Doctoral School of Chemical Engineering and Material Sciences

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ADVANCED COMPREHENSIVE WATER QUALITY ASSESSMENT

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INTRODUCTION

In light of the international requirements defined by Water Framework Directive (hereafter WFD) and the huge world demand for pure and potable water supply, water quality assessment is a very important tool to follow the variations in water quality of Lakes. When surface water is highly exposed to human activities, either from recreational or economic activity, the degree of vulnerability is high, and the quality of surface water is highly compromised. In order to maintain a good environmental status of surface waters, an assessment of water quality carried out at specific intervals to monitor the changes of water quality in function of time. Hence, the need for appropriate monitoring techniques to be implemented in order to check water quality on a regular basis is of primary importance. Lake Nasser is one of the largest man-made lakes on earth. It has a vital importance to Egypt for several decades because it safe water supply of the country. In case of Lake Balaton, there are many activities that can disrupt water dynamics. Therefore, the water quality of the lakes must be profoundly investigated, water parameter changes should be continuously monitored and assessed. Among various types of pollutants, heavy metals are of major concern, heavy metals cause deleterious effects on human health and drastically alter the biogeochemical cycles within freshwater habitats. Heavy metals in aqueous solution do not always exhibit direct toxic effects on the

environment; instead, they tend to bioaccumulate and to persist in the environment.

Moreover, these compounds are not biodegradable and cause detrimental effects on the environment and human health. Historically, the worldwide fish consumption increased directly with the interest in its nutritional value, mainly as a source of valuable proteins. Dietary guidelines in the United Kingdom recommend the consumption of fish and fish-based products at least twice a week to meet the daily requirements of polyunsaturated fatty acids. Given that fish fill upper positions within aquatic food webs, the heavy metals can bioaccumulate in their biomass via food, water and sediments in significant amounts, with direct toxic effects to humans. The human contamination with heavy metals via fish consumption leads sometimes to liver and kidney failures and cardiovascular diseases, to name just a few of the induced detrimental health effects. This led to the implementation of numerous international screening approaches with the aim of estimating the quality of fish meat, as well as to survey health of aquatic ecosystems. Moreover, accumulation rate of heavy metals such as lead, zinc, copper and cadmium in several tissues of the iconic fish Nile Tilapia (*Oreochromis niloticus* L.) from Lake Nasser and Bream (*Abramis* brama L.) from Lake Balaton have investigated. Therefore, in the current study, we tried to fulfill this knowledge gap through a holistic investigation of the distribution of these heavy metals in water, sediment, and fish in Lake Nasser and Lake Balaton, as well as through assessing their

accumulation rates in various fish organs. In this study the location of the least and most polluted sites around the lakes has been determined. The processing of data was carried out by using multi-criteria decision techniques and environmental impact assessment method based on physical–chemical parameters and heavy metals as special chemicals parameters in comparison with the limiting parameters as defined in Water Framework Directive and pertaining legal regulations. Additionally, effects of heavy metals bioaccumulation in aquatic ecosystem, via water, sediments and fish organs were investigated. In light of the tremendous demand for safe and healthy water supply in Egypt, Hungary and international requirements, water quality assessment is a very important tool for providing reliable information on water quality. The protocol for water quality assessment could significantly contribute to the provision of high-quality water supply in Egypt and Hungary.

1. SIGNIFICANCE, SCOPE OF THE TOPICS, AND DEFINITIONS

The purpose of the PhD work is to devise a quantitative type of water quality assessment method which could provide rapid, accurate, and reliable information on surface waters quality by using water parameters. The method is to be illustrated on Lake Balaton in Hungary and Lake Nasser in Egypt with special focus on physico-

chemical parameters and heavy metals as special chemicals which defined by WFD. The goal of this work is to elaborate a method for the comprehensive evaluation of water parameters and to illustrate its usability on Lake Balaton and Lake Nasser. Therefore, the main aims of this thesis are as follows:

- The first goal of this study aimed to determine the location of the least and most polluted sites around the lakes and monitoring the water supply lines both in Egypt and in Hungary with special focus on Lake Nasser and Lake Balaton.
- Main objective in Lake Nasser with focus on physico-chemical parameters and heavy metals as special chemicals which defined by WFD.
- The second goal is to compare water quality indices of lake Nasser and Lake Balaton and to make recommendations how to further improve water quality.
- To investigate the effects of heavy metals bioaccumulation in aquatic ecosystem, via water, sediments and fish organs.

2. MATERIALS AND METHODS

2.1 Physicochemical parameters

Water parameters were measured according to the stipulations of American Public Health Association based on standards of Hungary, which is in harmony with Water Framework Directive of European Union.

2.2 Heavy metal contamination as specific pollutant

Heavy metals concentrations in aquatic ecosystem, in water, sediments and fish organs were investigated.

2.2.1 Water samples

Water samples were collected in polyethylene bottles. The samples were acidified with nitric acid to prevent organic matter alteration by bacterial activity and transferred in an ice-box to the laboratory. The concentration of heavy metals in water samples was measured according to APHA standards, with the aid of an Atomic Absorption Spectrophotometer (AAS).

2.2.2 Sediment samples

Three replicates of sediments were collected with the aid of an electronic vibrational core sampler tube (vibracorers), which enables sampling efficiently to a depth of eight meters. Following the packing of sediment samples in polythene bags and chilled in an ice box, they were transported to the laboratory for further analysis. The samples were dried overnight at 105°C to constant weight for heavy metal analysis. The digestion of sediment was performed based on USEPA.

2.2.3 Fish samples

Nile Tilapia (*Oreochromis niloticus* L.) is a native fish species to Egypt which collected in this study from Lake Nasser and Bream (*Abramis brama* L.) type collected from

Lake Balaton.Various fish organs were extracted through dissection. Muscle, gills and liver organs were removed and their preparation for the measurement of heavy metals was carried. Cd, Cu, Pb and Zn contents were measured.

2.2.4 Atomic Absorption Spectroscopic Measurement

Heavy metal concentrations were measured with the aid of an AAS (Model ICE series 3000 AAS) with a GF 5000 graphite furnace in water, sediment and fish samples. In case of fish samples, the precision of the analytical procedure was checked by using standard reference materials (dogfish muscle (DORM 4) and liver (DOLT 5) Canadian Research Council) in five replicates.

2.3 Methodology

Methodology, which is deployed here in this study, uses 2010 version of Hungarian Decree and 2013 of Egyptian Decree and all threshold values are according to WFD 2010 standard.

2.3.1. Aquatic environmental index

Five water quality classes and categories were used during the assessment of AEI. The legal limit values for water parameters were determined from the pertaining specifications used for the quality categorization of water parameters according to Egyptian Governmental Decree No. 92/2013 and Lake Balaton which belongs to the Typology 16 according to the Decree No. ‘‘10/2010 (VIII.18.) of VM”. The methodology, which is deployed in Lake Balaton, uses the 2010 version of Hungarian Decree

and the entire threshold values are according to 2010 standard which is in harmony with Water Framework Directive of European Union.

2.3.2 Technique for Order Preference by Similarity to Ideal Solution Method

TOPSIS method used in several cases and it is one of multiple criteria decision-making methods (MCDM). TOPSIS procedure is based on an initiative and simple idea that maximize the benefit. In TOPSIS technique, basic solution method is defining positive and negative ideal (non-ideal) solutions. The positive ideal solution includes the best available value of parameters, while the non-ideal one is made of the worst available value of parameters. Finally, the best answer has both the shortest distance from the ideal solution and the longest from the non-ideal. Simplicity, rationality, comprehensibility, good computational efficiency, and ability are the advantages of TOPSIS method.

2.3.4 Simple Additive Weighting method

Simple Additive Weighting (SAW), also known as the weighted and simple weighted scoring method. This is commonly used for multiple decisions attribute (MADM) tools. The basic concept of SAW method is to find the weighted sum of performance ratings on each alternative on all attributes. SAW method requires the process of normalizing the decision matrix to a scale comparable to all existing alternative ratings.

2.3.5 Statistical analysis

A comprehensive evaluation method was used to evaluate the correlation between the contamination with heavy metals and sample types (i.e., water, sediment, liver and muscles) of investigated items. The main evaluation indexes included the coefficient of determination (R^2), and Pearson correlation coefficient (Corr).

Data were expressed as mean ± SE. Differences among data were assessed statistically by one way analysis of variance (ANOVA) as sources of variation. A multiple f-test was used to determine significance among means for significant main effects. The level of significance was set at ($p < 0.05$) with a confidence level of 95%.

2.3.6 Metal pollution index (MPI)

To understand the ecological risk related to heavy metal contamination, the metal pollution index (MPI) has been calculated. The MPI provided comprehensive information about the metal toxicity in a particular sample and offered a better understanding of the quality of aquatic environment.

3. NEW SCIENTIFIC FINDINGS

The new scientific findings obtained during my PhD research in several theses are as follows:

3.1 The application of various assessment techniques helps the interpretation of complex data matrices to

better understand the water quality and the ecological status of the studied systems.

3.2 The application of a novel evaluation approach that enabled the integration of a wide range of physicochemical parameters recorded at a large spatial scale throughout the lake areas.

3.3 The demonstration of the multi-criteria decision-making techniques (TOPSIS, SAW) and AEI assessment used to characterize the quality status of the considered lakes provide reliable quality rankings of the study sites.

3.4 Indicating that the N- and P loads as factors with the greatest environmental risk for Lake Balaton, while for Lake Nasser, the most critical factor was proven to be the water temperature.

3.5 Declaration of the benefits of combining different methods are maximization of the advantages of these methods and avoidance of the inherent differences between methods, by promoting the Sum of ranking differences (SRD), a novel statistical method that is rapidly becoming popular in various fields of applied science.

3.6 Investigating a biomonitoring study regarding heavy metal pollution by analyzing water and fish samples in particular; liver, gills, and muscles.

3.7 The current study provides new data concerning the trace metal pollution of Lake Nasser and Lake Balaton and highlighted spatial-temporal trends in contamination.

3.8 Usage of a comprehensive evaluation method to evaluate the correlation between the contamination with heavy metals and sample types (i.e., water, sediment, liver, and muscles) of investigated items. The main evaluation indexes included the coefficient of determination (R^2), and Pearson correlation coefficient (Corr).

3.9 Investigating the ecological risk related to heavy metal contamination; the metal pollution index (MPI). Which provides comprehensive information about the metal toxicity in a particular sample and offers an understanding of the quality of the aquatic environment.

3.10 Investigating the effects of heavy metals bioaccumulation in the aquatic ecosystem, via water, sediments, and fish organs.

3.11 Confirming the successful finding that Zinc has been shown to antagonize the toxic effects of heavy metals such as Cd^{2+} in biological systems (detoxification effect).

3.12 Observation of the most toxic trace elements that have been decreased due to awareness of society to HMs danger.

PUBLICATION LIST

Published articles related to thesis research

1. **Rizk, R.**, Juzsakova T., Cretescu I., Rawash M., Sebestyén V., Le Phuoc C., Kovács Z., Domokos E., Rédey A., Shafik H. (2020). Environmental assessment of physical-chemical features of Lake Nasser, Egypt. Environmental Science and Pollution Research Journal. 27 (16), 20136-20148. doi: 10.1007 / s11356-020-08366-3. **IF= 4.223.**
2. **Rizk, R.**, Alameraw, M., Rawash, M. A., Juzsakova, T., Domokos, E., Hedfi, A., … Rédey, Á. (2021). Does Lake Balaton affected by pollution? Assessment through surface water quality monitoring by using different assessment methods. Saudi Journal of Biological Sciences, 28 (9), 5250–5260. doi: 10.1016/j.sjbs.2021.05.039. **IF=4.219.**
3. **Rizk, R.**, Juzsakova T., Ben Ali, M., Rawash M., Domokos E., Hedfi, A., Almalki, M., Boufahja, F., Shafik, M. H., Rédey, Á. (2022). Comprehensive Environmental Assessment of Heavy Metal Contamination of Surface Water, Sediments and Nile Tilapia in Lake Nasser, Egypt. JKSU, 34 (1), 101748 doi.org/10.1016/j.jksus.2021.101748. **IF=4.011.**

Published articles not related to thesis research

1. Mahmoudi M., Bejaoui W., Ben Ali M., r Hedfi A., Almalki M., Essid N., Mahmoudi E., **Rizk R.,** Pacioglu O., Urkmez D., Dervishi A., Boufahja F. (2021). How effective is wastewater treatment? A case study under the light of taxonomic and feeding features of meiobenthic

nematodes. Environ Sci Pollut, doi.org/10.1007/s11356-021-15844-9. **IF=4.223.**

2. Hedfi A., Ben Ali M., Noureldeen A., Darwish H., **Rizk R**., Mahmoudi E., Plăvan G., Pacioglu O., Boufahja F. (2021). Effects of benzo(a)pyrene on meiobenthic assemblage and biochemical biomarkers in an Oncholaimus campylocercoides (Nematoda) microcosm. Environ Sci Pollut Res (2021). doi.org/10.1007/s11356-021-16885-w. **IF=4.223.**
3. Sellami, B., Bouzidi, I., Hedfi, A., Almalki, M., **Rizk, R.,** Pacioglu, O., Sheehan, D. (2021). Impacts of nanoparticles and phosphonates in the behavior and oxidative status of the mediterranean mussels (Mytilus galloprovincialis). Saudi Journal of Biological Sciences, 28(11), 6365–6374. doi:10.1016/j.sjbs.2021.07.017. **IF=4.219.**

Journal articles in Hungarian journals

1. **Rizk, R**., Rawash, M., Ismail, S. and Juzsakova, T. (2020). Protective effect of vitamins and epicatechin on cadmium toxicity in rats. Georgikon for Agriculture Journal, 24 (3), 51-64.

Conference presentation related to thesis research

1. Florin, L., **Rizk, R.,** Rawash, M., Silvia, C., Juzsakova, T., Sebestyén, V., Cretescu, I. A quality assessment tool for water resources management based on classification algorithm and water quality monitoring of Lake Nasser. Oral, **10th International Conference on environmental enginering and management. Iasi, Romania 18-21 September 2019. p. 311.**

2. **Rizk, R.,** Juzsakova, T., Domokos, E., Rawash, M. Bio-removal of heavy metal by using of water hyacinth plants. Oral**, International Conference. Óbuda University, Budapest, 21-22 November 2019. p 27.**

3. **Rizk, R.,** Juzsakova, T and Rédey, A. Advanced Comprehensive Water Quality Assessment. Oral, **Green solution Conf. Pannonia University, Veszprem 11 December 2019.p 9.**

4. **Rizk, R**., Juzsakova T., Alameraw M., Sebestyén V., Domokos E., Kovács Z., Rawash M. Surface Water Quality Monitoring for Lake Balaton by using different ASSESSMENT methods. Oral, **4 th Sarajevo Sdewes conference, SDEWES2020 June 28- 2 July, Sarajevo, Bosnia & Herzegovina . p 166**

5. **Rizk, R.,** Juzsakova T., Rédey A., Sebestyén V., Domokos E. Monitoring of the Heavy Metal Content of Fish Samples of Lake Balaton, Hungary. Oral, **4 th Sarajevo Sdewes conference, SDEWES2020 June 28- 2 July, Sarajevo, Bosnia & Herzegovina . p 167.**

6. **Rizk, R**., Juzsakova, T., and Rawash, M. Water quality studies on Lake Nasser. Poster, **Int. Conf. Cluj-Napoca, Romania 3–6 April 2019. p. 134.**

7. **Rizk, R.,** Juzsakova, T., Curteanu, S., Rawash, M., Le Phuoc Cuong, Cretescu, I., Kovács, Z., Sebestyén, V., Rédey, A. Surface water quality monitoring for River Nile. Poster, **10th International Conference on environmental enginering and management Iasi, Romania 18-21 September 2019. p. 359.**

8. **Rizk, R.,** Juzsakova, T., Shafik, M. H., Rédey, A. Monitoring of the heavy metal content of fish samples of Lake Balaton, Hungary. Oral**, International Conference. Óbuda University, Budapest, 17-18 November 2022.**

Conference presentation not related to thesis research

1. **Rizk, R.,** Rawash, M., Juzsakova, T., Thamer, A. Positive effects of green tea, vitamin C and E on hepatic and kidney disfunction induced by cadmium. Oral, **10th International Conference on environmental enginering and management. Iasi, Romania 18-21 September 2019. p. 239.**
2. **Rizk, R.,** Rawash, M., Juzsakova, T. Protective Effects of Green Tea, Vitamin C and E on Environmental Cadmium Toxicity. Oral, **61th Georgikon Scientific Conference, Keszthely, Hungary, 3-4 October 2019.p 90.**
3. **Rizk, R.,** Juzsakova, T., Domokos, E., Rawash, M. Bio-removal of heavy metal by using of water hyacinth plants. Oral**, International Conference. Óbuda University, Budapest, 21-22 November 2019. p 27.**
4. Thamer, A. A., Juzsakova, T., Ali, S., Al-Asadi, M., **Rizk, R**., Domokos, E. 2019. Hydrocarbons Removal from Water using Carbon Nanotubes Modified with Metal Oxide Nanoparticles. Oral. **Int. Conf. Cluj-Napoca, Romania 3–6 April 2019.**
5. Rawash, M., **Rizk, R.,** and Ali, S., 2019. Using Different dietary protein sources for limiting urea nitrogen content and ammonia emission of diary buffaloes milk. Oral, **Int. Conf. Cluj-Napoca, Romania 3–6 April 2019. p 192.**

6. Thamer, A. A., Juzsakova, T., Rasheed, R. T., Ali, S., Al-Asadi, M., **Rizk, R.** 2019. Metal Nanoparticles Modified Carbon Nanotubes as Adsorbent Materials to Remove Hydrocarbons from Water. Oral, **13th BUDAPEST International Conference on Chemical, Agricultural, Environmental and Biological Sciences (BCAEBS-19) Budapest (Hungary) 22-24 July, 2019.**
7. Thamer, A., A., Juzsakova, T., Domokos, E., Salman, A., Al-Asadi, M., **Rizk, R.** Iron Oxide Nano Particles Doped Multiwalled Carbon Nanotubes, Proceedings. Poster, **1st International Conference, Timisiora, Romania, November, 15-17, 2018. p. 3-4.**
8. Thamer, A., A., Salman, A., Juzsakova, T., Al-Asadi, M., Domokos, E., **Rizk, R.** Treatment of Oily Wastewater Using Electrocoagulation Method with Iron Poles. Poster, **1st International Conference, Timisiora, Romania, November, 15-17, 2018. p.5-7.**
9. **Rizk, R**., Rawash, M., and Rédey, A. Protective effect of zinc and selenium on cadmium-induced toxicity and disturbances in lipid metabolism and oxidative stress in rats. Poster, **Int. Conf. Cluj-Napoca, Romania 3–6 April 2019.p. 193.**
10. Rawash, M., **Rizk, R**., Irhayyim, T., Nikoletta, S., Anna, I., Andor, M., Farkas V., Dublecz, K. Effect Of Different Protein Sources In The Diet Of Lactating Buffaloes For Limiting Urea Nitrogen Content And Ammonia Emission. Poster, **61th Georgikon Scientific Conference, Keszthely, Hungary, on 3-4 October 2019.p-88.**

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