R E V I E W

for the competition for the academic position
"Associate Professor"
in the Professional Field 4.5 Mathematics

Scientific specialty
"Mathematical Modelling and Application of Mathematics"
(Mathematical Biology),

for the needs of the Institute of Mathematics and Informatics-BAS,

announced in Newspaper of State, No. 14 of February 10, 2023 and on the WEB page of the Institute of Mathematics and Informatics - BAS

The review is written by Prof. DSc Mikhail Ivanov Krastanov from the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences as a member of the Scientific Jury for the competition according to order № 184/7.04.2023 of the Director of the Institute of Mathematics and Informatics - BAS.

The only applicant who has applied for the position is

Dr Milen Kolev Borisov

from the Department "Mathematical modelling and numerical analysis" of the Institute of Mathematics and Informatics - BAS.

1 General description of the presented materials

The documents submitted by the candidate for the competition correspond to the requirements of the Law on the Development of the Academic Staff of the Republic of Bulgaria, Regulations for the implementation of the Law on the development of the academic staff in the Republic of Bulgaria, the Regulations on the terms and conditions for acquiring scientific degrees and for employment at academic positions at the Bulgarian Academy of Sciences and the Regulations on the terms and conditions for acquisition of scientific degrees and for employment at academic positions at the Institute of Mathematics and Informatics - BAS. To participate in the competition Dr. Milen Kolev Borisov submitted eleven of his papers published in foreign and Bulgarian scientific journals. Moreover, nineteen other documents are also presented. The submitted documents include: a request to the Director of IMI-BAN for admission to the competition; professional CV using European pattern; diploma for an acquired

educational degree "master"; diploma for an acquired educational and scientific degree "doctor"; certificate of internship in the specialty according to the requirements of art. 24 para. 1 item 2 of the LDASRB; general list of all publications; a list of the publications with which he participated in the competition; a hand-signed reference to the original scientific contributions in the papers proposed for participation in the competition; publication summaries for participation in the competition in Bulgarian and in English; reference from the "Sonix" system for reporting scientific and expert activity in BAS; copies of all publications with which he participated in the competition; common list of citations; list of citations for participation in the competition; Newspaper of State with the announcement of the competition; sample reference for fulfillment of the minimal national requirements under Art. 2b, paragraph 2 i 3, and the requirements under Art. 2b, para. 5 of LDASRB, as well as of the minimal requirements of IMI-BAN to which he applies the necessary evidence; proof of acceptance for publication of a paper; reference to summary information about the applicant; declaration that the publications, citations and other evidence on the various indicators in the reference for the fulfillment of the minimum requirements under this competition are not used to acquire the educational and scientific degree "doctor"(art. 24, para. 1, item 3 of LDASRB). All documents are well-formed and presented in a form convenient for work with them. The author reference of the presented results is comprehensive and correctly reflects the scientific contributions in the papers presented in this competition.

2 Biographical data for the applicant

Dr. Milen Kolev Borisov completed his higher education in the Faculty of Mathematics and Informatics of SU “St. Clement Ohridski” in 2008 as a Master of Bio- and Medical informatics. Since December 2008, he has been a PhD student at the Institute of mathematics and informatics at BAS with supervisor Prof. Dr Neli Dimitrova. In May 2013, he successfully defended his dissertation "Research of food chains in hemostat: sustainability and bifurcation of equilibrium points”. Since March 2020, and up to now he is chief assistant at the Institute of Mathematics and Informatics at the BAS.

3 General description of scientific works and achievements of the applicant

Dr. Milen Kolev Borisov participated in the current competition with eleven papers in peer-reviewed scientific journals, ten of which are already published, and the last paper is accepted for publication (the applicant has provided a proof of this). Seven of the papers are in journals with impact factor, two in journals with impact rank and two have been published in Bulgarian scientific journals.

More details:

1. The paper [5] was published in the International Journal of Robust and Nonlinear Control, which had an impact factor of IF 4.406/ 2020 and is in the first quartile Q1 of the Automation & Control systems group.

2. The paper [2] is published in Mathematical Methods in the Applied Sciences, which had an impact factor of IF 1.533 / 2018 and is in the second quartile Q2 of the group Applied Mathematics.

3. The paper [8] was published in the Journal of Mathematical Chemistry, which had an impact factor of IF 2.413 / 2021 and is in the second quartile Q2 of the group Mathematics, interdisciplinary application.

4. The paper [9] was published in Water, which had an impact factor of IF 3.530 / 2021 and is in the second quartile Q2 of the group Water resources.

5. The paper [10] is published in Processes, which had an impact factor of IF 3.352/ 2021 and is in the second quartile Q2 of the group Chemical engineering.

6. The paper [3] was published in the Bulletin of Mathematical Biology, which had an impact factor of IF 1.812/ 2019 and is in the third quartile Q3 of the group Biology.

7. The paper [6] is published in Processes, which had an impact factor of IF 2.847/ 2020 and is in the third quartile Q3 of the group Chemical engineering.

8. The paper [4] is published in Lecture Notes in Computer Science, which had an impact rank of 0.427 /2019.

9. The paper [11] had been accepted for publication in Lecture Notes in Computer sciences, which had an impact rank of 0.407 /2021;

10. The paper [1] was published in the Bulgarian magazine Serdica Journal of Computing, which is published by IMI and referenced in Zentralblatt;

11. The paper [7] was published in the Bulgarian magazine Journal of ecological engineering and environmental protection, which is published by the National Society for Environmental Engineering and Environmental Protection.

The papers included in the competition were published during the period 2017-2023 and are on the subject of the competition, therefore I accept them for review. I should note that the applicant has declared. that the scientific works presented by him for

participation in the competition are not used in the previous procedure in which he acquired the educational and scientific degree "doctor".

It is noteworthy to mention that all presented papers by Dr. Borisov are co-authored with various colleagues. I am sure that the participation of Dr. Borisov in the joint papers is essential, but he has not clearly declared what is the contribution of each of the authors.

It is not known of proven plagiarism in the papers included in the competition.

In the table below, it can be seen that the scientific works correspond to the minimal national requirements (according to Art. 2b, paras. 2 and 3 of the LDASRB) and respectively of the additional requirements of the Institute of Mathematics at BAS for occupying the academic "Associate Professor" position in the scientific field and professional direction of the competition.

Group	**А papers PhD**	**В Hab. Thesis**	**Г papers**	**Д references**	**Е participation projects**
Minimal number of points	50	100	220	70	20
Achieved number of points	50	100	232	192	63.6

4 Analysis of the scientific and scientific-applied achievements of the applicant contained in the materials for participation in the competition

I will briefly describe the main results contained in the applicant's presented papers, as well as my assessment of them. In the reference for his scientific contributions, the applicant has divided his publications in three groups: 1. Mathematical modelling of continuous bioreactors; 2. Reaction networks and applications in biomathematics; 3. Mathematical epidemiology. The following subgroups are within the first group: 1.1 Models of continuous bioreactors for wastewater treatment; 1.2. Models of continuous bioreactors for methane production; 1.3 Models of continuous bioreactors for methane production and hydrogen.

1. **Mathematical modelling of continuous bioreactors**

   Different models in continuous processes in bioreactors are considered. They are described by nonlinear systems of ordinary differential equations. There are

studied mathematical problems related to existence and uniqueness of positive solutions of the respective ODE systems, to finding invariant sets, to calculation of equilibrium points of the model and to study the asymptotic stability as well as bifurcations at the equilibrium points with respect to the parameters of the model, to stabilizability of the dynamics by using appropriate feedbacks to certain equilibrium points (for example, to an equilibrium point where the yield of methane is maximal or to an equilibrium point corresponding to certain environmental norms and others). A serious requirement is the closed feedback to depend only on quantities measurable in real time and to be robust with respect to model parameter inaccuracies. Different modern techniques of dynamical systems theory are used to solve these tasks.

1.1 Continuous bioreactor models for wastewater treatment.

In this subgroup are the papers numbered [9] and [10]. In [9] it is considered a three-dimensional model of a biological waste treatment process of water contaminated with a mixture of phenol and 4-methylphenol flowing in a continuous bioreactor. Typical for this model is that the specific growth rate of microorganisms is of the SKIP (Sum Kinetics with Interaction Parameters) type with an inhibitory effect that accounts for the influence of a single pollutant on the process of biological degradation of the other pollutant. To account the delay in the complete conversion of the consumed substrate in viable biomass, a time delay is introduced in the biomass differential equation. The equilibrium points of the model are determined, their local stability is proven, as well as the existence of local Hopf bifurcations with respect to the delay τ. Global asymptotic stability has also been demonstrated for the trajectories of the model depending on the parameter values of the delay. Appropriate numerical simulations illustrate the obtained theoretical results.

In [10], it is considered a three-dimensional model of biological degradation of mixture of phenol and sodium salicylate in wastewater. Equilibrium points of the model are determined: one internal (survival point) and one limit (washout point) – depending on the values of the dilution rate D. They are shown to be locally asymptotically stable. It is also studied the dependence of the global asymptotic stability with respect to the dilution rate. The theoretical results are illustrated by appropriate numerical simulations.

1.2 Continuous bioreactor models for methane production

In [1] it is considered a four-dimensional nonlinear functional-differential model of anaerobic process of degradation and treatment of waste water. Two different discrete time delays are included in the biomass differential equations. The equilibrium points of the model points are determined. It is shown that they are locally asymptotically stable. Under suitable conditions, it is also proven global

asymptotic stability. It is proposed a stabilization algorithm for the model to an equilibrium point where the biogas yield is maximal. Appropriate numerical simulations are also presented.

In [4], it is considered a two-dimensional functional-differential model of bioreactor describing an anaerobic fermentation process for biological degradation of organic waste with methane production. The delay has been added to account the delay in time of real on-line measurements. For a predetermined equilibrium point it is constructed appropriate feedback. The local asymptotic stability of the obtained "closed-loop system" at this point is studied, as well as the appearance of local Hopf bifurcations depending on the delay values. It is established the existence of positively invariant neighborhood of the equilibrium point such that the closed-loop system trajectories reach this set for finite time and remain in it forever if the parameter values of the delay is small enough.

In [5], as in [4], it is considered the same two-dimensional functionally-differential model of a bioreactor describing anaerobic fermentation process for biological degradation of organic waste with biogas production. For a fixed in advance equilibrium point it is constructed a piece-wise constant feedback control. Under suitable assumptions, it is proved that the obtained closed-loop system is asymptotically stable. An algorithm is proposed to stabilize the model to an equilibrium point where the yield of biogas is maximal. Numerical simulations illustrate the obtained results.

1.3 Models of continuous bioreactors for methane and hydrogen production

In [6], it is considered a new ten-dimensional mathematical model describing biotechnological process occurring in two continuously connected bioreactors for two-phase anaerobic biodegradation (ABD) with obtaining hydrogen (through the first phase occurring in the first bioreactor) and methane (during the second phase occurring in the second bioreactor). It is proved the existence of a unique uniformly bounded positive solution of this model defined on the interval $[0, +\infty)$. Under suitable conditions, it is proved the existence of two non-trivial equilibrium points which are locally asymptotically stable. It is established that transcritical bifurcation appears for a certain value of parameter D_1. The equilibrium points in which the yield of methane and hydrogen is maximal are also determined. Simulations results on the behavior of the model for different parameter values are presented too.

In [7], it is considered a 21-dimensional mathematical model describing biotechnological process occurring in two continuously connected bioreactors. This model is more precise than the model described in [6]. It is assumed that in the first bioreactor (as a result of hydrolysis and acidogenesis) acetate, butyrate, propionate and valerate are produced. In the second bioreactor, they are transformed by

the corresponding microorganisms to acetate, which in turn is transformed by methanogenic microorganisms to methane. Appropriate numerical simulations provide insight into the dynamics of the model,

2. **Reaction networks and applications in biomathematics**

   In the papers [2], [8] and [11] the law of mass action kinetics is used for modelling different bioprocesses of growth. The dynamic growth patterns are usually formulated using a simple system of ordinary differential equations. In many cases, to obtain such an ODE system, it is used a reaction scheme based on the law of mass action kinetics. This is how, for example, the Verhulst logistic model is obtained. For the Gompertz model, such reaction scheme is not known. The paper [2] suggests two new autocatalytic reaction schemes that lead to two new growth models (denoted VM and VSM), which are close in some sense to the Gompertz model. The so-called G-property is introduced. It is shown that the Gompertz model as well as the new two models have this property. Numerical simulations illustrate the dynamics of the VM model, the VSM model and the Gompertz model.

   In [8], there are studied in details (in the sense of monotonicity, asymptotes, extreme points, inflection points and others) the solutions of a dynamic system of three ODEs (2SED model), which corresponds to a two-step exponential decay reaction scheme. It is studied the dependence of the solutions regarding changes of system parameters. This model is then compared with the classical SIR model. The conclusion of this comparison is that the 2SED the model is suitable for modeling epidemics associated with the spread of diseases, the cause of which is in the infected environment (e.g. water or air), while the classical SIR model is appropriate in epidemics where contagion occurs through individual contacts between healthy and infected individuals. The comparative analysis made has led to the creation of a new epidemiological model (called the G-SIR model) obtained by substituting the logistic contact mechanism (type person-to-person) in the SIR model with a catalytic contact mechanism of Gomperts type. As a result of comparing the G-SIR model with the SIR model and with 2SED model it turns out that the G-SIR model is suitable for describing the epidemics in which infection can also occur through individuals contacts, and through the infected environment.

   In [11], the problem of 2SED model identification is considered using a large number of experimental data. It is assumed that this data can be numbers or intervals, i.e. we have a known uncertainty in the data in the second case. In both cases there are proposed numerical algorithms based on least squares estimation. Numerical simulations illustrate the proposed approach.

3. **Mathematical Epidemiology**

In [3], two dynamic models of immune response were proposed at dengue infection in which recently obtained experimental data imply different types of dengue virions that are produced in infected human cells. The first is an eight-dimensional model for primary infection with dengue, when the human body lacks antibodies, and the second is an eleven-dimensional model for secondary dengue infection. Within this model the existing antibodies can interact with the immature virions, in which case there are observed a more serious course of the disease. The basic reproductive number is determined in both infection scenarios. Different numerical simulations provide insight into the immune response at primary and secondary dengue infection for different values of the parameters.

5 Significance of the contributions to the science and to the practice

The obtained results in the research papers presented by the applicant in this competition, are interesting and meaningful. They contain new facts about known models previously studied by different authors, as well as for new models that appear in a natural way in some growth bioprocesses as well as in one immune response process in dengue fever.

6 Critical remarks and recommendations

I think that the applicant should outline more specifically and in more details his own contributions! He should highlight what kind of difficulties has overcome in the creation of the various software applications for the numerical simulations in the presented papers.

7 Personal impressions about the applicant

I have known Dr. Milen Kolev Borisov for 15 years and had the opportunity to watch his growth as a researcher. He always impressed me with the precise software applications he made, which provide invaluable assistance for the study of the relevant mathematical problems. In the papers [6] and [10] there are explicitly stated the contributions of Dr. Borisov: development of a suitable software written in Python for simulations and visualizations using the WEB-based platform SMOWEB (see http://platform.sysmoltd.com/). Very rare is this combination of a wonderful programmer who at the same time well understands the essence of the researched mathematical problem. This explains why Borisov is sought after as a co-author by many colleagues and has a well-deserved authority in the "Mathematical Modeling and Numerical Analysis"section.

8 Conclusion

After getting acquainted with the materials presented in the competition and scientific papers and based on the analysis of their significance and contained in them scientific contributions, **I confirm** that the scientific achievements meet the requirements of the Law on the Development of the Academic Staff of the Republic of Bulgaria for the academic position "Associate professor" in the scientific field and professional direction of the competition, as well as the Regulations for its application, the Regulations on the terms and conditions for acquiring scientific degrees and for employment at academic positions at BAS and the Regulations on the terms and conditions for acquisition of scientific degrees and for employment at academic positions at the Institute of Mathematics and Informatics - BAS. In particular the candidate satisfies the minimum national requirements in the professional direction and no plagiarism was found in the scientific works submitted for the competition. I give my **positive** evaluation to the application.

Based on the above, I **recommend** the scientific jury to propose to the Scientific Council of the Institute of Mathematics and informatics at the BAS to choose Dr. Milen Kolev Borisov to occupy the academic position of **"Associate Professor"** in professional direction 4.5 Mathematics "Mathematical modeling and application of mathematics" (Mathematical Biology).

25.05.2023 г.
Sofia

Signature:

/prof. DSc Mikhail Ivanov Krastanov/