REVIEW

on a competition for taking the academic position of **Professor** in Professional Field 4.2 "Chemical Sciences", Scientific Specialty "Processes and Apparatus in Chemical and Biochemical Technology" for the needs of the Institute of Chemical Engineering (IChE) at the Bulgarian Academy of Sciences (BAS) with a sole candidate Assoc. Prof. Dr. Elena Nikolaeva Razkazova-Velkova.
The competition was announced in the *State Gazette*, issue 77 of 10th September 2024, and on the website of the IChE-BAS.
Reviewer: Prof. Dr. Svetlana Georgieva Bratkova, University of Mining and Geology "St. Ivan Rilski".

1. General information about the candidate

The candidate was born on 18th January 1972. She is a graduate of the University of Chemical Technology and Metallurgy - Sofia, taking a degree in the specialty of *Engineering Chemistry* in 1995. She defended her doctoral thesis on the topic of "Creation of Packings for Column Apparatus for Operation at Extremely Low Liquid Superficial Velocity" at the Institute of Chemical Engineering - Bulgarian Academy of Sciences in 2006. During the period 1999 - 2012, she worked at the Institute of Chemical Engineering - BAS, successively holding the positions of Assistant Professor (research assistant III and II degree), and Chief Assistant Professor (research assistant I degree). Since 2012, she has been an Associate Professor at the same institute in the specialty of "Processes and Apparatus in Chemical and Biochemical Technology".

2. General description of the submitted materials

The candidate in the competition for the academic position of *"Professor"* Assoc. Prof. Dr. Elena Razkazova-Velkova has submitted all the necessary documents in accordance with the Regulations on the terms and procedures for holding academic positions at the BAS and Regulations for the implementation of the Academic Staff Development Act in the Republic of Bulgaria.
The coverage of the minimum national requirements for candidates for the scientific position of "Professor" by groups of indicators is as follows:

Indicator A: Diploma № 30491 of 22nd May 2006 awarded for the academic and scientific degree of "Doctor" (50 points).
Indicator V: Habilitation work – scientific publications in editions which are referenced and indexed in world-renowned databases of scientific information (Web of Science и

Scopus) (100 points). Eight publications (P1, P2, P3, P4, P5, P6, P7 and P8) are presented, which meet the requirement of 100 points.

Indicators G:

• **G7** Scientific publications in editions which are referenced and indexed in world-renowned databases of scientific information (Web of Science and Scopus), apart from the habilitation work (min. 220 points). Evidence for 14 scientific publications is presented (219 pts).

• **G8** Published chapter from a book or a collective monograph. One item is presented (15 pts).

• **G9** An invention, patent or useful model for which a protection document is issued under the due procedure. Two patents are filed (50 pts).

In accordance with the indicators from group G, the candidate collects 284 pts (min. 220 points).

Indicators D: Citations in scientific editions, monographs, collective volumes, and patents which are referenced and indexed in world-renowned databases of scientific information (Web of Science and Scopus) (min. 120 points). 62 citations of 21 papers are presented (124 pts). The proof part provides bibliographical data for the citing publication with a reference to the relevant database.

Indicators E:

• **E13** Advisorship of doctoral students who have successfully defended their theses (*n* is the number of co-supervisors of the respective doctoral student). Reference is given for one defended doctoral student (25 pts).

• **E14** Participation in a national scientific or educational project. Evidence for 2 such projects has been presented (20 pts).

• **E15** Participation in an international scientific or educational project. The candidate has participated in one international project (20 pts).

• **E16** Management of a national scientific or educational project. Evidence for 2 such projects has been presented (40 pts).

•**E18** External funding under projects managed by the candidate. Reference on funds raised for three projects is given (67 pts).

In accordance with the indicators from group E, the candidate covers 162 points (min. 150 pts).

The scientometric indicators of the candidate cover the minimum requirements for holding the academic position of *"Professor"* in professional fields (Table 1) under both the Regulations on the terms and procedures for holding academic positions at the BAS and the Regulations for the implementation of the Academic Staff Development Act in the Republic of Bulgaria.

Table 1. Indicator group *Minimum number of points* and *Number of points* of the candidate

Group of Indicators	Minimum points	Points of the candidate
A	50	50
B	-	-
V	100	100
G	220	284
D	120	124
E	150	162
Total	640	736

3. General characteristics and evaluation of the candidate's works

The scientific publications with which the candidate participates in the competition are in the professional field in which the competition was announced. Assoc. Prof. Dr. Razkazova-Velkova's research activities are in four main areas: 1. column apparatus with highly efficient metal packing; 2. decontamination of gases from sulphur dioxide; 3. research on catalysts and electrocatalysts; 4. design of fuel elements with an environmental focus for the disposal of various pollutants.

Area of scientific research 1. Studies related to packed columns. A total of 2 items is presented: The two publications (V - P5 and G - P7) were published in the journal of *Bulgarian Chemical Communications*, respectively in 2015 SJR (Scopus):0.153 (**Q4**) and 2020, SJR (Scopus):0.179 (**Q4**).

Area of scientific research 2. Decontamination of gases from sulphur dioxide. A total of 4 items is presented: The first article (V - P2) was published in the *Journal of Chemical Technology and Metallurgy*, 2013, SJR (Scopus):0.170 (**Q3**). The second paper (G - P9) was published in the journal of *Bulgarian Chemical Communications*, 2020, SJR (Scopus):0.179 (**Q4**). The third publication (G - P12) is in the journal of *Sustainability*, 2024, SJR (Scopus):0.664 (**Q1** does not top the rankings), and the fourth (G - P14) is in *E3S Web of Conferences*, 2024, SJR (Scopus):0.18.

Area of scientific research 3. Research on catalysts and electrocatalysts. The results of the candidate's research activities in this area are presented in 9 scientific papers and 1 patent. Research on the photocatalytic oxidation of a model azo dye pollutant with TiO_2 incorporated on activated carbon is reported in a paper (V - P3) published in the *Central European Journal of Chemistry*, 2013, JCR-IF (Web of Science):1.329 **Q2** (Web of Science). Four papers focus on studying the catalytic efficiency of metal oxides (Co_3O_4, Mn_3O_4, Fe_2O_3, ZrO_2) incorporated onto activated carbon: Three papers (V - P1, V - P4, and G - P1) were published in the *Journal of Chemical Technology and Metallurgy*, one in 2013 and two in 2014, respectively SJR (Scopus):0.168 (**Q3**) and SJR (Scopus):0.166. The fourth paper was published in *Bulgarian Chemical Communications*, 2020. SJR

(Scopus):0.179 (**Q4**). There are two scientific papers related to the application of catalysts (DG (standard Degussa carbon black), cobalt phthalocyanine, perovskite, graphite, and Pt) individually or in combination in the removal of sulphur dioxide and hydrogen sulphide: (V – P6) and (G – P2) published respectively in *Bulgarian Chemical Communications*, 2015, SJR (Scopus):0.153 (Q4) and in *International Journal of Electrochemistry*, 2016, JIF 2.3. In this area, patent for invention No. 66997B1 – Method for separating hydrogen sulphide and sulphur dioxide from fluids has also been presented. Two papers (V – P8 and G – P12) related to the use of electrocatalysts based on manganese deposited on fullerenes and carbon nanotubes have been published, respectively in *Bulgarian Chemical Communications*, 2015, SJR (Scopus):0.153 (**Q4**) and in *Catalysts*, 2022 г., JCR-IF (Web of Science):4.501 **Q2** (Web of Science).

Area of scientific research 4. Design of fuel elements with an environmental focus for the disposal of various pollutants. In this area, 7 scientific papers are presented which can be divided into three groups:

Fuel cells based on the sulphide/air system, Three publications are presented on the topic (G – P3 and P10, and V – P7), published in *Applied Sciences*, 2018, SJR (Scopus):0.315, JCR-IF (Web of Science):1.689, **Q1,** does not top the rankings (Scopus); in *Catalysts*, 2021, JCR-IF (Web of Science):3.52 **Q2** (Web of Science); and in *Bulgarian Chemical Communications, 2015,* SJR (Scopus):0,153 (**Q4**), respectively. Patent No. 66721 of 7th August 2018 – Method for oxidation of hydrogen sulphide and sulphide ions in fuel cells is also presented.

Fuel cells for simultaneous oxidation of sulphides and reduction of nitrates. Three scientific papers are presented: (G – P4, P8, and P11), published in the journal of *Bulgarian Chemical Communications*, respectively in 2018, 2020, and 2022, indexed in Scopus.

Fuel cells for sulphite oxidation. One scientific paper (G – P5) is presented, published in the journal of *Bulgarian Chemical Communications*, 2018, indexed in Scopus.

In this area, the candidate also contributes with a chapter in the book *Energy Storage Battery Systems - Fundamentals and Applications*, published in 2021, IntechOpen, London, on the topic of "Bioelectrochemical Processes in Industrial Biotechnology".

The publications in the order of the authors are distributed as follows:

First place in the list of authors - 1 publication – (G – P8);

Second place in the list of authors - 12 publications – (V – P1, P2, P4, P6, and P7), (G – P1, P2, P3, P4, P9, P10, and P14);

Third place in the list of authors - 5 publications – (V – P5 and P8), (G – P5, P6, and P7);

Post third place in the list of authors - 4 publications – (V – P3); (G – P11, P12, and P13).

The candidate submitted a list of 62 citations on 21 papers. Based on the presented list of citations, her Hirsch index is 8. The reference in Scopus gives the H-index the value of 6.

4. Evaluation of the submitted materials.

In this competition, the candidate presents 22 scientific papers published in journals that are refereed and indexed in world-renowned databases of scientific information and 1 in edited collective volumes (according to group of indicators G of the Regulations for the implementation of the Academic Staff Development Act in the Republic of Bulgaria).

The main part of the candidate's scientific production is in the field of fuel cells and their application in the removal of sulphides, sulphites, and nitrates from fluids. This topicality is particularly up-to-date, which is confirmed by the significant number of scientific studies and the publication activity worldwide. The works related to the application of catalysts and electrocatalysts in fuel cells and their impact on the kinetics of the studied processes is of particular interest. Another group of works concerns the removal of sulphur dioxide from flue gases, and solutions to this important environmental problem have been proposed.

Assoc. Prof. Dr. Razkazova-Velkova's works are characterised by a concise and precise style, good knowledge of literary data, saturation with experimental data, objective analysis of the results obtained, and the derivation of logical hypotheses and conclusions.

It should also be noted that Assoc. Prof. Dr. Razkazova-Velkova has been the leader of or participant in scientific projects on her scientific topic at the Bulgarian National Research Fund, such as: the FNI E 02/10 project, 2014 on the topic of "New Fuel Cells Based on Chemical and Microbial Processes"; the project with entry No. KP-06-PN37/23, 2019 on the topicof "Integrated Absorption-Adsorption Process for Waste-Free Decontamination of Gases from Sulphur Dioxide"; and project No. KP-06-PN67/31, 2022 on the topic of "Bioelectrochemical Systems for the Removal of Organic Pollutants". The candidate also participated in the project DNS 7 RP 01/32 of 15th December 2011 "Obtaining Hydrogen from the Black Sea Water through a Sulphide Fuel Cell", funded under the 7th Framework Programme, as well as in the National Scientific Programme "Low Carbon Energy for Transport and Households (EPLUS)", 2018.

The submitted materials testify that the candidate's professional qualifications fully correspond to the specialty of the announced competition.

5. Major scientific and science-applied contributions

The reference for scientific contributions was made based on the 22 publications submitted for participation in the competition, which were published in journals indexed in the Web of Science and Scopus global databases. The scientific and science-applied contributions can be summarised as follows:

Scientific contributions:

1. Using a model of average concentrations and convective-diffusion models of absorption and adsorption, modelling of the absorption-adsorption process for capturing sulphur dioxide from flue gases has been performed.
2. The efficiency of various catalysts (metal oxides, like Co_3O_4, Mn_3O_4, Fe_2O_3, ZrO_2), incorporated on activated carbon and obtained by pyrolysis with a simultaneous activation upon the application of a catalyst precursor) for the oxidation of sulphides from model seawater systems was determined. Of the catalysts studied, ZrO_2 performed best. The oxidation rate in continuous aeration processes is twice as high as in constant-speed stirring processes without aeration. To increase the active surface area and to use it as an electrode in a fuel cell, ZrO_2 is incorporated into a substrate of pyrolysed and activated carbon.
3. The use of electrocatalysts based on manganese deposited on fullerenes and carbon nanotubes for the oxidation of SO_3 to SO_4 and the reduction of NO_3 to NO_2 and N_2 is proposed; thus, an SOx/NOx fuel cell suitable for the environmental protection is created and electrical energy is generated. Mn was deposited on double-walled carbon nanotubes (DWCNTs) and higher fullerenes (HFs) from manganese acetate by thermal treatment and/or freeze-drying. The obtained results clearly show that electrodes containing HF, DWCNTs, and manganese oxides are effective catalysts in SOx/NOx fuel cells.
4. Various fuel elements with a salt bridge, cylindrical membranes, a battery of two fuel cells and graphite plates as electrodes, and a membraneless fuel element have been designed and studied. Information was obtained on the efficiency of a fuel element based on sulphide oxidation. The predominant output products of the energy production process are sulphite and sulphate ions. The observed current and power densities are comparable to and even better than some of the results for similar systems. When using the Fumapem and Neosepta membranes, high results and sensitivity to hydroxyl ions were obtained, while Celgard 3501 manifested better endurance.
5. A solution to the process-limiting oxygen reduction reaction at the sulphide oxidation cathode in a fuel cell is proposed by using a gas diffusion electrode or by highly efficient oxygen saturation in a Venturi tube ejector. The oxidation products are sulphates, sulphites, and thiosulphates. Most of the results indicate a high fuel cell efficiency of 80%.
6. By testing different anode catalysts for HS oxidation, like graphite, cobalt phthalocyanine (CoPc), and perovskite ($La_{1.3}Sr_{0.7}NiO_4$), it was established that perovskite and CoPc are suitable catalysts for fuel cells based on hydrogen sulfide oxidation. The fuel cell characteristics were tested with optimised HS anodes and pre-developed oxygen (air) cathodes. The electrical power obtained was P = 7.5 mW.
7. A fuel element has been designed for simultaneous oxidation of sulphides and reduction of nitrates. The results for biological and chemical denitrification in the

cathode compartment were compared. The influence of various concentrations of sulphides and nitrates on the electrical power of the fuel cell was studied, as well as their simultaneous neutralization.

8. New data have been obtained for fuel cells with microbiological oxidation of sulphides and chemical denitrification and in the implementation of microbial processes for both reactions. A comparison between microbial and chemical fuel cells under the same conditions is also presented. A new type of electrodes with pyrolysed activated carbon were used to immobilise the bacterial strains. *Pseudomonas putida* 1046 was used for sulphide oxidation, and *Pseudomonas denitrificans* was used as a model strain for denitrification.
9. A membraneless fuel cell for the remediation of contaminated streams has been designed and tested. The core of the fuel cell is a cylindrical tube of activated carbon, serving as both an electrode and a non-selective membrane. The ability to operate at elevated temperatures and the relatively inexpensive production and operating costs are additional advantages. Both abiotic conditions and microbial fuel cells were investigated for the purification of polluted streams with different initial concentrations of sulphide and nitrate ions, as well as their electrical power output.
10. A fuel cell for the oxidation of sulphites has been designed. The use of catalysts has been found to improve fuel cell performance. The experiments show that a nickel-plated graphite fibre makes an appropriate candidate to be used as an electrode for the anode compartment of the fuel cell. Nickel-plated graphite fibres exhibit the best oxidation rate and lowest production costs, but also have very low wear resistance. Of the oxidants studied, nitrates showed the best results.

Science-applied contributions:

1. More precise equations for predicting the hydraulic resistance of high-performance metal Raschig Super-Ring (RSR) packings for column apparatus have been derived based on experimental data.
2. Based on experimental data, dimensionless criterion equations for Metal Raschig Super-Ring (RSR) and Intalox Metal Tower Packing (IMTP) high-efficiency packings for column apparatus are proposed. The proposed equations take into account not only the geometry of the packings, but also the effect of recharging in the column. They can be successfully applied to the design and correct equipment sizing of industrial devices.
3. An improved Wellman-Lord method is proposed with the following advantages: lower steam consumption, by about 60%; the heat of evaporation of the solution can be used in the condenser for heating district heating water; lower capital costs and higher SO_2 removal rates from flue gases. The application of the improved Wellman-Lord method is envisaged in small-capacity combustion systems, which will allow their efficient and waste-free operation with coal and other conventional fossil fuels.

4. An integrated absorption-adsorption method for the capture of sulphur dioxide from flue gases is proposed, and after screening for a suitable ion exchange resin, Dowex® 66 was selected as the most promising adsorbent. Additional experiments were performed regarding adsorption and desorption times, as well as varying the concentration of the desorbing agent. Important technological parameters have been determined, such as: the amount of resin for almost complete adsorption of sulphurous acid, the adsorption time and the concentration of the desorbing NH_3. These parameters can be used to further scale up, implement, and explore the new technology for waste-free capture of sulphur dioxide from gases.
5. A physical model of a column for the removal of sulphur dioxide from flue gases is constructed, which contains a bubble-cap tray fabricated by 3D printing. As a result of an experimental research, data on hydraulic resistance and gas retention capacity of the bubble-cap tray have been determined and verified. The kinetic parameters of the absorption-adsorption process have been determined. The application of modern techniques, such as CFD modelling and additive manufacturing in reactor design, allows obtaining process data at different scales.
6. The photocatalytic oxidation of a model azo dye pollutant (Acid Black 194.) with TiO_2 incorporated on activated carbon was evaluated by testing 4 samples: activated carbon with and without TiO_2. The samples were obtained by an original pyrolysis method with simultaneous activation, where those with TiO_2 were pre-impregnated with a catalyst precursor. Tests with monochromatic UV-C illumination show that the TiO_2/AC-680°C photocatalyst is more effective due to its greater activity under visible spectrum illumination compared to the TiO_2/AC-830°C photocatalyst.
7. A new method for the simultaneous purification of sulphur dioxide and hydrogen sulphide has been proposed, and the conditions for the simultaneous reduction of sulphur dioxide and oxidation of hydrogen sulphide have been established. The method is based on the electrochemical affinity of the pair H_2S and SO_2. The H_2S oxidation and SO_2 reduction curves were investigated electrochemically with various catalysts (DG (standard Degussa carbon black), cobalt phthalocyanine, perovskite, graphite, and Pt). The process can be carried out in acidic or alkaline conditions. Based on experimental results, a method for purifying both pollutants at atmospheric pressure, by electrochemical means, has been developed.

6. Reflection of the candidate's scientific publications in the Bulgarian and foreign literature

Assoc. Prof. Dr. Razkazova-Velkova's publications have been acclaimed in Bulgaria and in the international scientific community. Ten scientific papers have been cited in publications by Bulgarian teams working in the candidate's scientific field. 52 of all 62 citations presented are by authors from abroad. Besides, most of these are in journals with very high scientometric indicators, such as: *Chemical Engineering Journal* (IF = 13.4 and SiteScore = 21.7), *Applied Catalysis B: Environment and Energy* (IF =

Chemical Engineering Journal (IF = 13.4 и SiteScore = 21.7), *Applied Catalysis B: Environment and Energy* (IF = 20.3 и SiteScore = 38.6), *Renewable Energy* (IF = 9 и SiteScore = 18.4), *Separation and purification technology* (IF = 8.2 и SiteScore = 14.0), *International Journal of Hydrogen Energy* (IF = 8.1 и SiteScore = 13.5), *Journal of Water Process Engineering* (IF = 6.3 и SiteScore = 10.7), *Process Safety and Environmental Protection* (IF = 6.9 и SiteScore = 11.4) и т.н. Подобно цитиране дава информация за значимостта на публикациите и високите наукометрични данни на представените работи.

7. Критични бележки и препоръки.

Представените за конкурса материали са много грижливо подготвени и подкрепени документално. Нямам критични забележки нито по тях, нито по отношение на научните и научно-приложните приноси. Моята препоръка е да продължи със същото темпо научно-изследователската дейност и да публикува своите научни резултати в най-престижните световни издания.

8. Лични впечатления на рецензента за кандидата

Познавам бегло доц. д-р Елена Разказова-Велкова, но от кратките ни срещи съм останала с впечатление за мил, внимателен, отговорен и отзивчив човек. Въз основа на научната й продукция считам, че тя е изключително трудолюбив, задълбочен и етичен изследовател.

ЗАКЛЮЧЕНИЕ

Представените материали отговарят на изискванията на ЗРАСРБ, на Правилника за приложението му и вътрешния Правилник за условията и реда за заемане на академични длъжности в ИИХ-БАН. Въз основа на запознаването с представените научни трудове, тяхната значимост, съдържащите се в тях приноси, намирам за основателно да предложа **доц. д-р Елена Николаева Разказова-Велкова** да заеме академичната длъжност „**Професор**“ в професионалното направление 4.2. Химически науки по специалността „Процеси и апарати в химическата и биохимичната технология“.

Дата: 05.01.2025 г.

Рецензент: [redacted]

(проф. Св. Браткова)