heat storage tanks. The models are included in a two-stage stochastic optimization problem. Design variables related with the heat integration equipment and mass

flow rate are defined in both stages of the approach. The annual capital costs for the main and auxiliary equipment are used as an optimization criterion. The problem is solved using BASIC genetic algorithm with an original chromosome, representing a combination of both types of variables. A simulation of the operation of the ATAD system was then performed. For this purpose, artificial neural networks (ANNs) were used to model the bioreactors of the two stages as well as a model of heat integration of the ATAD system. ANN models of bioreactors were developed in order to predict the TSk, the maximum outlet temperature, and the volatile solids reduction at certain values for the parameters of inlet raw sludge. The simulation was carried out for 15-day winter and summer periods of the stream parameters for a real two-stage ATAD system. The simulation results show a TSk reduction of 5°C–6°C, an increase of the inlet sludge temperature of 8°C–10°C, the achievement of stable operating temperatures, and a reduction of the solids in the two bioreactors by about 2 wt.%.

18. **Vladova, R.,** Kirilova, E., Vaklieva-Bancheva, N., "Method for overcoming uncertainties and increasing resilience through heat integration of flows in batch production systems". *Автоматика и информатика, 1-2, Съюз по автоматика и информатика "Джон Атанасов"*, 2021, ISSN:ISSN 0861-7562 Print, ISSN 2683-1279 Online, 5-10, https://sai-bg.com/wp-content/uploads/2021/08/1.-Paper-1-R.Vladova-E.Kirilova-N.Vaklieva-Bancheva-pages-5-10-AI-1-2-2021.pdf

By definition, sustainable development is a way of using natural resources that aims to meet human needs while maintaining the natural balance with the environment, so that these needs can be met both now and for future generations. The creation of highly efficient technological processes, energy efficiency in every sphere of the economy and society, the production of energy from renewable energy sources, the economy of materials, the use of renewable natural resources, the development of green and eco-technologies, prevention of harmful waste; effective governance of the economy, society and the environment are part of the most important policies underlying the European Union's (EU) Sustainable Development Strategy. Creating energy efficient production systems involves less impact on the environment. One of the most powerful tools for creating this type of system is the integration of energy and mass processes. Process integration covers a wide range of system-oriented methods and approaches that are used in the design and reconstruction of industrial processes to obtain optimal use of resources. In recent years, the focus on energy integration of processes has shifted from the integration of processes in continuous systems to the integration in systems with batch processes. From the conducted researches it is clear that the production systems with batch processes have sufficient energy potential, which can be used to improve their energy efficiency. The recovery and use of this heat is complicated by the batch nature of the processes, and the task is further complicated by the impact of stochastically changing flow parameters such as temperature, volume, etc., overcoming which is a serious challenge to the sustainability of batch production systems. The aim of the present study is to propose a method for dealing with uncertainties and increasing resilience through heat integration of flows in periodic production systems. The method includes three main stages: 1. Uncertainty analysis and selection of a suitable scheme for energy integration of processes and its mathematical description; 2. Defining the problem of optimal redesign of an energy-integrated batch production system by incorporating the integration model within a stochastic optimization

problem and its solution; 3. Assessment and decision making to choose the most appropriate solution, whereby the production system is sustainable of the impact of the uncertain parameters in the widest borders, by defining the flexibility index.

19. Apostolov, A., Kirilova, E., **Vladova, R.**, Vaklieva-Bancheva, N., Rangelov, T. "Influence of geometry and mechanical load on the delamination in the graphene/ polymer nanocomposite under axial load". *Chemical Engineering Transactions*, 94, Italian Association of Chemical Engineering, 2022, ISSN:2283-9216, DOI:https://doi.org/10.3303/CET2294077, 463-468, https://www.cetjournal.it/cet/22/94/077.pdf

This paper presents a theoretical study on the influence of the geometry (layer thickness and length) and the magnitude of axially applied tension load on the delamination in a three-layer graphene/PMMA nanocomposite. Two different analytical solutions (Case 1 and Case 2) for the interface shear stress in the middle layer of the nanocomposite structure are obtained, based on the application of a two-dimensional stress-function method and minimization of the strain energy. The theoretical criterion for delamination in the interface layer, which is based on the model interface shear stress, is formulated. The obtained non-linear equation with respect to debond length is solved numerically, for both solutions, at different values of the mechanical load and geometry of the structure layers. For both solutions, it was found that the magnitude of the applied tension load influences strongly the appearance of delamination in the structure. For Case 1 (thinner PMMA layer) the delamination could be observed over 350 MPa external load; for Case 2 (thicker PMMA) it could be seen over 750 MPa. If the structure length decreases, under the above-mentioned conditions, the delamination begins at slightly lower values of the tension load. The magnitude of the applied load influences also the value of debond length. The obtained results could be used for fast prediction of safety intervals of applied loads and geometry design (without delamination) in similar nanocomposite devices to assure their safety working as sensors, nano- and optical electronic devices, energy devices, etc.

20. Dzhelil, Y., Ganev, E., Kirilova, E., **Vladova, R.,** "An approach for design and management of a supply chain for biodiesel production taking into account the uncertainties at two scenarios with different locations of the fuel blending centers". *International Scientific Journal Mathematical Modeling*, 6, 2, Scientific Technical Union of Mechanical Engineering "Industry-4.0", 2022, ISSN:2603-2929, 63-66, https://stumejournals.com/journals/mm/2022/6/63

This study proposes a mixed integer linear programming (MILP) approach to the design and management of the biodiesel / diesel (SC) supply chain. The approach was applied to two scenarios with different locations of the fuel blending centers. For both scenarios, optimization problems were formulated and solved while satisfying environmental and economic criteria. The latter are defined in terms of minimum total costs and minimum greenhouse gas emissions generated during the performance of all activities included in the supply chain. The approach was applied to a real case from Bulgaria, where its 27 administrative regions were considered. An analysis was carried out in terms of uncertainties regarding the obtained optimal routes for transportation of raw materials and products, the optimal quantities of feedstocks for cultivation

and optimal quantities of biodiesel produced, which is transported to the search areas under both scenarios.

21. Ivanov, B.**,** Nikolova, D., Kirilova, E**.**, **Vladova, R.**, "A MILP approach of optimal design of a sustainable combined dairy and biodiesel supply chain using dairy waste scum generated from dairy production". *Computers & Chemical Engineering*, 166, 107976, Elsevier, 2022, ISSN:0098-1354, DOI:https://doi.org/10.1016/j.compchemeng.2022. 107976, https://www.sciencedirect.com/science/article/pii/S0098135422003106

The present study proposes a mixed integer linear programming (MILP) approach for optimal design of a sustainable combined supply chain for the production of biodiesel using as a feedstock dairy waste scum generated from the implementation of optimal product portfolio of dairy supply chain. The latter includes models of economic and environmental impacts of the combined supply, constraints and an optimization criterion in terms of capital and operation costs. The environmental impact is assessed through greenhouse gas emissions obtained through whole life cycle of the products. The proposed approach is implemented on a real case study from Bulgaria. As a result, optimal operating conditions of the considered supply chain, which includes: dairy farms portfolios, dairy plants portfolios, production capacity and location of biorefineries that should be built, performance of biorefineries and transportation routes are obtained. It can be used as a tool for decision-making.

22. Kirilova, E., Vaklieva-Bancheva, N., **Vladova, R**., Petrova, T., Ivanov, B., Nikolova, D., Dzhelil, Y. "An approach for a sustainable decision-making in product portfolio design of dairy supply chain in terms of environmental, economic and social criteria". *Clean Technologies and Environmental Policy*, 24, Springer, 2022, DOI:https://doi.org/10.1007/s10098-021-02110-2, 213-227**,** https://link.springer.com/article/10.1007/s10098-021-02110-2

The production of dairy products is related to water and energy costs and generation of large amounts of emissions of pollutants. Full sustainability of these systems can be achieved by optimizing all activities in the supply chain (SC) taking into account not only the environmental and economic aspects, but also the social ones. This study proposes a multi-objective modeling approach for optimal design of three-echelon SC for production of dairy products according to different recipes while satisfying environmental, economic and social criteria defined in terms of costs. The environmental costs are associated with the generated wastewater from dairy production and CO_2 emissions due to energy consumed and transport of raw materials and products. The social ones are related to the employees hired for implementation of the SC activities. It was implemented on a real case study from Bulgaria. Four mix integer nonlinear programming optimization models were defined–one without and three with social impact consideration. They were solved at different values of the environmental and social constraints. The obtain results showed that stricter environmental constraints lead to higher economic costs and lower profit. Conversely, higher environmental constraints result in higher profit and lower economic costs. The greatest share in the environmental impact has the wastewater generated, followed by CO_2 emissions related with energy consumed and CO_2 emissions due to transport.

The obtained solutions can be used in the decision-making process in terms of seeking a trade-of between profit, environmental and social impact.

23. Kirilova, E., Vaklieva-Bancheva, N., **Vladova, R.**, Petrova, T., Nikolova, D., Ganev, E., Dzhelil, Y. "Impact of product demand uncertainties on the optimal design of a sustainable dairy supply chain: A case study of Bulgaria". *Chemical Engineering Transactions*, 94, Italian Association of Chemical Engineering, 2022, ISSN:2283-9216, DOI:https://doi.org/10.3303/CET2294091, 547-552, https://www.cetjournal.it/cet/22/94/091.pdf

Population growth and income, together with urbanization, have caused a significant increase in demand for dairy products. This creates opportunities for increasing the profit from dairy production, but on the other hand, it is associated with the generation of large amounts of pollutants that are released into the air and water and require costs for their treatment and disposal. The presence of fluctuations in the product demands in the markets also influences the sustainable operation of considered supply chain (SC) activities. This study proposes a robust optimisation approach for handling the uncertainty of product demands in a dairy SC to produce different dairy products according to different recipes while satisfying environmental and economic criteria. The latter is associated with the generated wastewater from dairy production and CO_2 emissions due to the energy consumed and transportation. The approach has been implemented in a real case study from Bulgaria. Deterministic and robust optimization problems have been formulated and solved under nominal data for the product demands and three different uncertainties levels – 0.2, 0.5 and 1. The obtained results show that the increase in the uncertainty level leads to decreasing profit from the dairy SC with a relatively small standard deviation. The lowest mean value of the SC profit of 232,882 BGN is obtained at the greatest uncertainty level of 1. The results for SC total costs show that they also do not change significantly with an increase in the uncertainty level. The largest value of 154,018 BGN has been obtained at an uncertainty level of 0.5. Given the latter, it can be said that the developed robust optimization model is a sustainable, which leads to obtaining results for the SC profit and costs that do not change significantly with an increase in the uncertainty level of consideration of product demands.

24. **Rayka Vladova**, Tatyana Petrova, Elisaveta Kirilova, Apostol Apostolov, Boyan Boyadjiev. "Comparison of the model axial graphene strain distributions in graphene/epoxy/polymethyl methacrylate (PMMA) nanocomposite under mechanical and thermomechanical loading". *Bulgarian Chemical Communications*, 54, 4, Bulgarian academy of sciences, 2022, ISSN:0324-1130, DOI:10.34049/bcc.54.4.5539, 349-354. http://www.bcc.bas.bg/bcc_volumes/Volume_54_Number_4_2022/bcc-54-4-2022-349-354-vladova-5539.pdf

The current report presents a theoretical study of the application of a two-dimensional stress-function method to analytically describe and compare the strains in graphene/epoxy/polymethyl methacrylate (PMMA) nanocomposite structure under three types of loading - mechanical, thermal and thermo-mechanical. Respectively, three model case solutions for all 2D strains in the nanocomposite layers at different cases of loading are developed, considered and compared

with each other to illustrate the temperature influence on the strains. All results for the behavior of the axial, peel and shear strains for all three layers of the structure are illustrated in figures and discussed.

The model axial strain in the graphene layer at two different mechanical external strains - 0.3% and 0.8%, was compared and validated with experimental data at mechanical loading. The obtained results could be used for fast prediction of strain distributions in similar nanocomposite devices as sensors, nano- and optical electronic devices, energy devices, etc., at different types of external loadings.

25. Tatyana Petrova, Elisaveta Kirilova, **Rayka Vladova**, Boyan Boyadjiev, Wilfried Becker, Petia Dineva-Vladikova. "Modelling and validation of the axial strain distribution in WS2 flakes at WS_2/Epoxy/PMMA nanocomposite under axial load". *U. Porto Journal of Engineering*, 8, 6, Faculdade de Engenharia da Universidade do Porto, 2022, ISSN:2183-6493, DOI:https://doi.org/10.24840/2183-6493_008.006_0011, 160-169, file:///C:/Users/Raika/Downloads/10_24840_2183-6493_008_006_0011-1.pdf

In the present study, a two-dimensional stress-function method is applied to model the axial strain distribution in the tungsten disulfide (WS_2) flake embedded in an epoxy/polymethyl methacrylate nanocomposite structure subjected to an axial tension load. The analytical model strain distribution along the flake is calculated and compared with experimental and shear-lag model literature data for monolayer flake at an external strain of 0.35% and 0.55%, as well as with results for few-layer flakes at an external strain of 0.55%. The comparison shows good agreement and confirms the applicability of our model method for describing strains in nanocomposite layered structures in the elastic region of applied loads. The presented method is not appropriate for few layers flake at an external strain of 0.55% because of the appearance of relaxation zone and the formation of wrinkles in the flake.

26. **Vladova, Rayka K.,** Vaklieva-Bancheva, Natasha. "Analysis of the Possibilities for Energy Recovery in WWTP". *Proceedings of 3th International Conference on Technologies & Business Models for Circular Economy: Conference Proceedings*, 2022, ISBN:978-961-286-598-6, DOI: https://doi.org/10.18690/um.fkkt.2.2022.10, 127-135, file:///C:/Users/Raika/Downloads/Analysis+of+the+Possibilities+for+Energy+Recovery+in+WWTP-2.pdf

In recent years, there has been increasing talk of improving energy efficiency and the ability to reduce greenhouse gases in wastewater treatment plants. This necessitates exploring the possibilities for reducing energy costs and the possibilities for obtaining energy from wastewater. In the present study, an analysis of the energy consumed at different stages of wastewater treatment in a municipal WWTP in the Republic of Bulgaria is made, and the average monthly consumption of electricity required for the treatment of one cubic meter of wastewater is estimated. Based on the collected and analyzed data, an assessment was made of the possibilities for energy recovery from dry matter from sludge, by combustion and anaerobic digestion. The obtained results allow for the reconstruction of a facility and the use of the hitherto unused energy potential contained in the sludge.

27. Elisaveta Kirilova, Tatyana Petrova, Natasha Vakleva-Bancheva, **Rayka Vladova**, Tsviatko Rangelov, Apostol Apostolov. "Theoretical study about influence of geometry and mechanical load on the delamination in tungsten disulfide/poly(methyl methacrylate) nanocomposite structure under axial load". *Procedia Structural Integrity*, 43, Elsevier, 2023, ISSN:2452-3216, DOI:10.1016/j.prostr.2022.12.272, 282-287, https://colab.ws/articles/10.1016%2Fj.prostr.2022.12.272

The influence of the geometry and the magnitude of axially applied mechanical load on the delamination in three-layer tungsten disulphide (WS_2)/SU-8/poly(methyl methacrylate) (PMMA) nanocomposite, is investigated theoretically. First, for considered nanostructures with thinner and thicker PMMA layer two different analytical solutions (Case 1 and Case 2) for the interface shear stress (ISS) in the middle layer of the structure are obtained, based on the application of two-dimensional stress-function method and minimization of the strain energy. Second, the theoretical criterion for delamination in the interface layer, based on the model ISS, is formulated and the obtained non-linear equation in respect to debond length is solved numerically, for both solutions, at different values of mechanical load and geometry of the structure layers. It was found that delamination doesn't appear at fixed WS_2 length of 10 μm, if the loading is up to 5 GPa for Case 1 and up to 1.175 GPa for Case 2, respectively. With increasing WS_2 length, the delamination occurs at increasingly higher values of the applied external load, for Case 2. For Case 1 a delamination is not occurs. At fixed applied load, it was found for Case 2, that as the length of WS_2 increases, the debonding length increases, too. The obtained results could be used for fast prediction of delamination in similar nanostructured devices.

28. Ganev E., Nikolova D., Dzhelil Y., **Vladova R**., "Sustainable strategy for design and management of biodiesel supply chains on a Bulgarian case study". *Proceedings of 62nd Annual Science Conference of Angel Kanchev University of Ruse and Union of Scientists – Ruse "New Industries, Digital Economy, Society - Projections of the Future VI"*, 62, 10.1, 2023, ISSN:2603-4123, 20-27, https://conf.uni-ruse.bg/bg/docs/cp23/10.1/10.1-4.pdf

This article examines the application of a mixed integer linear programming (MILP) mathematical model for optimal design and planning of the biodiesel supply chain within Bulgaria. Sunflower and rapeseed are used as raw materials for biodiesel production. The country is divided into twenty-seven regions corresponding to its districts. Existing crops in each region, oil processing and biodiesel production plants, as well as potential crops are represented as discrete variables in the model. The mathematical model is solved using GAMS software and is a comprehensive decision- making tool. The proposed strategy can also be applied to different time intervals as well as to different countries or regions by adjusting the necessary modeling data.

29. Petrova, T., **Vladova, R.**, Kirilova, E., "A robust optimisation model for the sustainable design of a dairy supply chain under uncertain environmental conditions". *Chemical Engineering Transactions*, 103, The Italian Association of Chemical Engineering, 2023, ISSN:2283-9216, DOI:10.3303/CET23103143, 853-858**,** https://www.cetjournal.it/cet/23/103/143.pdf

The production of dairy products in the relevant supply chains (SCs) is associated with the generation of significant amounts of pollutants in the wastewater and CO_2 emissions into the air, which released into the environment can cause a great risk of its pollution. The presence of uncertainties regarding the released amounts of pollutants further exacerbates the environmental problem. One of the ways to capture these uncertainties and control the environmental risk of pollution is by applying approaches to optimal design of sustainable supply chains operating under uncertainty conditions. The present study proposes a mixed integer non-linear programming approach to the optimal design of a sustainable SC for the production of two types of dairy products with a choice of technology, which includes models of economic, environmental and social impact as well as dairy production. The latter takes into account uncertainties regarding the environmental impact costs for treatment of the generated pollutants in terms of wastewater and CO_2 emissions related to the SC activities. The efficiency of the proposed approach has been proved in a real case from Bulgaria, which includes suppliers of two types of milk and dairy plants for the production of two types of dairy products and markets.

30. Tatyana Petrova, Elisaveta Kirilova, Wilfried Becker, Natasha Vaklieva-Bancheva, **Rayka Vladova**, Petia Dineva-Vladikova. "Modelling of the two-dimensional stresses in a three-layered adhesively bonded tungsten disulfide/poly(methyl methacrylate) nanocomposite structure under axial load". *Procedia Structural Integrity*, 43, Elsevier, 2023, ISSN:2452-3216, DOI:10.1016/j.prostr.2022.12.239, 83-88, https://www.sciencedirect.com/science/article/pii/S2452321622008022

For the first time a two-dimensional stress-function method describing the stress transfer in a three-layered adhesively bonded tungsten disulfide/poly(methyl methacrylate) nanocomposite structure, subjected to axial load has been developed and applied. The governing fourth-order ordinary differential equation of with constant coefficients for the axial stress in the first layer has been obtained minimizing the strain energy in the whole structure and solved analytically. Depending of the sign of the discriminant of the respective characteristic equation of the 4th order differential equation for the considered nanocomposite structure, two different analytical solutions have been obtained for axial stress in the first layer. The type of solutions depends strongly from the geometry (length and thickness of the layers), material properties and magnitude of applied load. The two-dimensional stresses (axial, shear and peel) in the structure's layers are expressed and calculated as functions of this axial one and its derivatives and illustrated with three-dimensional graphics, for both solutions. The model results for axial stress in tungsten disulfide (WS_2) were compared with shear–lag results and show good agreement in elastic region of applied tension load.

31. **Vladova, R.**, Kirilova, E., Petrova, T., Kirilov, K. "A Sustainable Multi-Objective Optimization Model for Design of Supply Chain Under Uncertain Products Demands and Products Prices: a Real Case of Dairy Industry". *Chemical Engineering Transactions*, 105, The Italian Association of Chemical Engineering, 2023, ISSN:2283-9216, DOI:10.3303/CET23105065, 385-390, https://www.cetjournal.it/cet/23/105/065.pdf

Dairy production has a significant environmental impact related with wastewater and air pollution. In addition, it is a large consumer of water and energy. The most effective way to improve its sustainability is through analysis of the food-water-energy nexus, which can be done by optimizing all activities in the supply chain (SC) from the raw materials to the end user while meeting environmental, economic and social criteria. However, the presence of uncertainties regarding the main parameters of the SC would lead to problems related to the implementation of processes and the operating the system as a whole. To solve these problems an implementation of models for optimal design of dairy SCs that handle these uncertainties is needed. The present study proposes an extended version of already developed mixed integer non-linear programming (MINLP) approach to optimal design of a sustainable SC for the production of different dairy products according different recipes under uncertain products demands and products prices. The model has taken into account economic, environmental and social aspects. The obtained results show that the increase in the uncertainty level leads to an increase of values of economic, environmental and social costs as well as the profit, with the standard deviation of the same being the highest at the lowest level of uncertainty, while at the others it is preserved relatively constant. The number of workers employed by the supply centers, dairies and markets is kept constant regardless of the variation in the level of uncertainty of products demands and products prices.

32. **Vladova, R.**, Petrova, T., Nikolova, D., Kirilova, E., Kirilov, K., "Robust Optimization of Sustainable Dairy Supply Chain with Products Demands Uncertainty and Environmental Impact Consideration". *Chemical Engineering Transactions*, 105, The Italian Association of Chemical Engineering, 2023, ISSN:2283-9216, DOI:10.3303/CET23105064, 379-384, https://www.cetjournal.it/cet/23/105/064.pdf

Milk and milk products are an important part of the daily menu of millions of people around the world. Increasing the efficiency and competitiveness of this type of production is related to the implementation of the strategy of sustainable management of supply chains, which cover all processes from raw materials, through production to end users. The presence of fluctuations in the product demands on the markets also influences the sustainable operation of considered supply chain activities. The present study proposes an application of already developed robust optimization approach for optimal design of a sustainable dairy supply chain operating under uncertain products demands on a new case study from Bulgaria which include three milk suppliers, two dairies and three markets. The considered supply chain is related with a production of different dairy products according to different recipes while satisfying environmental and economic criteria defined in terms of costs. The latter is associated with the generated wastewater from dairy production and CO_2 emissions due to the energy consumed

and transportation. Several optimization problems have been formulated and solved under nominal data for the product demands and four uncertainties levels - 0.25, 0.5, 0.75 and 1.
The obtained optimal values of the economic and environmental costs show that the optimization approach implementation results in sustainable solutions that do not change significantly with an increase in the uncertainty level of consideration of the product demands.

33. Apostol Apostolov, Tatyana Petrova, Elisaveta Kirilova, **Rayka Vladova**, Boyan Boyadjiev. "Analysis of parameters influencing delamination in thermo-mechanically loaded graphene/polymer layered nanocomposites". 2024, *25th International Conference on Thermal, Mechanical and Multi-Physics Simulation and Experiments in Microelectronics and Microsystems (EuroSimE),* 2024, DOI:10.1109/EuroSimE60745.2024.10491498,https://ieeexplore.ieee.org/document/10491498

The aim of this work is to predict analytically and determine the factors, influencing the interface delamination in layered graphene-polymer nanocomposite structures, subjected to external static thermo-mechanical loading. A 2D analytical modeling (stress-function variational method) of interface shear stress in 3-layered nanocomposites, subjected to thermomechanical loading, is used. The criterion for the model interface delamination in the structure is defined and solved. The parametric analysis of the factors, influencing interface delamination, has been performed and investigated for 3 case studies of combine loaded graphene-polymer nanocomposites: graphene/SU-8/PMMA, graphene/SU-8/PET, and graphene/MoS_2/PET. The considerable main factors are geometry characteristics of the nanocomposite structure and magnitude and type of external loading. The expected results will serve as a fast prognosis tool in the future experimental and model research on the graphene-polymer nanocomposite behaviour.