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Aim and Scope

Quality of Life publishes original research papers and reviews and aims to provide a forum for the rapid dissemination of significant novel research in the various disciplines encompassing the Science and technology of food, Public health engineering, Sanitary inspection and control, Environmental and public health. Topics covered by the journal include:

- Dietetics; Nutrition principles applied to foods
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- Water; Sanitation; Water treatment
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- Urban hygiene; Wastes; Refuse; Rubbish; Garbage; Collection and disposal of town wastes
- Measures against industrial and other nuisances
- Occupational health hazards; Occupational health and hygiene
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- Related topics

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Dear readers and authors,

As Editor-in-Chief of the journal Quality of Life, I look forward to the challenge of creating a journal that will enhance the quality of research in the various disciplines encompassing the Science and technology of food, Public health engineering, Sanitary inspection and control, Environmental and public health in our country, the region as well as at the international level. The journal Quality of Life was registered in the Register of Public Media in 2010 by the Decision of the RS Ministry of Education and Culture. Over the past years, this journal has published a large number of original scientific research papers, communications and review papers. Quality of Life is published twice a year by Pan-European University "Apeiron" Banja Luka. All the papers published so far have undergone a thorough review by the editorial board and the reviewers, made up of experts from both RS/B&H, the surrounding and other countries, from proven and recognized university and research institutions. As a result of a professional approach to selecting and reviewing papers, and raising the quality of the journal, Quality of Life was classified in the first category of journals in 2019 by the Ministry of Education and Culture.

We are proud to say that Quality of Life has been well received by the scientific and the general public in a relatively short period, which gives the editorial board a strong motivation for further work. The editorial team would like to thank our many reviewers who helped to maintain the journal standard; our many authors who submitted their best work to the journal; and, most importantly, our readers for your continuing support. I shall assure all our readers that our consistent efforts will be aimed toward increasing the visibility, impact, editorial cycle time, citations and overall quality of our journals. We very much look forward to strengthening the reputation of our publications, and we want to attract more higher-quality submissions.

In the spirit of continuous improvement, any constructive input on streamlining our processes is very welcome. Please help us grow by citing articles that you read in Quality of Life. We look forward to receiving your contributions in the near future.

Editors

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Original scientific paper

Phytoremediation of Soil Contaminated With Heavy Metals Using the Sunflower (*Helianthus Annuus L.)*

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ABSTRACT: Phytoremediation has proven to be a suitable method for removing heavy metals from the soil with the help of plants. To examine the phytoremediation potential, the experimental study monitored the influence of high and low concentrations of heavy metals (Pb, Cd, and Zn) on Helianthus annuus L., as well as their accumulation in seeds, roots, stems and leaves. The experiment was carried out during one growing season in outdoor conditions, in pots with a volume of 5L in which Helianthus annuus L. was planted, and the soil was contaminated with these heavy metals in concentrations below and above the maximum allowable concentration prescribed by the Rulebook on Determining Permissible Quantities of Harmful and Dangerous Substances in Soil and Methods of Their Testing. After growth and development of the plant, the experimental research examined the accumulation potential of the plant, the growth of the plant itself and its ability to survive depending on different concentrations of heavy metals. By processing the obtained results, statistically significant differences of heavy metals were determined in individual parts of the plants, depending on the applied concentration. The highest concentration of Zn was recorded in the leaves of the plant in the amount of 18.21 mg/kg, and the lowest concentration in the stem, 3.92 mg/kg. The measured values of heavy metals Cd and Pb differ from the above because the lowest concentrations of these heavy metals were recorded in the seed, and were 12.02 mg/kg for Pb and 9.20 mg/kg for Cd, which is a statistically significantly lower determined value relative to other parts of the plant.

Keywords: phytoremediation, Helianthus annuus L., heavy metals.

INTRODUCTION

Heavy metals are a major group of inorganic contaminants. Significantly large areas of land are contaminated with heavy metals due to the use of sludge or municipal compost, pesticides, fertilizers, emissions from municipal waste incinerators, car exhaust, metallurgical industry, residues from mining and military activities, and smelting industry (Abdelhafez et al., 2012.). Unlike organic pollutants, heavy metals are not biodegradable and pose a problem to living organisms and the environment due to their carcinogenic effects (Wu et al., 2018.). The presence of heavy metals in the soil in high concentrations negatively affects plant growth and agricultural productivity (Roy et al., 2005.). Plants differ in their tolerance to heavy metals; however, most growing plants are not hyperaccumulators for heavy metals (Peixoto et al., 2001; Hall, 2002.). Hyperaccumulation is defined as the uptake and sequestration of exceptional concentrations of an element in the aboveground parts of a plant under field conditions (Pollard, 2000.). Hyperaccumulation depends on the plant species, soil physicochemical properties (pH, cation exchange capacity, organic matter content, electrical conductivity (E.C), and different types of heavy metals. In hyperaccumulators, there is a rapid and active translocation of the heavy metals to the shoot via the xylem, which could probably be upregulated by transpiration (Chaudhary et al., 2016.). Some plants are known for their ability to accumulate abnormally high concentrations of metals, such as Zn, Ni, Mn, or Pb, in their aboveground parts to more

than 1% of their dry weight. These plants are called hyperaccumulators. About 450 plant species have been identified as hyperaccumulators for different heavy metals (Balafrej et al., 2020.).

Cd, Cr, Cu, Hg, Pb and Zn are the most common heavy metals that occur as contaminants (Jing et al., 2007.). Phytoremediation is a method that should be considered for remediation of contaminated sites due to its cost-effectiveness, aesthetic benefits, and long-term applicability (Marques et al., 2008.). Phytoremediation is a method of remediation, recovery, cleaning of the soil (water or air) using plants. Phytoremediation technology includes phytoextraction, phytostabilization, and phytovolatilization to remove metal ions from soil and water (Alaboudia et al., 2018.). Phytoextraction is an effective way to remove heavy metals from contaminated soil into plant tissue (Abbas and Abdelhafez, 2013.); after which it can be easily and safely processed or recycled (Lasat, 2002.). Plants differ in their ability to accumulate heavy metals (Kacalkova et al., 2015.). The choice of plant species for phytoextraction of heavy metals depends mainly on the tolerant capacity and biomass of the selected plant (Rezania et al., 2016.). Some plant species can accumulate high concentrations of heavy metals in their tissue; however, they produce little biomass and grow slowly, making them impossible to use for phytoremediation. Plants used for phytoextraction of metals from contaminated soil must have certain characteristics, including (i) tolerance to high concentrations of metals; (ii) short growing season and efficient accumulation of metals in biomass; (iii) metal concentration in the aboveground part of the plant; and (iv) easy to pick (Nehnevajova et al., 2007.). Plant species that generate large amounts of biomass, such as *Helianthus annuus L*, have the potential to remove large amounts of heavy metals that accumulate in the aboveground part of the plant (Safari Sinegani and Khalilikhah, 2008.).

Helianthus annuus L.

Helianthus annuus L. is an annual plant native to America that belongs to the *Asteraceae* family with a large flower head (inflorescence) and grows in a wide range of different soil types. The flower stalk can grow to a height of 3 m, with a flower head reaching up to 30 cm in diameter (Alaboudia et al., 2018.). *Helianthus annuus L*., a fast-growing crop, is tolerant of heavy metals. It is used for rhizofiltration because it shows a large intake of heavy metals through the roots, but also shows low efficiency in their translocation from root to shoot (Zou et al., 2008.). The ability of *Helianthus annuus L*. to absorb heavy metals was tested in the field, container, and hydroponic conditions with different concentrations of pollution. *Helianthus annuus L.* has been found to accumulate large amounts of metals (Zn, Pb, Cu) (Angelova, 2016.). According to most authors, heavy metals mainly accumulate in *Helianthus annuus L.* root (Lin et al., 2003; Marchiol et al., 2007.). Other authors have reported that some metals move from the root to the aboveground part of the plant (Adesodun et al., 2010; Herrero et al., 2003.). According to Rivelli et al. (2012) during the cultivation of *Helianthus annuus L.* on soil contaminated with cadmium (Cd) and on soil with combined pollution (Cd, Zn, and Cu), a significant impact on the physiology and growth of the plant was observed only in the variant where the soil was contaminated with more metals, with significant accumulation of metals in the tissue, especially in the roots and in the old leaves. Nehnevajova et al. (2005) evaluated the potential use of the *Helianthus annuus* L. for phytoremediation and reported that *Helianthus annuus L*. can be used for phytoextraction of soils contaminated with heavy metals.

This study aimed to examine the phytoremediation potential of the *Helianthus annuus L*. in soil contaminated with high and low concentrations of heavy metals (Pb, Cd, and Zn), as well as accumulation of the same in the seed, root, stem, and leaves of the plant.

MATERIAL AND METHOD

The experiment was conducted during one growing season in pots with a volume of 5L in outdoor conditions, on the property of the Biotechnical Faculty of the University of Bihać and consisted of control (soil without heavy metals) and soil contaminated with high and low concentrations of heavy metals (Pb, Cd, and Zn). *Helianthus annuus L*. was used as a test plant. It was chosen because is known to be a fast-growing deep-rooted industrial oil crop that can remove heavy metals such as zinc or copper from a polluted environment (Nehnevajova et al., 2005.). Before conducting the experiment, a chemical analysis of the soil was performed, the results of which are shown in Table 1. For the purposes of the research, three pots were used, in three replications. 4 *Helianthus annuus L.* seeds were sown in each pot. Pots with soil and *Helianthus annuus L.,* without the addition of heavy metals, were treated as a control. The soil in other pots was treated with a certain concentration of heavy metals (Pb, Cd, and Zn).

Table 1. Chemical analysis of the soil used in the research

Parameter	Measuring unit	Analysis results
Depth	cm	0-30
Hygroscopic moisture (Hy)	%	4.70
Organic part	%	21.42
Mineral part	%	78.58
Humus	%	0.54
Active acidity		7.07
pH in KCl		6.95
NH3-N	mg/kg	3.68
NO3-N	mg/kg	7.05
NO3-	mg/kg	30.38
P	mg/kg	1.62
PO43-	mg/kg	4.88
P2O5	mg/kg	3.79
SO42-	mg/kg	27.13
K2O	mg/kg	9.22
K	mg/kg	7.59
Ca2+	mg/kg	553.48
Mg2+	mg/kg	81.39

As a criterion for determining the concentration of heavy metals added during the research, the maximum permitted amounts (MPA) of pollutants prescribed by the Rulebook on Determining Permissible Quantities of Harmful and Dangerous Substances in Soil and Methods of Their Testing were taken (Official Gazette of the Federation of BiH, 72/09). Accordingly, solutions of the corresponding salts (solution of lead nitrate Pb $(NO)_3$ 1 mol/L; cadmium sulfate $CdSO_4$ 0.1 mol/L and zinc sulfate $ZnSO_4$ 1 mol/L) were prepared and then diluted and adjusted the mass of the soil in order to define the exact mass concentration of the ions present, which are removed by the remediation procedure. The low concentration (LC) of lead

ions (Pb^{2+}) was 1000 mg, cadmium (Cd^{2+}) 20 mg, and zinc (Zn^{2+}) 1000 mg per kilogram of soil. The high concentration (HC) of lead ions (Pb^{2+}) was 2000 mg, cadmium (Cd^{2+}) 100 mg, and zinc (Zn^{2+}) 2000 mg per kilogram of soil. Prepared solutions of heavy metals were applied directly to the pots. This experiment lasted 30 days. After 30 days, the preparation of plant material for determining the concentration of heavy metals in the seeds, roots, stem, and leaves of the plant was started. Preparation, storage, and analysis of soil samples were done according to the requirements of ISO standards. The roots were dug up and separated from the soil by washing. Shoots are divided into stem, leaf, and head of the *Helianthus annuus L*. The samples were packed in plastic bags and transferred to the laboratory of the Biotechnical Faculty. In the laboratory, they were washed with water, cut into pieces, and then dried for 78 hours at 60°C. To determine the concentration of heavy metals, the samples had to be prepared properly. Atomic air/acetylene flame absorption spectroscopy using ready-made standards for all three heavy metals (F-AAS, Flame AAS) (Perkin Elmer, AA800) was used to determine the concentration of Pb, Cd, and Zn.

RESULTS AND DISCUSSION

The obtained results of the analyzed plant material with standard deviation and the results of statistical data processing (One-Way ANOVA and Tukey test) depending on the applied concentration and part of the plant are presented in Tables 2, 3, and 4.

Table 2. Recorded Pb values in plant material

Pb (mg/kg)	root	stem	leaf	seed
Control	7.332±0.32b	3.029±0.99a	11.914±0.98c	12.02±0.99c
Low concentration	17.11±0.51b	16.87±0.83b	21.32±0.93a	16.41±0.98b
High concentration	24.35±0.08a	22.05±0.23b	22.03±0.59b	18.97±0.97c
ANOVA p≤0.05 p≤0.05p≤0.05p≤0.05				

Plant culture (*Helianthus annuus L*.) was chosen for experimental research due to its high biomass, rapid growth rate, and plant ability to remove heavy metals from contaminated soil (Forte and Ronca, 2017). The plants looked healthy during the control treatment in the first stages of growth and development. By monitoring the parameters of plant growth and development, significant changes were observed on young leaves, leaf chlorosis, plants remained low and poorly developed, which is not the case with plants grown in soil contaminated with low metal concentrations, which developed normally and achieved the expected development characteristic of the mentioned type. Symptoms of plant toxicity with Pb, Cd, and Zn in higher concentrations were reflected in the formation of dark green leaves, necrosis of tissue of older leaves at the end of vegetation, but also the formation of a significantly shorter root system compared to control treatment, extremely dark in color. Based on the results of the analysis of the variance of the conducted research, a significant influence of the treatment (high and low concentration of the solution) on the phytoremediation ability of the plant and the uptake of heavy metals from the soil into various plant organs was determined. According to Mitić et al., (2013), plants are more difficult to absorb lead in inorganic form and move to aboveground organs, except on acidic soils, while it is much easier to absorb organic lead compounds and transported to aboveground parts of plants. Plants with phytoremediation ability are characterized by the accumulation of lead in the root system, and according to Mitić et al., (2013), this in a way represents a form of protection of the aboveground part. Natural concentrations of lead in plants range

from 5 to 10 mg/kg (Radojević and Bashkin, 1999). The concentrations of lead in the tested plants during the treatment with low and high concentrations are significantly higher. Research by Angelova et al., (2016) and the determination of *Helianthus annuus L*. potential, as well as its phytoremediation ability, depending on soil type and fertilization applications, showed that the highest lead concentration was recorded in leaves (59%) and significantly lower in seeds (1%). The conducted studies are in accordance with the research of Angelova et al., (2016) because at low concentrations of lead in the soil the highest concentration of this heavy metal was recorded in leaves (21.32 mg/kg), while at treatment with high concentrations of lead the highest value in the root system (24.03 mg/kg).

Table 3. Recorded values of the tested heavy metal Cd in plant material

Cd (mg/kg)	root	stem	leaf	seed
Control	2.626±0.64a	9.44±1c	9.20±0.97c	4.638±0.96b
Low concentration	10.32±0.07 b	9.10±0.71 a	11.92±0.95c	9.16±0.83a
High concentration	11.82±0.54c	11.97±1.19c	16.13±0.47a	12.91±0.98b
ANOVA p≤0.05 p≤0.05p≤0.05p≤0.05				

Studies conducted by Alaboudia et al., (2018) prove that generally, *Helianthus annuus L.* accumulates a higher amount of Pb in the root compared to the shoot. However, *Helianthus annuus L.* also accumulates large amounts of Cd in its shoots compared to Pb, but an increase in soil Cd concentration above 20 mg/kg leads to a decrease in BCF (bioconcentration factor) below 1, which affects the potential phytoremediation capacity of plant species (Zu et al., 2005.). The obtained results showed that *Helianthus annuus L*. can accumulate large amounts of Cd in its tissues in relation to Pb and therefore this plant can be effectively used for the remediation of soils contaminated with cadmium. The obtained results of the conducted experimental research, where the highest concentrations of Cd in the treatment of HC and LC were measured in the aboveground part of the plant (leaf), and the amounts for LC 18.21 mg/kg and HC 14.96 mg/kg, agree with previously conducted studies. Lee et al., (2013) and Forte and Mutiti (2017), who found that the plant *Helianthus annuus L*. is significantly more favorable for the accumulation of Cd in its tissues compared to other heavy metals.

Table 4. Recorded values of the tested heavy metal Zn in plant material

Zn (mg/kg)	root	stem	leaf	seed
Control	4.64±0.09^{a}	4.638±0.99^{a}	8.54±0.66^{c}	7.25±0.99^{b}
Low concentration	7.05±1.64 ^{a}	9.10±1.55 ^{c}	8.21±0.69^{b}	7.74±0.99^{b}
High concentration	10.337±0.34^{a}	11.97±0.25^{b}	14.696±1.32^{c}	12.64±0.79 ^{b}
ANOVA p≤0,05 p≤0,05p≤0,05p≤0,05				

Zinc belongs to the group of elements whose mobility through the plant is mediocre when both the ascending and descending flow is in question. In the case when the concentration of Zn in the soil is extremely low, the consequence is a low intensity of transfer from older to younger parts of the plant. In cases when its concentration in the soil is high, it mainly settles in the roots of plants. If its concentration

decreases to 10 to 20 mg/kg, a latent (hidden) deficiency occurs, and if it decreases below 10 mg/kg, an acute deficiency occurs with symptoms of deficiency and plant death (Živanović, 2010.). Symptoms of Zn toxicity in plants are manifested in reduced growth, tiny leaves with reddish-brown spots, and reduced roots (Alloway, 2008). The results show that the lower concentration of Zn below 10 mg/kg remained mostly in the stem, which resulted in the formation of small leaves covered with spots, while at high concentrations of Zn the highest value was recorded in the leaves (14.69 mg/kg) and slightly lower in seeds (12.56 mg/kg).

Table 5. Translocation factor (TF)

Element	Control	Low concentration	High concentration
Pb	1.62	1.24	0.90
Cd	3.50	1.15	1.36
Zn	1.84	1.16	1.42

TF = metal (shoot) / metal (root)

The translocation factor is defined as the ratio of the mass fraction of metal in the aboveground part of the plant concerning the share of metal in the root and is used to determine the efficiency of the plant in translocating heavy metal from root to aboveground part. The translocation factor indicates an enhanced ability of plants to bioaccumulate heavy metals compared to the control sample. The obtained values for TF are the most important test that can be used to assess the phytoremediation potential of the plant (Angelova et al., 2016.). The results of this study show that in *Helianthus annuus L*. from the control sample for all three heavy metals TF is greater than 1, and based on this indicator, *Helianthus annuus L*. can be classified as an accumulator of these heavy metals (Pb, Cd, and Zn). Angelova et al. (2016) in their study, which examined the phytoremediation potential of *Helianthus annuus L*. for heavy metals (Pb, Cd, and Zn), also obtained values of TF> 1, and their results showing the highest value of TF in the control sample for Cd, and the smallest for Pb.

CONCLUSIONS

The experimental study was conducted to identify the ability of *Helianthus annuus L.* to remove heavy metals (Pb, Cd, and Zn) from contaminated soil. The main mechanism of remediation of heavy metals using the plant *Helianthus annuus L*. is based on the extraction of contaminants from the soil (phytoextraction, followed by translocation and accumulation of contaminants in the aboveground part of the plant). Analysis of the collected and processed data showed that *Helianthus annuus L*. has the ability to accumulate Pb, Cd, and Zn in its tissue (shoots and root system) depending on the type of metal and the applied strength of concentration. The highest concentrations of Pb were recorded in the root system of the plant (24.03 mg/kg), while higher concentrations of Cd (16.13 mg/kg) and Zn (14.696 mg/kg) were recorded in the aboveground part of the plant (leaf). The accumulation of heavy metals and their distribution depends on the type of plant, plant organs, phenological stage, degree of contamination, and combination of metals in the soil.

Based on the obtained results, it can be concluded that *Helianthus annuus L.* is a tolerant plant species in soils that are low to moderately contaminated with heavy metals (Pb, Cd, and Zn) and can be successfully used in phytoremediation of soil contaminated with these heavy metals.

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Original scientific paper

Glass-Ceramics Produced by Vitrification of Coal Fly Ash

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ABSTRACT: Glass-ceramics based on CAS (CaO-Al2O3-SiO2) system was produced by controlled crystallization of vitrified fly ash. Fly ash was pre-treated by magnetic separation and nonmagnetic part of fly ash (NFA) was used. Maximal crystallization of parent glass occurs in the temperature region from 900 oC to 1160 oC. Glass-ceramics was produced by consolidation of parent glass i.e. pressing (45 MPa) and sintering at 950, 1000, 1050 and 1100 oC, and isothermal time at the final temperature of 30, 60, 120 minutes. The dominant crystalline phase was calcium aluminum silicate (anorthite). The obtained glass-ceramics could be potentially used in construction applications.

Keywords: coal fly ash, parent glass, quenching, vitrification, glass-ceramics.

INTRODUCTION

Fly ash generated as by-product from the thermal power plants is mainly used in the cement industry [Hwang & Cortés, (2021); Cavusoglu et al., (2021); Qin et al., (2019)] mostly as supplementary cementitious materials. However the utilization rate is much smaller than production rate (ECOBA, 2020) and the rest of the ash disposed in a landfill causes huge environmental problem. There are many existing applications of fly ash as construction materials, but also green transformation is foreseen in the future (Gollakota, et al*.,* 2019). One of the possibilities fly ash to be used in construction is the production of glass-ceramics. It is characterized with attractive appearance, excellent mechanical properties, good chemical resistance *etc.* [Zhu et al., (2016); Rzepa et al., (2020)]. The useage of fly ash for the production of glass-ceramics achieves savings in the exploitation of natural resources, and on the other hand, waste from one industry can be used as raw material in another industry, which is in line with the principles of circular economy [Bielecka and Kulczycka, (2020)]. The significant content of SiO_2, Al_2O_3 and CaO in fly ash is essential for production glass-ceramics in the CaO-Al_2O_3-SiO_2 (CAS) system. There are numerous papers and methodologies for modifying the composition of fly ash in order to obtain glass with the desired properties [Zong et al., (2015), Zhang et al., (2019), Baowei et al., (2013), Angjusheva et al., (2011), etc.] .

Production of glass-ceramics involves controlled nucleation and crystallization of glasses through specific temperature treatments. Dense, fine grained microstructure with excellent physical and mechanical properties can be obtained. Zhang et al., (2020) reported the production of low cost additive free glass-ceramic from coal fly ash and municipal bottom ash. By variation of the content of fly ash and the temperature they obtained anorthite and anortite-diopside glass-ceramics with density 2.55 g/cm^3, water absorption 0.1 % and compressive strength 299 MPa. Binhussain et al*.,* (2014) reported the production of glass by the vitrification mechanism, and transformation into low cost glass-ceramics. By combining direct sintering of waste mixture and sintering of waste derived glasses they create layered hybrid glass-ceramic with good mechanical properties and homogeneous microstructure that could be used in building facades as lightweight tiles.

The aim of this paper was to produce glass-ceramics from fly ash originated form the largest power plant in the Republic of North Macedonia – REK Bitola. Anorthite glass-ceramics were prepared by vitrifi-

cation of fly ash and sintering of parent glass in defined thermal treatment. Physical and mechanical properties in relation to the microstructure have been studied.

MATERIALS AND METHODS

Raw fly ash (RFA) used in the investigation was from the thermal power plant REK Bitola, Republic of North Macedonia. In order to decrease iron content and to increase the content of glass formers, such as SiO_2 and Al_2O_3, pre-treated fly ash was used to synthesize glass composition. Namely, nonmagnetic fly ash (NMA) was obtained by dry magnetic separation using magnetic separator Frantz, Model L-1, with a front slope of 20^o and a lateral slope of 30^o with a magnetic field of 0.07*T*.

Chemical analysis of the NFA was obtained using X-ray fluorescence spectroscopy (XRF; model ARL 9900). Loss of ignition (LOI) was determined on a dried sample heated for two hours at 900 ^{o}C. To investigate the phase composition of raw material and crystalline phases formed during heat treatment, powder and heat treated samples were analyzed using X-ray diffractometry (Philips X-ray diffraction unit, Model PV 105-1) operating at CuKα - radiation at an accelerating voltage of 40 kV and current of 40 mA.

The granulometric composition of the NFA was determined by sieving analyses (Retsch AS200). The specific gravity of the NFA was obtained by the pycnometer method. The morphology of the fly ash was followed by a scanning electron microscope (Leica S 440I).

The glass was obtained by melting the NFA at 1450-1500 ^{o}C/ 120 min in the graphite molds using the electrically heated furnace. The melt was quenched into water. The obtained glass was crushed and milled in the ball mill for 30 min. Glass granulation of less than 0.063 mm was used. The glass transition (Tg), crystallization (Tp) and melting temperatures (Tm) were determined using differential thermal analysis (DTA) (NETZSCH STA 409PC/PG) at heating rate of 10 ^{o}C/min in dry air.

Prior to the sintering parent glass powder was pressed using a binder (5% distillate water) by uniaxial pressing at P= 45 MPa (Weber Pressen KIP 100). Sintering was realized in the chamber furnace at sintering temperatures: 950, 1000, 1050, 1100 ^{o}C using heating rate of 10 ^{o}/min. The isothermal period at the final temperatures was 30, 60 and 120 min. The glass-ceramics was coded as NFA-T-time of isothermal treatment.

Bulk density was determined from the ratio of weight and volume of the sintered glass-ceramics. The porosity of the glass-ceramics was calculated from the relative density. Shrinkage (%) was estimated from the differences of the green and fired sample's length.

Mechanical properties (bending strength and E-modulus) were determined by three point bending tester (Netzsch 401/3) with a 30 mm span and 0.5 mm/min loading rate. Five specimens with dimensions 50 mm × 4 mm × 4 mm were used for the investigation and the average values were presented. Microstructure of the final glass-ceramics was followed by scanning electron microscope (SEM, Leica S440I) and energy dispersive analysis (EDS, JSM - 6460LV, JEOL).

RESULTS AND DISCUSSION

Table 1 presents the granulometric composition of the fly ash (NFA). Around 40 wt.% of fly ash particles are with dimensions less than 63μm.

Table 1. Granulometric composition of FA

Sieve diameter [mm]	NFA [wt.%]
+ 1.0	0.58
- 1.0 + 0.5	1.59
- 0.5 + 0.25	7.19
- 0.25 + 0.125	21.97
- 0.125 + 0.063	28.15
- 0.063 + 0.045	40.51
Σ	99.99

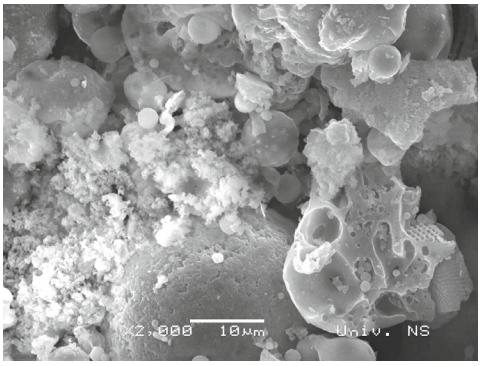


Figure 1. Morphology of raw fly ash, bar 10µm;

SEM analysis shows the presence of small spherical particles with diameter 1-10 µm, hollow particles and larger particles with undefined geometry and dimensions between 20-150 µm. Agglomerations of the small particles is evident. Specific gravity of the NFA was 2.095 g/cm^3.

Table **2***. Chemical composition of the NFA*

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	LOI	Σ
NFA[wt.%]	56.56	18.63	5.77	8.11	6.06	0.78	1.52	0.83	1.15	99.41

Fly ash belongs to class F according to ASTM (SiO_2+Al_2O_3+Fe_2O_3 >70 wt.%). The major components of NFA are SiO_2 (56.56 wt.%) and Al_2O_3 (18.63 wt.%) contributing around 75 wt.% of NFA (Table 2). As far as nonmagnetic part of fly ash was used in the investigation, Fe_2O_3 (5.77 %) was still present in fly ash. Its presence can be prescribed to the agglomerates and unburned porous coal particles, both composed of magnetic and nonmagnetic particles (Shoumkova, 2010). The basicity of fly ash is defined based on the CaO/SiO_2 ratio, and for the investigated fly ash it is 0.14. This is important factor for the phase transformations during sintering (Tabit et al., 2020).

The mineralogical composition of NFA was quartz, anorthite, albite, hematite, anhydrite and amorphous phase.

Glass-ceramic formation

Differential thermal analysis (DTA) carried out on parent glass to determine the nucleation and crystallization temperatures for production of glass-ceramic is presented in Figure 2. The results indicate that the NFA glass is in accordance to the typical events of vitreous materials that transform into glass-ceramics.

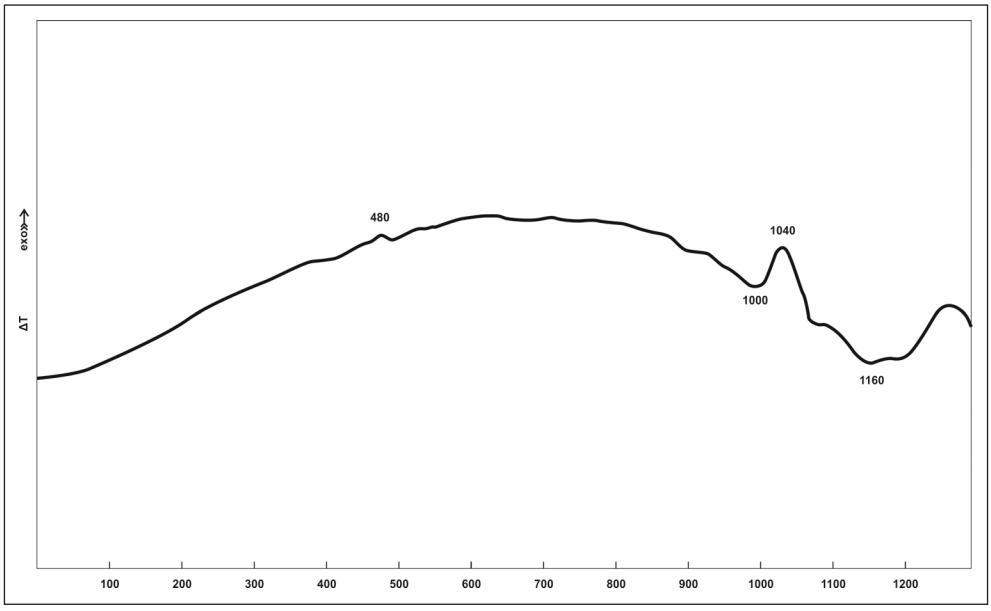
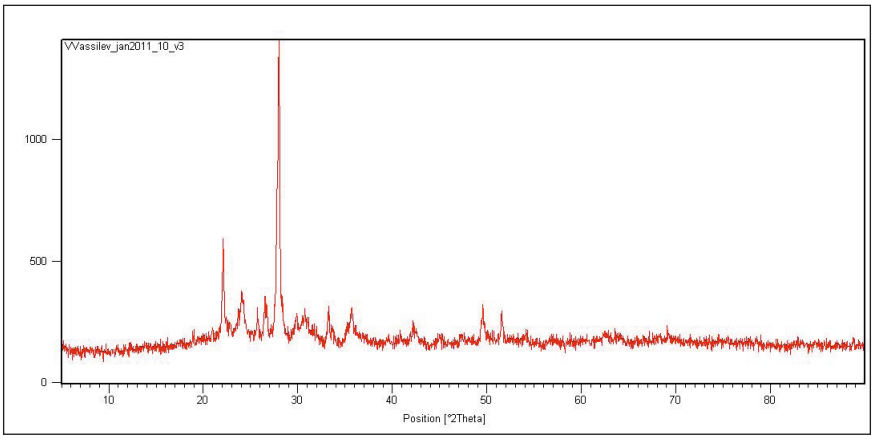


Figure 2. DTA curve of glass sample at heating rate of 10 °C/min

DTA curve indicates that glass transformation temperature (Tg) is at 480 °C and the exo peak of crystallization (Tp) occurs at 1040 °C, suggesting that the crystallization process is intense at the temperature region of 900-1050 °C. Glass transition, crystallization and melting temperatures generally decrease by increasing the content of alkaline oxides. (Vu et al., 2012). Endo effect refers to glass melting (Tm) appears at 1160 °C. Based on the above results, the maximal crystallization of glass obtained by NFA melting occurs in the temperature region from 900 °C to 1160 °C.

Mineralogical composition of glass-ceramics

Fig. 3 presents the XRD pattern of glass-ceramics sintered at 1050 °C/60 min. The main crystalline phase in glass matrix is anorthite ($CaSi_2Al_2O_8$). Tabit et al., (2020), reports that CaO/SiO_2 ratio ranging from 0.12 to 0.38 promotes the high content formation of anorthite. The content of anortite (68 wt.%) in the present study proves Tabit's reports based on the CaO/SiO2 ratio in NFA of 0.14.



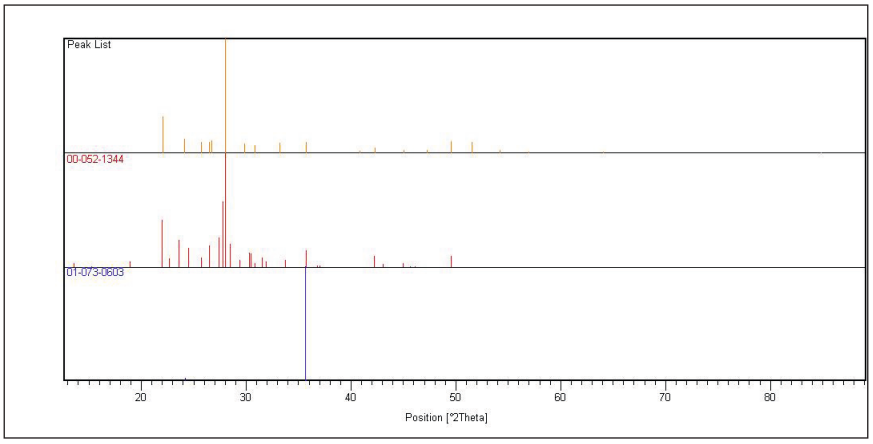
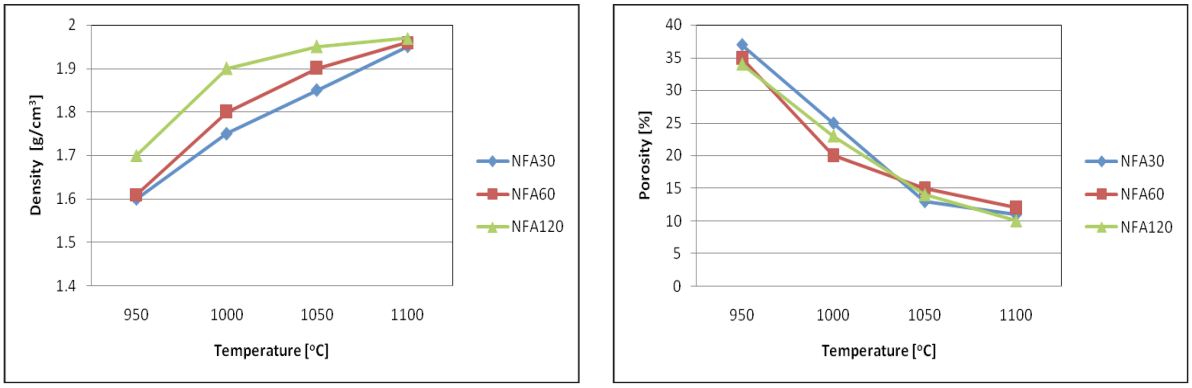


Figure 3. XRD patterns of glass-ceramics of NFA sintered at 1050 °C/60', Phase 1: Calcium Aluminum Silicate 00-052-1344; Phase 2: Iron oxide (III) reference ICSD. 01-073-0603

Physical and mechanical properties of glass-ceramics

Density and porosity of glass-ceramics are the typical parameters to evaluate the degree of sintering of glass-ceramics. The sintered density and porosity of glass-ceramic as function of temperature are plotted in Figure 4 with respect of different time of isothermal sintering. The density increases with the rise of the sintering temperature (from 1.60 to 1.98 g/cm^3), and consequently porosity decreased (from 37 % to 10 %). As far as sintering conditions act as an important parameter, also careful control of basicity (CaO/SiO_2 ratio) is required to optimized the properties of glass-ceramics (Zhang, 2020, Tabit, 2020).



(a) (b)

Figure 4. Physical properties of glass-ceramics sintered at different temperatures, (a) Density [g/cm^3]; (b) Porosity [%]

In addition to bulk density, sintering behavior of glass-ceramics was further described by linear shrinkage, Figure 5. The linear shrinkage rate of glass-ceramics varied evidently from 950 to 1050 °C, but above this temperature glass-ceramics were over-burning and entered the expansion process (Montodo, 2009). However, the linear shrinkage of glass-ceramics did not change significantly. Maximal shrinkage (12%) of glass-ceramics was achieved at 1050°C/60 min which is in accordance to the reported values (13-15%) from Ikeda et al., (2007).

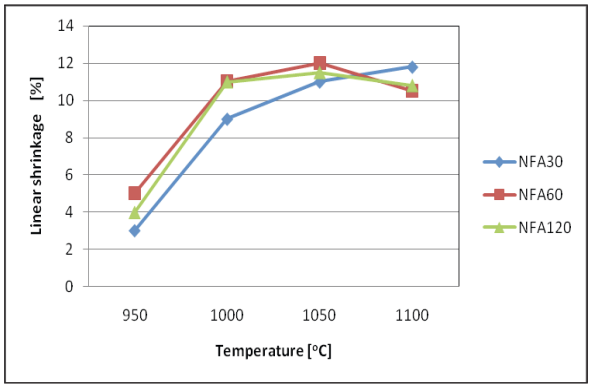
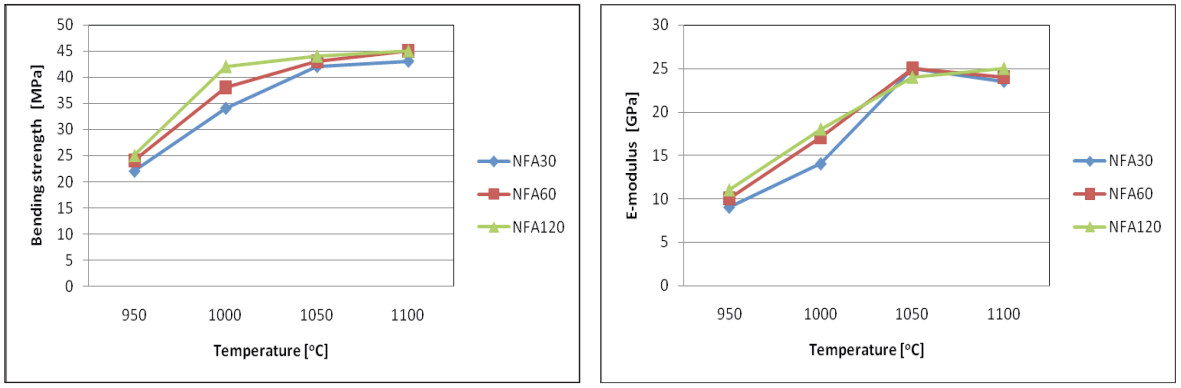


Figure 5. Linear shrinkage of glass-ceramics after exposure on defined temperature treatments

Figure 6 shows the bending strength and E-modulus of glass-ceramics sintered at 950- 1100 °C. Regardless the isothermal treatment of sintering, the bending strength and E-modulus of sintered glass-ceramics increases with the rise of sintering temperature. Mechanical properties of glass-ceramics sintered at 1050-1100 °C are much higher not only due to the densification and crystallization (anorthite has good mechanical properties) (Bernardo, 2008), but also to the lower porosity. Also, basicity i.e CaO/SiO_2, rather than the sintering temperature, has a more important impact in changing crystallinity of glass-ceramics (Zhang, 2020). The isothermal sintering is less influential on the mechanical properties of glass-ceramics. The maximal values for bending strength (45 MPa) and E-modulus (25 GPa) are comparable to the values reported in the literature. (Savvilotidou et al., 2019)

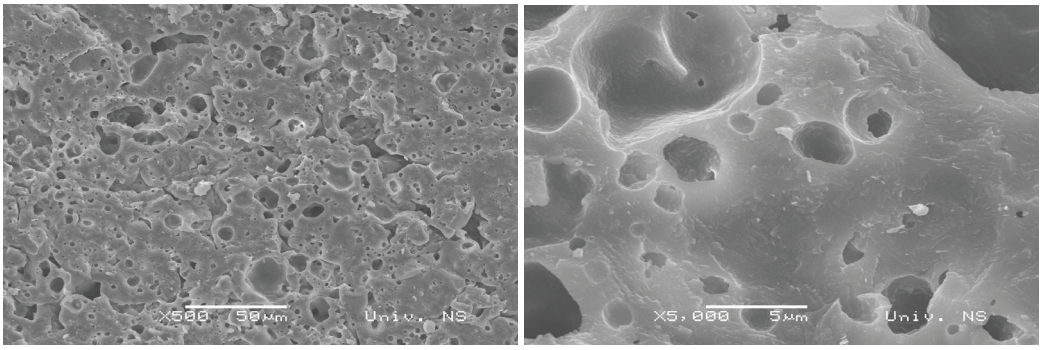


(a) (b)

Figure 6. Mechanical properties of glass-ceramics after exposure on defined thermal treatments, a) bending strength (MPa); b) E-modulus (GPa)

Microstructure of the glass-ceramics

The microstructure development of the glass-ceramics sintered at 1050/60 min is presented in Figure 7.



(a), x500 (bar 50µm) (b), x5000 (bar 5µm)

Figure 7. SEM micrographs of fractured glass-ceramic sample from NFA, sintered at 1050/60 min

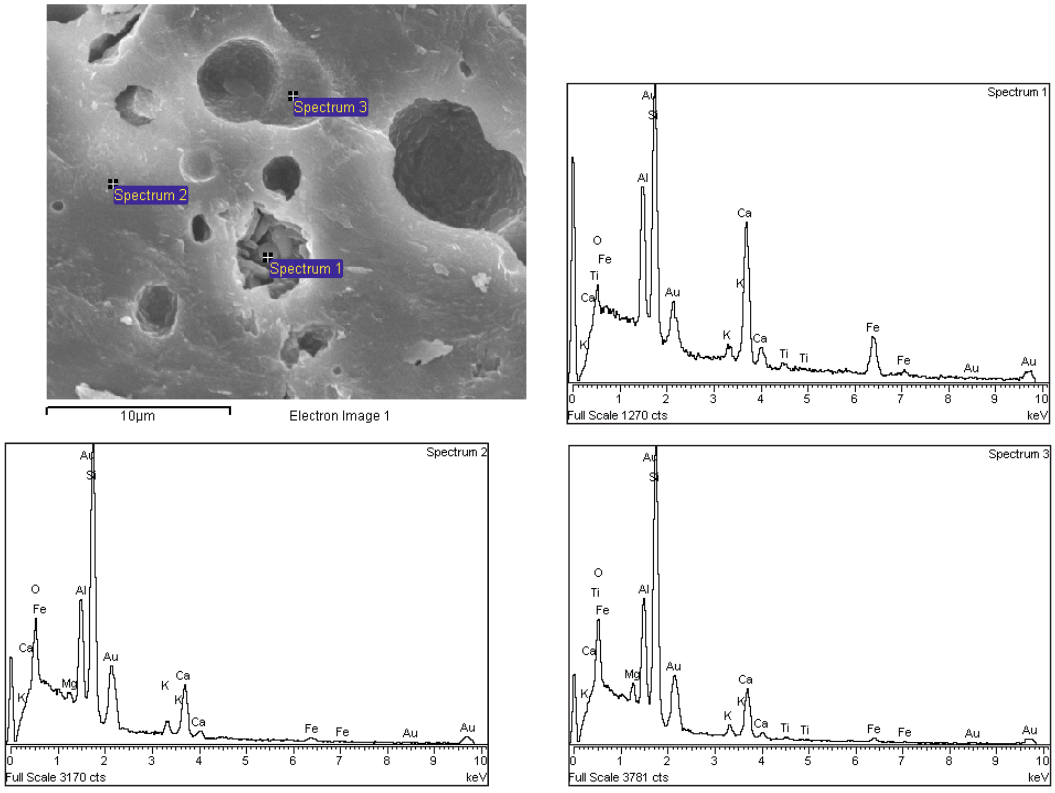


Figure 8. EDS analysis of glass-ceramic sample from NFA, sintered at 1050/60 min

Figures 7 (a) and (b) show that the fractured surface is homogeneous and crystal phases are well incorporated in the glassy matrix. Also, the presence of closed unconnected pores with dimensions between 2 and 20 mm is evident. The presence of small pores in the microstructure is reported to be usually formed around the anorthite phase. (Zhang et al., 2020). From EDS analysis (Fig.8) it is evident presence of detected predominant phase of calcium aluminum silicate (spectar 2 and 3) while inside the pores (spectrum 1) is iron oxide incorporated in the silicate matrix.

CONCLUSION

Anorthite-based glass-ceramics was produced without any additives from coal fly ash. Nonmagnetic fraction of fly ash was vitrified and glass-ceramics were obtained by controlled crystallization of parent glass.

The crystallization behavior of the parent glass revealed the glass transition temperature (Tg=480 °C), peak temperature (Tp=1040 °C) and melting temperature (Tm=1160 °C). Glass-ceramics with optimal

properties (density 1.98 g/cm^3; porosity 11 %; bending strength 45 MPa and E-modulus 25 GPa) was produced at 1050 ^{o}C/60 min. Calcium aluminum silicate (anorthite) as dominant crystalline phase (68 %) was homogeneously dispersed in the glass matrix. The obtained glass-ceramics can be potentially used as a substitute for traditional materials in construction, such as tiles, panels, bricks and other products.

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Original scientific paper

Performance Evaluation of Polymeric Membrane Permeability Characteristics Using Different Aqueous Solutions

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ABSTRACT: In the last decade the application of membrane separation technology is more increasing. The membrane in water purification and wastewater treatment is essential separation process used for water reclamation. The production of new membrane types with different permeable characteristics and performances allows them to be fitted in different membrane modules that can be used in the membrane filtration.

The water characteristics are important for the membrane performance. It can seriously affect the permeability characteristics and increase the fouling on the membrane surface. In wastewater treatment, the characteristics of the aqueous influent can reduce the permeability of the membrane and the process efficiency of the membrane bioreactor (MBR). The aim of this paper is to explore the effect of different aqueous solutions on membrane permeability using dead end filtration process. For this purpose, NaCl solution with different concentration were prepared and the effect of the concentration polarization on the membrane was observed. The constructed membrane module was also tested with real water sample and the membrane permeability was analyzed.

In this experiment a polymeric membrane produced from polyether sulphonate (PES), with diameter of 5.0 cm and pore size of 0.04 μm was assembled in a constructed module for dead-end filtration. The module was constructed in a way that would allow turbulence of the solution on the membrane surface. The following working parameters were examined: transmembrane pressure (TMP), the types of solutions, the working temperature, and the influence of agitation on the feeding to the specific membrane flux and permeability. The results showed that the membrane permeability is affected by the water organic and inorganic constituents and in the process of design of membrane reactor for wastewater treatment, the water composition should be taken in consideration.

Keywords: membrane permeability, PES, dead-end filtration module, TMP

INTRODUCTION

The need for clean water is increasing every day. The pollution of a water resources and need for treatment is important key driving factor for development of new purification technologies. The ultrafiltration process uses a membrane as a selective barrier (Abdessemedet al. 2000). The pore size can be in range of 0.01 μm to 0.1. μm (Fane et al. 2010). Choosing the right membrane configuration and its material is crucial for each application, since it depends on obtaining good separation and yields. Ultrafiltration (UF) membranes have been challenged to maintain their flux stability (Bolton et al. 2006). The UF membranes can be used in wastewater treatment, constructed in a way to be integrated in a membrane bioreactor (MBR). The MBR is a novel approach in producing effluent with superb quality. But one of the main problems of this technology is that UF membrane is prone to severe flux decline (Boerlage et al. 2002; Jin et al. 2015). The main reason for the membrane flux decline canbe connected to accumulation of organic material on the membrane surface or the effects of inorganic constituents and concentration polarization of the membrane surface (Brauns et al. 2002). In addition, due to fouling impact and maintaining constant flux of the permeate, the operational pressure is

increasing, which further increases the energy consumption as well as operating cost with need for higher membrane area (Gao et al. 2011).

There are two main membrane pressure driven filtration technics. The first one is that produce permeate and retentate (rejected part) and is known as crossflow filtration, and the second one that only produce permeate without retentate and is known as dead-end filtration (Lee et al. 2003).In dead-end filtration, because of the retention of feed water constituents during ultrafiltration at constant transmembrane pressure, the flux changes in time (Poele and Van der Graaf, 2002; Li et al. 2020). For the design of the membrane processes it`s important to know how the flux will develop for a given time, especially in the design of MBR, where the effect of the solid has a heavy toll on the membrane permeability and fouling (Wuet al. 2006). But before determination of the solids effect, the effect of the water constituents on the membrane permeability and fouling should be known.

In terms of membrane material, membranes are classified as either organic or inorganic. Organic membranes are made from organic polymers. These include polyethylene (PE), polyethylene sulphate (PES), polytetrafluorethylene (PTFE), polypropylene (PP) and cellulose acetate among others (Aliyuet al. 2018). All of them have different permeability and hydrophilic properties. Inorganic membranes are made from ceramics, metals, zeolites, or silica carbide. They are chemically and thermally stable and used widely in industrial applications in the processes of ultrafiltration and microfiltration (MF) (Mallada and Menéndez,2008; Parket al. 2020).

Today, the membranes separation processes as microfiltration, ultrafiltration, nano filtration and reverse osmosis, are generally made from synthetic organic polymers (Cetinkaya and Bilgili, 2019). The wastewater treatment of membrane bioreactor is a combination of biological processes with activated sludge and membrane separation processes with UF or MF. The MBR are used for wastewater treatment purposes or for resource recovery from wastewater (Singh and Hankins, 2016; Judd, 2010). Over the past couple of decades, MBRs have emerged as efficient wastewater treatment technology as they fill in the gaps left by conventional activated sludge processes such as their inability to cope with fluctuations in effluent flow rates and composition as well as their failure to meet higher effluent discharge limits for reuse purposes or the tighter water legislatives. MBRs having much smaller footprint, also save much space compared to conventional treatment systems (Judd, 2016). Currently there are two configurations that are used, the side stream MBR and immersed MBR (Wanget al. 2020). The side stream MBR was the first to be developed. With the side stream MBR, the membranes or filtration element are installed outside the bioreactor, needing an intermediate pumping system which transfers the biomass to the filtration module and the concentrate from the filtration set up back to the bioreactor (Loet al. 2015). This set up is advantageous, in that the membrane module is easily accessible for cleaning, however, due to the high energy and pressure requirements, the side stream MBR have had limited application (Yanget al. 2006).

The aim of the paper is to investigate the membrane filtration permeability characteristics with different water solutions. It is experiment made to determine the effect of the water inorganic constituents and turbulence to the filtration characteristics of the membrane that is used for separation of the active sludge in bioreactor. There are studies for the membrane permeability when is used for separating the active sludge in the membrane bioreactor, but there a few experimental set-up regarding the composition of the inorganic constituents and filtration characteristics of the membrane where the active sludge effects on the membrane is neglected. In this work we used the water composition and turbidity, without the presence of the active sludge, to determine the permeability characteristics of a flat sheet membrane that is used as submerged membrane module in membrane bioreactor for wastewater treatment.

MATERIALS AND METHODS

The polyethylene sulphate membranes (PES) that were used were obtained from Microdyne-Nadir. The average pore size of the PES membrane was 0.04 μm (150 KDa). The PES membrane is used in the removal of macromolecules or concentration of large organic solutes in process applications and can be used for membrane bioreactor (MBR). NADIR PES flat sheet membrane is available in an A4 sample size of 210 mm x 297 mm and in a nominal roll size of 150 m x 1016 mm. As supporting layer for the PES membrane, polypropylene backing material is used. The membrane material was formed to have net membrane area of 0.009 m2. The module was constructed using polyvinyl chloride (PVC) parts and fittings that can withstand 8 bar pressure and was designed to fit the membrane of 9.07 cm^2. Using a build in membrane surface mixer, turbulence could be created on the membrane surface. It was connected to high pressure dosing pump and pressure gauge with pressure transmitter. The PLC was connected and the pressure in the system was maintained at 1bar. On the side a manual pressure gauge was installed. The valves were installed for controlling the process and if needed, for a pressure correction. The material used for the module and the system was tested at 5 bar pressure. The module was design for dead -end filtration. For the control of the process LOGO SOFT PLC was used. The constructed membrane module is shown in Figure 1.

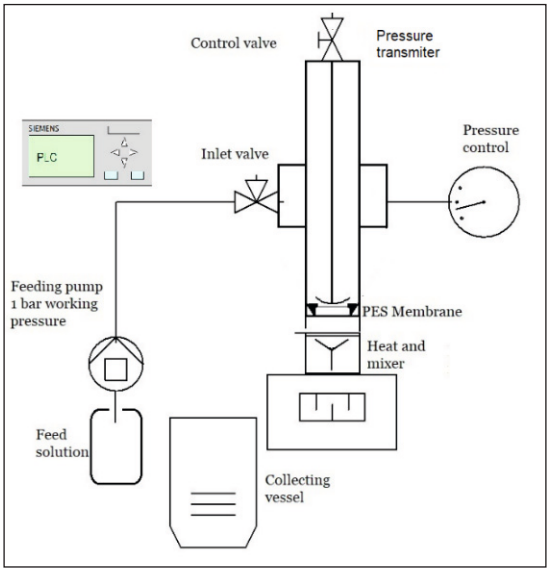

Figure 1. Schematics of the laboratory set up for dead-end membrane filtration

The membranes were shaped in circles with same dimensions. For the filtration, using different aqueous solutions, one membrane at a time was placed in the membrane module. The mechanical magnetic stirrer above the membrane surface was be used to promote the turbulence. The mixing speed was controlled with the magnetic stirrer below the module. For every new experiment, the membrane was replaced. The used membranes were not chemically cleaned or used again, instead, a new membrane was applied. The prepared aqueous solutions were placed in 5 L feed container. The container could be easily replaced every time when a new solution was used. The dosing pump feeds the solution into the module and maintains operational pressure of 1 bar. The permeate from the membrane filtration, was collected in a container that could measure the flow as mg/min or ml/min. The membranes that shaped from NADIR and used are shown in Figure 2.

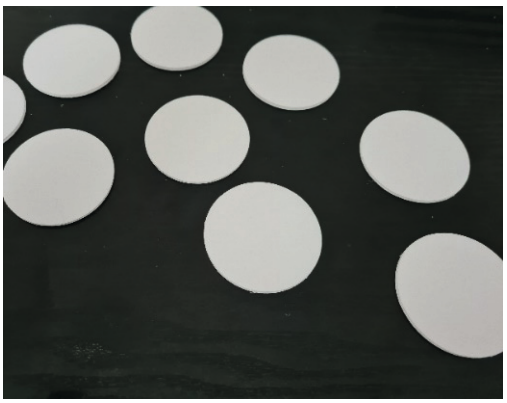

Figure 2. Shaped and prepared PES membrane for dead end filtration

The aqueous solutions used for this experiment were prepared with permeate water from reverse osmosis (R.O.) that has conductivity (EC) of 20 μS and pH=6.7. In this investigation, tap water with the characteristics shown in Table 1, obtained from Skopje city public water system and treated effluent from wastewater treatment plant at the airport in Skopje was also used. The analysis was made in the laboratory of the center for sanitary control, public enterprise for water supply and sewage of Skopje.

Table 1. Characteristics of tap water from Skopje

Parameter:	Value
pH	7.3
EC [μS]	540
COD_{KMnO4}	1.30
NO_3[mg/l]	6.50
SO_4^{2-}[mg/l]	6.80
Na^+ [mg/l]	7.10
Cl^- [mg/l]	7.10
HCO_3^-[mg/l]	434

The effluent that was obtained from Sequencing batch reactor (SBR), treating wastewater from airport terminal in Skopje, had the properties shown in Table 2. The analysis was made in the laboratory of the center for sanitary control, public enterprise for water supply and sewage of Skopje.

Table 2. Characteristics of effluent SBR from airport terminal in Skopje

Parameter:	Value
pH	7.3
BOD_5[mg/l]	12
COD_{Cr207}[mg/l]	42
NO_3^-[mg/l]	8.25
SO_4^{2-}[mg/l]	23.8
TSS [mg/l]	3.6

The aqueous solutions were prepared using reverse osmosis water with different concentrations of NaCl. The analysis of the water was conducted with LUTRON YK-2005 WA and Spectroquant Prove UV/VIS spectrophotometer. The reverse osmosis produced water was used for preparing 10% NaCl solution that would be used in the membrane filtration. The prepared solution was placed in a new container and feed to the system. During the experiment the membrane was replaced with a new one and the membrane module was cleaned.

In dead-end filtration, the relation between the permeate flux gravimetrically measured at different time intervals and TMP is defined by the fallowing Equation 1, that is the modified Darcy`s equation for describing the role of different fouling resistances that cause flux decline on the membrane (Rushton et al. 1995; Sousa et al. 2020).

$$J_p = \frac{1}{A_m}\frac{d\, m_p}{\rho\, dt} = \frac{\Delta P}{\mu\,(Rt+Rf)} \quad (1)$$

where J_p is the permeate flux (l/m^{2}h), A_m is the effective membrane area (m^2), m_p is the total mass of permeate (kg), ρ is the volumetric mass density (kg/m^3), t is the filtration time (s), ΔP is transmembrane pressure drop (Pa), μ is the filtrate viscosity (Pa·s), Rm is the intrinsic membrane resistance (1/m) and Rf is the fouling resistance (1/m).

The membrane flux can be calculated using Equation 1 and the fallowing derived Equation 2 (Judd, 2010).

$$J = \frac{Q_{permeate}}{A_{membrane}} \quad (2)$$

where J (l/m^2 h) is the membrane flux and Q is the amount of permeate produced from the installed active membrane area A of 1 m^2 in one hour. The standardized membrane permeability (l/m^{2}h bar) at 20˚C was calculated using the Equation 3 (Judd, 2010).

$$J_{20} = \frac{J \cdot 1.024^{(20-T)}}{\Delta P} \quad (3)$$

where $J_{20(l/(m^2h\ bar))}$ is the normalized permeability of the membrane at 20˚C and (bar) is the transmembrane pressure.

RESULTS AND DISCUSSION

The different types of aqueous solutions were prepared and set for continuously feeding to the membrane module. The membrane flux and the TMP were measured. Then the normalized membrane permeability at 20 ˚C was calculated. During the filtration period back flush of the membranes was not applied.

The membrane permeability with tap water is shown in Figure 3. In the first hour there is a permeability decrease, that is a result of the water constituent, concentration polarization and membrane resistance to the filtration process. The filtration was carried out without promoting turbulence on the membrane surface. The initial permeability with tap water was calculated as 277 l/ m^2 h bar. In the research made by Li et.al (2019), using the filtration cell Amicon 8400 and ultrapure water, the initial flux for 150 KDa PES membrane was calculated in the range of 410 l/ m^{2}h bar in. According to the producer of the membrane, the initial clean water flux of the membrane is 285 l/ m^{2}h (Microdyn-Nadir, Germany).

In the test results obtained by the producer using stirred cell 700 RPM with 0.7 bar pressure at 20°C the membrane clean water permeability is characterized as more than 200 l/ m^{2}h bar (Debien et al. 2013).

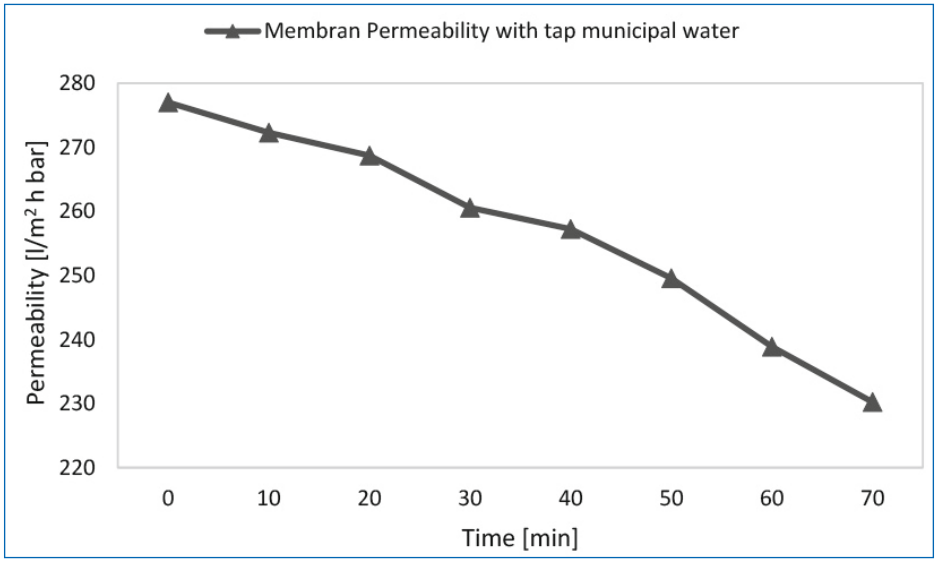

Figure 3. Permeability characteristics of PES membrane with tap municipal water

Then, the aqueous solutions were prepared using permeate water from reverse osmosis with conductivity EC=20 μS and pH=6.7. The water from reverse osmosis was placed in the container and feed to the designed module. The surface mixing was not activated and no turbulence on the membrane surface was promoted. The parameters were monitored for 2.5 hours. Then the membrane was replaced with a new one and the solution again was feed to the module. This time, during the dead-end filtration, the mixer in the module was activated and turbulence was promoted.

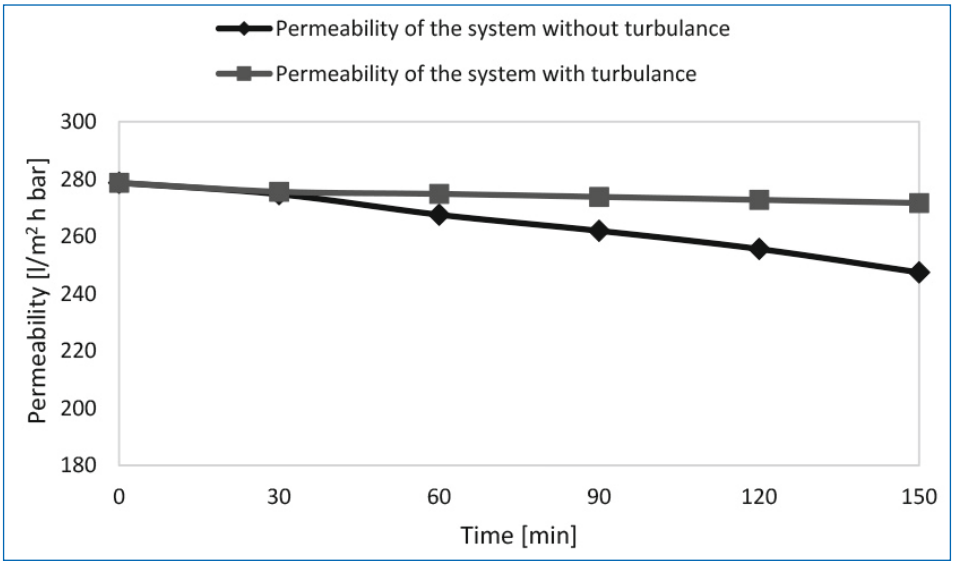

Figure 4. Permeability characteristics of PES membrane with R.O. water and surface mixing

The results are shown in Figure 4 and can be seen that the permeability characteristics of the membrane are better when turbulence is promoted. There is a permeability decrease with both aqueous solution but with adding turbulence to the membrane surface, the permeability reduction is steadier. This is due to the effect of reducing the surface concentration polarization and the membrane fouling effect, making the membrane flux more sustained. Figure 5 shows the permeability characteristics of the PES membrane with 10% NaCl solution, where there is no mixing on the membrane surface to promote the turbulence. Adding NaCl to the system increases the concentration polarization of the membrane and reduces the membrane permeability characteristics withing minutes during the dead-end filtration.

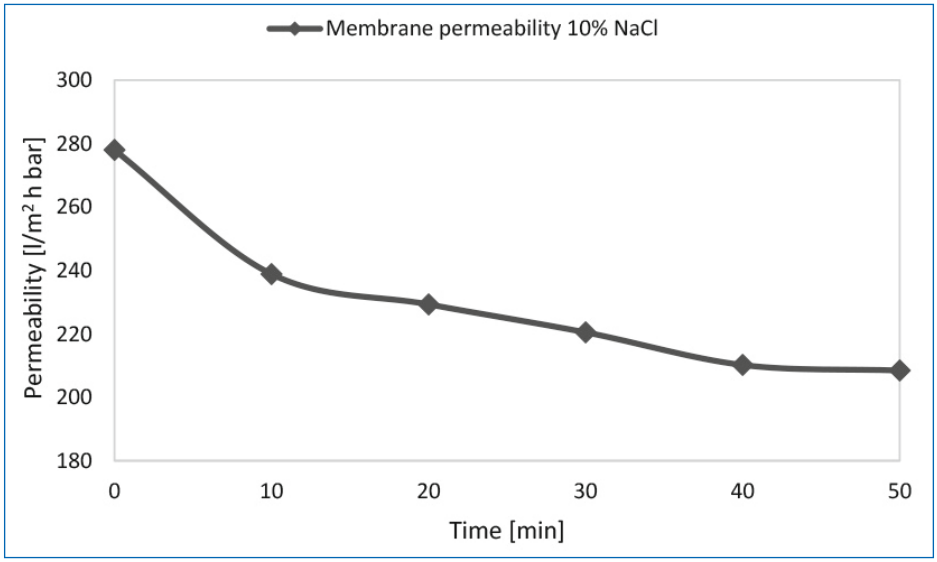

Figure 5. Permeability characteristics of PES membrane with 10% NaCl without mixing

Then the membrane was replaced with new one and the filtration continued with activating the mixing unit and promoting turbulence on the membrane surface. The results of the membrane permeability are shown in Figure 6. In Figure 6 are shown the permeability characteristics of PES membrane with 10% NaCl and promoting surface turbulence. In the beginning of the experiment, when using 10% NaCl aqueous solutions as feed to the module as shown in Figure 5 and Figure 6, the promotion of turbulence did not affect the permeability of the membranes. But after some time, as the dead-end filtration was continuing, the difference in permeability characteristic were clearly visible.

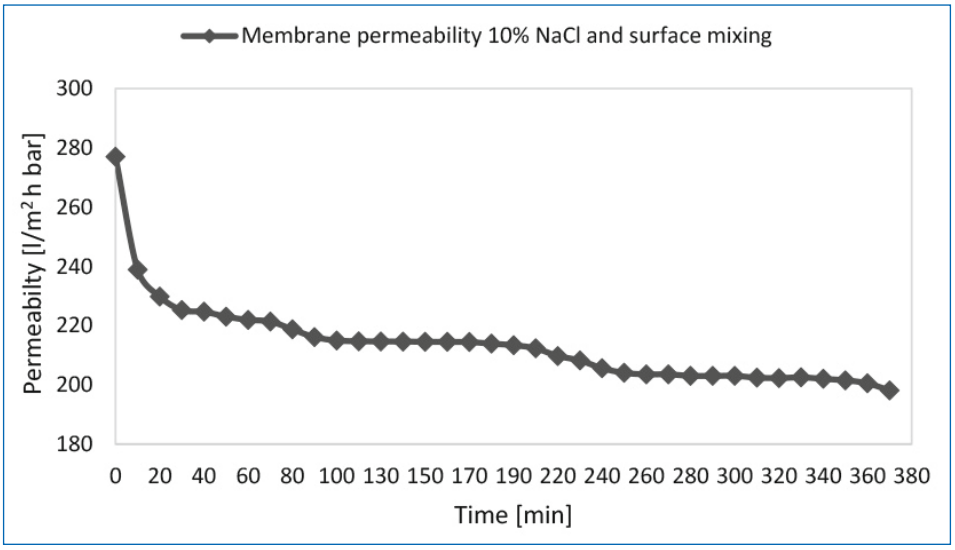

Figure 6. Permeability characteristics of PES with 10% NaCl with mixing

The permeability of the membrane is clearly affected by the water compostion and the type of filtration.Adding turbulance to the filtration proces gives better permeability caracteristcs of the membrane.

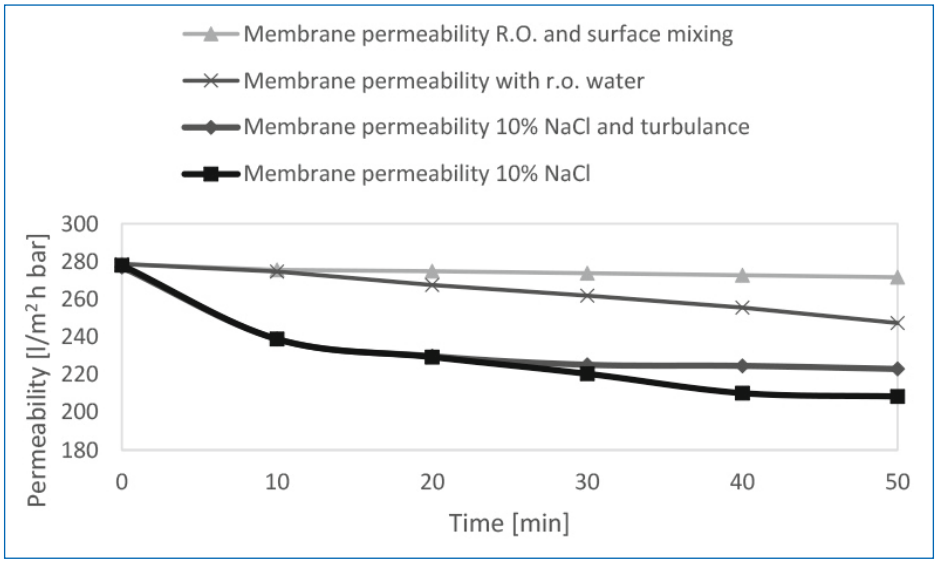

Figure 7. Permeability characteristics of PES membrane with different feed water characteristics and mixing

The differnces in the membrane permeability when using aqueus solutions with different characteristics and different filtration strategies with or without adding turbulance on the membrane surface is shown in Figure 7. At the end of the experiment a new membrane was used for dead-end filtration with 20% NaCl solution. The results from this filtration and membrane permeability are shown in Figure 8. During the filtration membrane surface turbulence was not promoted.

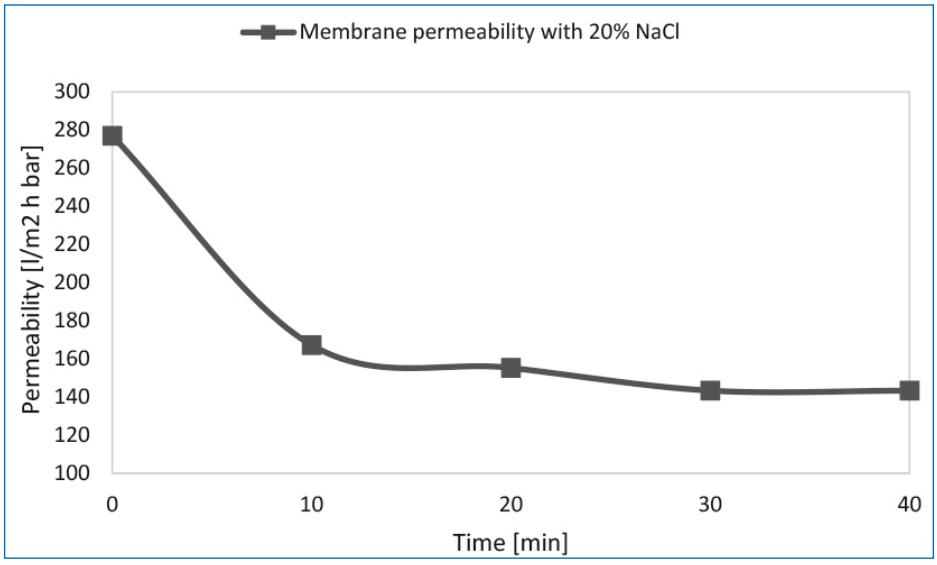

Figure 8. Permeability characteristics of PES membrane with 20% NaCl solution without mixing

When comparing the membrane permeability characteristics where there is no turbulence promoted and dead-end filtration is used, we can see as the concentration of the constituents is higher the permeability starts to drop faster. In Table 3 are presented the permeability characteristics of the membrane with different aqueous solutions, where membrane surface turbulence is not promoted. The higher the concentration of NaCl, the faster the permeability decline is observed. The inorganic constituent in the water clearly affects the permeability decline of the membrane. With time their concentration increases, consequently a boundary of higher surface concentration is created. On the other hand, the mixing and creating surface turbulence improves the permeability characteristics of the membrane.

Table 3. Membrane permeability within time using different aqueous solutions.

Time [min]	Membrane permeability with sanitary water	Membrane permeability with 10% NaCl	Membrane permeability with 20% NaCl
0	277	278	277
10	272.2682	269.253	167.1975
20	268.7102	238.8535	155.2548
30	260.5675	229.2994	143.3121
40	257.2268	229.2994	13.3121

In general, differences in membrane composition are related to differences in filtration characteristics (Boerlage et al. 2003;). In the research made by Roorda (2004) the tested membrane permeability with pre-treated wastewater treatment plant effluent was in range of 170-250 l/m^2 h bar and the maximum flux for stable performance showed large differences. As the applied membrane systems were comparable, the major determining factor for the membrane fouling problems should be related to the feedwater composition (Roorda, 2004). In the last experiment, the effluent from an SBR that is treating wastewater from an airport treatment plant was collected.

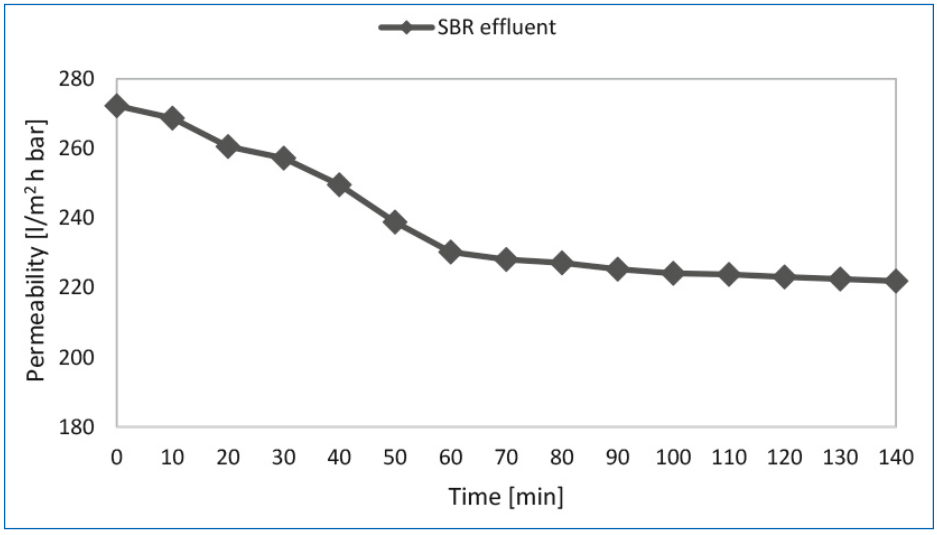

Figure 9. Dead-end filtration using SBR effluent

The SBR is designed for operating in 4 cycles per day with effluent sand filtration unit. It is treating 75 m^3/day wastewater originating from the Airport passenger terminal in Skopje. The collected effluent was used as a feed solution to the dead-end membrane filtration module, shown in Figure 9.

The decline in permeability is alike to the membrane filtration with tap water characteristics, as the concentration polarization is having a similar effect. The difference in the membrane permeability originates from the concentration of organic constituents in the SBR effluent. These results indicate that the components retained on the membrane surface predominantly determine the filtration characteristics.

CONCLUSION

The membrane reactors are state of the art systems. They are used for water and wastewater treatment. The membrane filtration always leads to increase membrane resistance to the permeate flow. The transmembrane pressure (TMP) is one of the key parameters when operating with membrane filtration and

shows the tendency of membrane fouling. To keep the permeate flow constant, the applied membrane pressure should be increased, thus resulting in higher energy consumption. Another option is to install higher membrane area which would increase the investment costs.

The stability of the process is important for any MBR. The membrane permeability is important factor when designing membrane reactors, especially membrane bioreactors (MBR). In this investigation, the result showed us that the membrane flux can be seriously affected by the aqueous solutions constituents. The concentration polarization on the membrane surface can have a negative impact on the membrane flux. In the design approach of the MBR, detailed characterization of the solution must be made. In the feed water, the organic and inorganic foulants can be pre-determined. Only then we can minimize the effect of the concentration polarization and the membrane fouling in the MBR, and with the right membrane area applied, we can have a stable permeate flux and lower energy consumptions. The findings of this study would provide theoretical supports for the control and design of the MBR in treatment of urban wastewater. The results show as that this type of membrane with adding turbulence can be used in construction and design of MBR whit ultrafiltration properties where the water composition plays an important role in membrane permeability reduction.

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Original scientific paper

The Influence of Recreational Aerobics on Subjective Assessment of Psychosomatic Status of Women

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ABSTRACT: Sedentary life significantly affects the working abilities and health status of middle-aged women. On the other hand, appropriate systematic exercise can have a preventive effect on reducing symptoms and the appearance of some diseases, and thus have a positive effect on improving psychosomatic status. The research aimed to determine the subjective assessment of the psychosomatic status of women under the influence of recreational aerobics. The population from which the sample was drawn is a population of healthy women, age from 35 to 45 years, who dominantly live a sedentary lifestyle. For this study, a scale of subjective psychosomatic status assessment (SPPPS) was applied. The scale consists of 32 characteristic discomforts (disorders) which are divided into eight groups: shoulder and arm pain; back pain; leg pain; fatigue and sensorial discomfort; indigestion; cardiovascular disorders; neuropsychiatric disorders, symptoms of general fatigue. The Wilcoxon Signed Ranks test revealed statistically significant changes ($p = 0.000$) in all analyzed variables between initial and final measurements. Based on this finding, it can be concluded that recreational aerobics has a positive effect on improving the psychosomatic status of sedentary middle-aged women.

Keywords: recreational aerobics, subjective assessment of psychosomatic status, middle-aged women.

INTRODUCTION

A sedentary lifestyle causes serious health problems, negatively affects health, and causes many disorders (Çolakoğlu 2003, Biçer et al., 2005). A habit in an inactive lifestyle is one of the most important diseases affecting human health (Aydos and Dönmez 2000). An active lifestyle increases one's life energy and mobility and frees a person from an inactive life (Arcury et al., 2006). We must emphasize that the World Health Organization has set a goal for all countries to introduce, actively manage and control programs that improve healthy lifestyles (Van Herten LM et al., 1999). For a healthy life and quality-of-life improvement, physical activity is considered a necessary need of all people. Physically active people consider their active lifestyles to be a key factor in increasing the quality of long and healthy life (Haskell et al., 2007; McGrath et al., 2011). A sedentary lifestyle is associated with an increased risk of acute myocardial infarction and death from coronary heart disease (Kokkinos et al., 1995), and coronary heart disease is the cause of death in most countries of the world (Buyukyazi, 2008). This risk is approximately twice as high in inactive individuals compared to physically active people (Kokkinos et al., 1995). Physical inactivity has been recognized by the American Heart Association as an independent risk factor and comparable to other identified risk factors for coronary heart disease (Fletcher et al., 1992). Middle-aged women (35-45 years) who live a sedentary life, especially women who do office work, are exposed to risk factors due to insufficient movement, and the premenopausal period is marked by additional difficulties because of hormonal level changes. At this stage of life, most women are mostly familial, but they are left with great concern for their parents, who, among other things, pose an additional problem to change the concept of inactive to an active lifestyle. Premenopausal women are aware of their health status, and one of the ways to positively affect their psychophysical health and work abilities is certainly systematic recreational exercise.

With systematic exercise, we can prevent non-communicable diseases such as hypertension, diabetes, cardiovascular diseases, as well as other diseases. If we want to influence general health through exercise, then it is recommended to apply programs for improving cardiovascular endurance (CVE) because they are the most important measure of overall health (Koksal et al., 2006). A person's level of cardiovascular endurance helps prediction of disease likelihood, quality of life, and ability to respond to acute physical and mental stress (Forbes, 1991). Corbett (2009) implied that "For healthy individuals, higher cardiovascular endurance indicates an increased level of physical ability." The aerobic exercises applied in this research, use large groups of muscles to increase the pulse, which with their faster work cause deeper breathing as well as higher oxygen consumption. This is evidence that cardiovascular endurance improves after aerobic exercise and therewith causes positive changes in the body's cardio-respiratory system (Probart et al., 1991).

One of the ways how we can assess current health is through a subjective assessment. Subjective health or self-assessment of health is used in health research (Congdon, 2001) and is considered one of the most reliable indicators for health status evaluation (Okano et al., 2003) as well as a strong predictor of mortality (Tsuji 1994, Kaplan et al., 1996; Idler and Benyamini, 1997; Sundqist and Jonson, 1997; Miilunpalo et al., 1997). McKee and Ryan (2003) consider subjective health assessment to be a significant indicator of health. Determining the health status of an individual and a group by self-assessment is now done with standardized questionnaires in epidemiological and populational research. Self-assessment of health, as a subjective measure, is related to human well-being, because it includes the assessment of both physical and emotional health. For most people, subjective health is primarily a determinant of quality of life-related to health (Despot Lučanin et al., 2006). The basic concept of subjective health assessment is that people have a sufficient degree of control over their health behavior and the belief that behavior has a certain impact on their health (Lim, 2021). Physical activity can affect subjective health assessment (Sun et al., 2016) and significantly reduce the risk of cardiovascular disease, overweight, obesity, and diabetes (Van den Berge et al., 2016). For health promotion and prevention of chronic diseases, endurance training of moderate intensity (60% to 75% of maximum heart rate) is recommended, at least 3-5 times a week for 30-45 minutes (De Backer et al., 2003). To test our hypothesis, we devised an experiment in which the treatment was recreational aerobics, and the dependent variable we had an interest in were changes in self-assessment of participants' subjective psychosomatic status after the experiment. The scale of subjective psychosomatic status assessment (SPPSS) used in this study is a comprehensive health self-assessment. The scale was first developed by Blagajac et al. (1992) and it has been accepted through studies on the subjective assessment of psychosomatic status.

In previous research, the effects of different exercise models on health were determined, and health assessment was also measured using different questionnaires. This research differs from the previous ones in that the sample consisted of premenopausal sedentary women aged 35-45 who did office sitting jobs and a recreational aerobics experiment was performed and changes in the subjective assessment of psychosomatic status were determined.

MATERIALS AND METHODS

Sample of participants and variables

The study was conducted on a sample of 38 female participants, aged 35 to 45 years. For this study, women who do sedentary office work were randomly selected. They underwent a medical examination and had to be healthy for inclusion in the systematic exercise under the "Recreational Aerobics" program.

Respondents who participated in the study had to meet the following criteria: to be workers and to do office work in a sitting position; that they have no somatic defects or diseases; not to engage in other organized forms of physical activities other than participating in the "Recreational Aerobics" program; to participate in the exercise regularly (three times a week) and to have voluntarily accepted the exercise program. There were 36 recreational aerobics training (classes) led by a licensed aerobics instructor. Participants were also given instructions on the benefits of exercise and proper nutrition. Before and after the exercise program, the Scale for subjective assessment of psychosomatic status - SPPSS (Blagajac, 1992; Vučković, 2003) was applied to evaluate the impact of the experimental treatment. The SPPSS scale consists of 32 characteristic ailments (disorders) that are divided into eight groups: shoulder and arm pain; back pain; leg pain; fatigue and sensorial discomfort; indigestion; cardiovascular disorders; neuropsychiatric disorders; symptoms of general fatigue. Each participant estimates the existence and severity of each of the 32 listed disorders. In this way, a numerical expression of the subjective assessment of the severity is attained for each disorder on a scale of 1-9 (from 1 - does not feel to 9 - unbearable) and the average value of the assessment for each of the eight groups of problems, as well as for the whole scale.

Experimental treatment

The recreational aerobics program lasted for three months, ie. 12 weeks. Training sessions were held three times a week in the evening. Each training lasted 60 minutes and was realized according to the basic structure of aerobics classes: warming up, the main part of the training, cooling down and stretching (Zagorc, Zaletel and Ižanc, 1998). The intensity of the exercise was determined by the tempo of the music, which changed during the training (differed in accordance with the parts of the training). Warming up (8-10 minutes, tempo music 120-135 bpm, march, step touch, side to side) means preparing the whole body for the following efforts, in order to increase body temperature and blood circulation (Brick, 1996). The main part of the training includes the aerobic (A) part and body shaping exercises (Part B - treatment of specific muscle groups). The aerobic part (20-30 minutes, tempo 135-155 bpm, combinations of Low impact and High impact steps) contains activities aimed at the development of the cardiovascular and respiratory systems (Mišigoj-Duraković, 1997). The conditioning part of the class (Part A) is programmed so that the subjects are in the aerobic zone during workout. The load was measured based on internal indicators (heart rate) by palpation on the carotid artery after a given block of exercises (during the break between the next set of exercises). Based on the obtained heart rate, the intensity of the load was monitored during the realized task. Before each activity, participants knew what the expected heart rate during the activity is. Within the B part of the training (10 minutes, tempo 120-135 bpm), exercises were performed to strengthen the abdominal muscles, back, arms and shoulder girdle, abductors and adductors and gluteal muscles (Furjan - Mandić et al., 2011). Cooling down and stretching (5-10 minutes, tempo up to 100 bpm, relaxation, and static stretching exercises) in this part of the training primarily aimed to lower the heart rate. After that, gradual transfer from standing to sitting and lying position on the abdomen and back is performed, with a combination of relaxation and stretching exercises of fatigued muscles, all with appropriate music that enhances mental and psychological relaxation (Kostić, 1999; Nićin, 2003). The recreational aerobics program is adapted to the participants' age and is designed to include exercises and movements that activate muscles that are not sufficiently engaged during professional work. Training sessions are planned for each month and adjusted to the volume and intensity of the load, and the participants' capabilities. The optimal load intensity was determined according to the limits of 60% to 85% of the maximum heart rate (Stojiljković, 2005), which means that in the first month the load ranged from 60–65% of the maximum individual's heart rate, and in the second month 65–75%. In the third, the last month of the experiment, the load was in the zone of 75–85% of the maximum individual heart rate.

Statistical data analysis

Data collected during the survey were processed using the IBM SPSS 20.0 personal computer statistical application program. For the analysis of basic statistical data and distribution of results at the initial and final measurement, the basic descriptive parameters - arithmetic mean and KS test of normality of distribution of results were calculated. The Wilcoxon Signed-Rank test was used to test the difference between the initial and final state of the subjective assessment of psychosomatic status. The statistical significance was determined at the level of $p < 0.05$.

RESULTS AND DISCUSSION

The analysis of the health status of the participants was performed using a questionnaire that contained 8 composite variables. They are formed by summing the scale scores of assessment indicators that are grouped on these variables. Given the initial characteristic of the assessment scale that belongs to the ordinal level of measurement, we checked the normality of the distribution of the formed composite variables (Table 1) to choose further data processing. The obtained values of the Kolmogorov-Smirnov test indicate the fact that the distributions of the obtained variables in most cases deviate statistically significantly from the normal distribution, especially on the initial measurement.

Table 1: Normality distribution test of variables for subjective assessment of the psychosomatic status of the participants at the initial and final measurement

Variable	Initial			Final		
	AS	KS test	p	AS	KS test	p
Shoulder and arm pain	5.78	1.75	.004	9.42	1.07	.202
Back pain	5.57	1.28	.074	9.73	.67	.760
Leg pain	5.65	1.23	.097	9.52	1.12	.162
Fatigue and sensorial discomfort	5.60	1.30	.065	8.68	.88	.408
Indigestion	3.81	2.14	.000	4.92	1.65	.009
Cardiovascular disorders	6.26	1.08	.188	11.21	.91	.368
Neuropsychiatric disorders	7.68	1.14	.148	11.60	.92	.363
Symptoms of general fatigue	7.52	1.12	.160	12.28	.88	.409

Table 2: Analysis of differences between initial and final subjective assessment of the psychosomatic status

Variable	Rank	N	Mean rank	Z	p
Shoulder and arm pain	Negative rank	2	4.00		
	Positive rank	26	15.31	-4.452	.000
	Equal rank	10			
Back pain	Negative rank	1	2.50		
	Positive rank	32	17.45	-4.985	.000
	Equal rank	5			
Leg pain	Negative rank	1	7.00		
	Positive rank	30	16.30	-4.738	.000
	Equal rank	7			

Fatigue and sensorial discomfort	Negative rank	2	2.75		
	Positive rank	24	14.40	-4.335	.000
	Equal rank	12			
Indigestion	Negative rank	3	9.17		
	Positive rank	17	10.74	-2.911	.000
	Equal rank	18			
Cardiovascular disorders	Negative rank	1	3,00		
	Positive rank	33	17.94	-5.052	.000
	Equal rank	4			
Neuropsychiatric disorders	Negative rank	2	4.50		
	Positive rank	31	17.81	-4.862	.000
	Equal rank	5			
Symptoms of general fatigue	Negative rank	1	2.50		
	Positive rank	33	17.95	-5.053	.000
	Equal rank	4			

When the difference between the initial and final subjective assessment of the psychosomatic status of the participants is analyzed (Table 2), it is noticeable that the values of the Z coefficient are high, positively oriented ranks predominate, i.e., higher score values on the initial measurement. The differences in all analyzed variables are high and statistically significant. The conclusion is that upon the utilization of treatment, the subjective assessment of the psychosomatic status of the subjects of the experimental group "Aerobics" significantly improved.

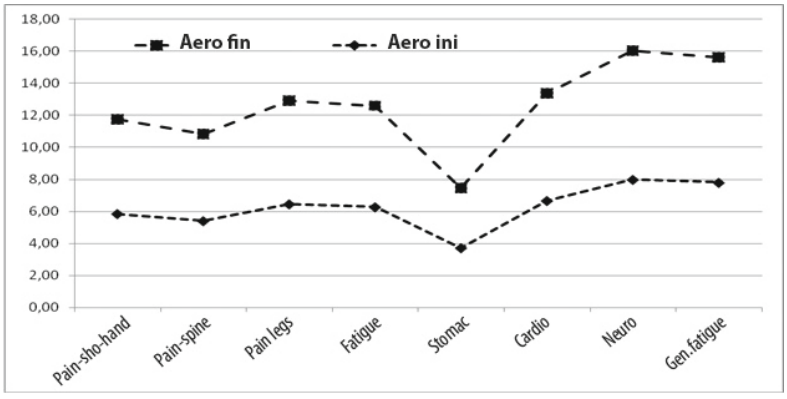

Figure 1. Linear changes in psychosomatic status indicators

This study aimed to examine whether exercise based on the recreational aerobics model improves the psychosomatic status of middle-aged women who do office sedentary work. For this purpose, 38 middle-aged women (35–45 years), who completed a questionnaire on subjective assessment of psychosomatic status before and after the experiment, were included. Variables were assessed to assess the psychosomatic status of women with eight groups of symptoms - pains, namely: shoulder and arm pain, back pain, leg pain, fatigue and sensorial discomfort, indigestion, cardiovascular disorders, neuropsychiatric disorders, and general fatigue symptoms. The results show that the differences between the initial and final subjective

assessment of the psychosomatic status of the participants (Table 2), in all variables are high and statistically significant. The values of the Z coefficient of the analyzed variables are high and positively oriented ranks predominate, i.e., higher score values on the initial measurement. The largest differences were registered in the variables: symptoms of general fatigue (Z = - 5.053, p <.000) and cardiovascular disorders (Z = -5.052, p <.000), and they are slightly weaker in the variable back pain (Z = - 4.985, p <.000). The weakest results, but statistically significant, were achieved in variable indigestion (Z = - 2.911, p <.000). Other variables, neuropsychiatric disorders (Z = - 4.862, p <.000); leg pain (Z = - 4.738, p <.000); shoulder and arm pain (Z = - 4.452, p <.000); fatigue and sensorial discomfort (Z = - 4.335, p <.000) showed moderately statistically significant results.

These results were expected given that the participants were inactive before joining the experimental program, and they were not included in any systematic physical exercise. It is very easy to bring the organism to the general fatigue, it is only necessary to do sedentary work. Symptoms/discomforts of monotony, drowsiness, insomnia, feeling weak and sluggishness of movement can be easily eliminated by aerobic training. Certainly, everyone needs a personal diagnostic, a recommendation of a specific exercise program and a professional instructor who will supervise the work, control and determine the load, and motivate the program participants. However, the best results (symptoms of general fatigue) indicate that office sedentary work caused general fatigue that should be compensated by another type of activity, the opposite to work-related one. A good indicator of the previous statement is the result achieved in the second variable cardiovascular disorders (shortness of breath, faster fatigue, profuse sweating, chest pain) with the achieved result Z = -5.052, p <.000, where the recreational exercise program had a good - opposite effect of professional work. Cardio exercises of recreational aerobics have a good effect on cardiovascular health (prevention of myocardial infarction, normalization of blood pressure, better blood circulation of the muscular and vascular system, strengthening of lung capacity). It is hard to tell which symptom should be addressed first, but cardiovascular health can prevent most other diseases. Symptoms of back pain (neck area, chest area, lumbar area) are typical pains due to the lack of stretching of the spine and the profession associated with sitting jobs. Stretching allows for better blood flow to the spine muscles as well as all the vertebrae of the spine. In our therapeutic recreational aerobics, each workout included spinal stretching exercise complexes resulting in this improvement. Our results suggest that the symptoms of indigestion (nausea, indigestion, loss of appetite) are weaker, but statistically significant (Z = - 2.911, p <.000). We believe, as confirmed by this research, that moderate aerobic training, a balanced diet, and life hygiene can alleviate these problems. Other variables, neuropsychiatric disorders (Z = - 4.862, p <.000); leg pain (Z = - 4.738, p <.000); shoulder and arm pain (Z = - 4.452, p <.000); fatigue and sensorial discomfort (Z = - 4.335, p <.000) showed moderately statistically significant results. If we analyze these variables and their symptoms, it can be concluded that the cause of most of these symptoms is constant sitting and mental strain with the dynamics of work conditioned by deadlines. Furthermore, we can accept that with prolonged sedentary jobs there is a lack of movement during working hours, sitting causes a lack of necessary circulation in the extremities, breathing and pulse are in a much lower load, which slows down and insufficiently activates the functions of organ systems and the body as a whole. Some studies that have dealt with similar issues and in which the results corroborate in some variables with our study are mentioned in the further text of the paper.

A questionnaire on the subjective assessment of the effects of exercise (functional and motor abilities, mood, reduction of health problems - Trkulja Petković, 2000) on the life quality of middle-aged women was used by Katić et al. (2018). The study included two groups of middle-aged women (Group A: up to 5 years of exercise experience and Group B: over 5 years of exercise experience) who attend dance recreational activities. The participants from group B achieved statistically significant higher results in all

statements on subjective assessment of the effect of dance recreational activities compared to participants from group A. The biggest differences were observed in the following statements: I maintain body weight more easily, I move easier and safer, my self-confidence has improved, I am more satisfied with my appearance, and I made new friends. The authors concluded that the active participation of middle-aged women in dance recreational activities has a positive effect on their life quality and contributes to the experience of better life satisfaction. The participants from group B attained statistically significant higher results on all statements of subjective assessment of dance recreational activity. The largest differences were noted in the following statements: I maintain body weight more easily, I move easier and safer, my self-confidence has improved, I am more satisfied with my appearance, and I made new friends.

The scale for subjective assessment of psychosomatic status was applied by Vučković (2003) on 100 participants who were subjected to an experiment with different models of recreational activities and physio-prophylactic procedures. By factor analysis, seven factors were extracted (emotional lability, locomotor apparatus pain, indigestion, exhaustion, shortness of breath, leg pain, sensorial fatigue) that author regards as important ones to lower the subjective feeling of existence of most indicators (health problems and disorders) in all eight groups. The author concludes that the scale is suitable for diagnostic and prognostic purpose, as well as for the assessment of the effects in individual models of sports recreation.

The level of physical activity and subjective assessment of health status was researched by Jurakić (2009) on a representative sample of the working, middle-aged population, from 40 to 65 in the Republic of Croatia. The total sample consisted of 766 participants (52% women and 48% men). The IPAQ questionnaire was applied to assess the level of physical activity, and the SF-36 questionnaire was used to assess health status. The study aimed to determine the status and relationship between physical activity and health status of middle-aged workers in the Republic of Croatia and to classify the participants into homogenized groups concerning physical and mental strain in the workplace and determining groups' interest in sports and recreational programs in order to design appropriate models of sports and recreational programs. The study has determined the middle-aged workers' level of physical activity. The results indicate that the recommended level of physical activity in leisure time, which is 30 minutes of moderate-intensity physical activity five times a week, is reached by 29.67% of men and 32.75% of women, meaning that approximately two-thirds of participants are not physically active enough. Furtherly, a negative correlation between physical activity at work and physical activity during commuting with subjectively assessed physical health and a positive correlation between physical activity in leisure time with subjectively assessed physical and mental health were determined. The author concluded that there is a positive correlation between physical activity in leisure time and health in middle-aged workers in Croatia.

CONCLUSION

Exercise based on the "Recreational Aerobics" model improves the psychosomatic status of middle-aged women who do office sedentary work. The variables used to estimate women's psychosomatic status had statistically significant changes after the experimental treatment. The best results were obtained in the variables symptoms of general fatigue, cardiovascular disorders, and back pain. Considering that the experimental treatment has achieved positive results on the psychosomatic status of middle-aged women, the latter can be recommended for leisure activities. The authors also suggest testing of other recreational exercise models, e.g., recreational swimming, where the influence of the exercise in water on the health status of middle-aged women would be examined.

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Professional Paper

Risk Factors in Musculoskeletal Disorder Development in Children Connected With the Extended use of Information and Communication Technologies

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ABSTRACT: ***Introduction:*** The way of life in modern society goes along with new technological discoveries and achievements. This lifestyle leaves its positive and negative consequences on children. Such changes are especially reflected on health already in earliest stages of life. The studies show that most children have been using computers even since kindergarten and that children's computer use is longer than recommended. It is more effective and cheaper to prevent musculoskeletal disorders than to cure them. ***Goal:*** To examine all risk factors concerning the development of musculoskeletal disorders connected with a long use of information and communication technologies by reviewing scientific literature. ***Material and methods:*** Non-experimental qualitative research into the risk factors of the development of musculoskeletal disorders connected with a long use of information and communication technologies based on relevant databases. ***Results and discussion:*** Based on a discussion of the attitudes and opinions of other authors, risk factors are divided in three basic groups: ergonomic, individual, and psychosocial risk factors. As it is shown in the discussion of this paper, a disbalance of the desk for a desktop computer, the non-ergonomic design of the furniture, the type and time of the ICT usage device, the sedentary way of using the ICT devices at school and at home are just some of the numerous risk factors to children's health. ***Conclusion:*** By examining the risk factors in the development of musculoskeletal disorders in children connected with an extended use of information and communication technologies, the presented evidence in the discussion section based on other authors' attitudes and opinions, leads us to the conclusion that numerous risk factors that affect children's health are due to a larger and more frequent use of computers, console games, tablets and mobile phones.

Keywords: Risk factors, information and communication technologies, musculoskeletal disorders, health, children.

INTRODUCTION

Nowadays students are more often to experience their reality through a virtual world that leaves negative consequences on their mental and physical health. The virtual world of imagination that is shaping itself for a purpose of mass use, decreases the possibility of personal imagination and divides it from the real world and personal initiative, thus creating stereotypes of unified mentalities (Andrijašević, 2009). Most children are constantly looking at mobile phones, tablets, and spend most of their time playing games, miss physical and health education classes, and go to school by car (Badrić et al., 2011). The recent technological progress inspired a new

movement of portable, compact and personalised IT devices, such as laptop, tablets and smartphones sensitive to touch. Mobile phones can be useful in a wide range of physical environments at the time of acquiring position range. In other words, everything can be considered as an IT work environment nowadays (Petrić et al., 2019). The studies about the position of school children while using IT as a work environment were mostly at school (Ciccarelli et al., 2011). The way of life in modern society goes along with technological discoveries and achievements. This way of life leaves its positive and negative consequences on children. Such changes are especially reflected on health in the earliest childhood (Ciccarelli et al., 2015). Children and young people have much more free time than adults, and because of their specific biopsychosocial status in the environment and society, their free time must be organised and specific, and not left to chance (Prskalo et al., 2010). The population of students of all ages is affected by hypokinesia, regardless of where they live, resulting from sedentary way of life (Berčič, 2010). The life habits such as inactivity, reduced walking and reduced mobility of the entire locomotor system have been adopted (Berčič, 2010). The sedentary way of life leads to an unbalanced growth of muscular groups (Badrić & Barić, 2006). Although bad posture does not always mean bad health, maintaining good posture helps body to function better in everyday life. Considering that the problem of improper posture in children, which is one of the most relevant problems of modern society, begins at an early age, it is important to recognise it on time and diagnose it accurately (Badrić & Prskalo, 2011). The surveys show that most children from the time of enrolling in kindergarten use computers and use them longer that that is recommended (Berisha, 2015). Sitting is a burden for the spine, especially improper sitting, that leads to other negative consequences. It is important to carry out timely measurements of the spine so deviations can be detected on time (Robotić, 2015). A disbalance between the dimensions of school furniture and the anthropometry of the body is one of the main reason that leads to pain and musculoskeletal disorders in various parts of the child's body. There is limited research about postural risks connected with children's IT use at home (Rapajić, 2015). When they are at home, children will probably use their mobile phones to spend their free time and social activities. At home they take several different positions when using IT, and use IT technologies longer to finish their tasks than when they are at school (Namwongsa et al., 2018). Laboratory studies show extreme angles of the cervical part of the neck spine and a deeper head flexion. The surveys in adolescents show a bigger risk of neck pain, lower part of the spine as well in eyes after a long use of the laptop (Dockrell et al., 2012). Time spent on the computer involves a muscular activity of a low level in the area of the neck, shoulder girdle and back, which as a consequence can have a local muscle tension, a compression and inflammation of the peripheral nerves and a reduced blood circulation (Breen et al., 2007). One of the main conditions of the proper posture of the body during the class is an ergonomic shape of school furniture, especially chairs and desks. Nevertheless, when designing ergonomic furniture, the ergonomic features as a condition for good health and motivation improvement and successful learning are insufficiently taken into account. With ergonomically designed computers suitable for children and with suitable preventive exercises, the improper posture can be prevented and even corrected on time (Howie et al., 2017). Preventing musculoskeletal disorder development is much more effective and cheaper than its medical treatment. Parents and experts have a leading role in this (Alibegović et al., 2020).

The goal of this research was to examine risk factors of the musculoskeletal disorder development connected with a long use of information and communication technologies by reviewing scientific literature.

MATERIAL AND RESEARCH METHODS

The research is a non-experimental (qualitative) research, i.e. a scientific review of literature. In creating this paper, various databases were used, including Pub Med, Google Scholar, Medline, using the keywords "risk factors", "information and communication technologies", "musculoskeletal disorders", "health", "children". The research is limited to articles published in the Serbian, Croatian and English languages.

RESULTS

In a research of young children (0-4 years old) from rural areas with a low income in the USA, 97% of children used mobile phones and two-thirds of four-year-old children owned their own tablet (Kabali et al., 2015). In a research of children in Singapore, over 60% of children from 18 to 24 months use mobile technology every day (Goh et al., 2016).

Two-third of American high school children aged 16 to 18 years reported that they use their tablets more than 4 hours a day (Sommerich et al., 2007). The Hong Kong students, 12 to 16 years old, reported that they used computers 2,5 hours per day on average (Ho & Lee, 2001). However, it has been observed that even young children use computers. More than a quarter of children, 4 to 6 years old, in the USA use computers 64 minutes a day on average (Sommerich et al., 2007), and more than a half of five-year-olds in Australia use computers every week (Staker et al., 2006).

The abduction of the upper arm during the IT technology use was 13,6 degrees higher compared to the situations when the IT technology is not used ($p < 0,001$). The average elevation of the shoulder was 10,2 degrees higher compared to the situations when the IT technology is not used ($p = 0,001$). The average head flexion during IT technology use was 18,6 degrees higher compared to new IT technology ($p < 0,001$) and 16,4 degrees higher compared to the situations when the IT technology is not used ($p < 0,001$). The average torso flexion during the old IT technology use was 5,7 higher compared with the new IT technology ($p = 0,011$), while the medium value of lateral torso bending while using the old IT technology was 1,6 degrees higher when compared with the situations when the IT technology is not used (Ciccarelli et al., 2011).

In a research in Thailand most smartphones users reported some form of musculoskeletal disorder in the upper part of body: torso flexion (82,74%), shoulder contraction (56,61%), elbow flexion (65,16%), finger and wrist bending (22,40%), hand supination to support the device (21,62%), upper part of the back flexion (67,50%) and lower part of the back flexion (43,23%), that are acquired while using smartphones (Namwongsa et al., 2018).

The results of Nordic Questionnaire (SNQ) showed that musculoskeletal disorders are the biggest in the neck (90,00%), than in the shoulder 73,30%, the upper part of the back 63,30%, the wrist 36,70% and the lower part of the back 30,00 %. The musculoskeletal disorders were less spread in the hip bone and quadriceps 13,30 %, the knee 13,30%, the ankle 10,00% and the elbow 6,70% (Namwongsa et al., 2018).

The Jones and Orr study shows that 28%, 40%, and 41% of students reported a discomfort in hands, a neck/back pain, and a pain in the body, respectively, after using the computer. The carpal tunnel syndrome was reported by 4% of respondents. The evidence reveals that from 30% to 60% of school children report some form of musculoskeletal discomfort, and they think it got worse by computer use (Harris & Straker, 2000).

The Harris and Straker report that 60% of students has discomfort while using the laptop, and 61% has discomfort while carrying the laptop (Straker et al., 2002).

Three of the children reported that the pain got worse, moving from 2 to 3 on the VAS scale (Visual Analogue Scale). Other 12% (n ¼ 8) did not have any pain at the beginning, but had pain (2 on the VAS) at the end of computer use (Breen et al., 2007).

Compared with watching TV, while playing on a tablet device children have a bigger torso flexion (median 12,8, 95% CI: 6,2, 19,3, $p < 0,001$), head bending (33,3, 95% CI: 23,4, 43,4, $p < 0,001$), lateral head bending (6,9, 95% CI: 10,5, 2,3, p ¼ 0,002), upper arm bending (6,6, 95% CI: 2,2, 11,0. P ¼ 0,003), and a bigger medium upper arm abduction (5,9, 95% CI: 1,1, 10,7, p 0,016). Compared with the game Toy, while playing it children have bigger medium torso flexion (9,6, 95% CI: 3,1, 16,2, p ¼ 0,004), medium lateral chest flexion left (3,0, 95% CI: 0,2, 5,7, p ¼ 0,030), medium head flexion (11,6, 95% CI: 1,6, 21,6, p ¼ 0,023), and medium upper arm flexion (11,1, 95% CI: 6,8, 15,3, $p < 0,001$). The muscular activity was bigger while playing with a tablet device than while watching TV (the median distinction of 10,6% of the submaximal contrac-

tions 95% CI: 1,6, 19,5, p ¼ 0,021), but lower while playing with tablet devices compared with toys (14,9% of the submaximal contractions 95 % CI: 23,8, 6,0, p ~ 0,001) (Howie et al., 2017).

The research in Dublin shows that eight children reported discomfort on the BDC (Body Discomfort Chart) at the beginning of the class before the intervention (VAS 1). Three children reported back pain, one child reported neck pain and four of them reported lower extremities pain. The average intensity of pain was 0,9 ± 1,5. Fourteen children reported pain during classes (VAS 2). The most common area of reported pain was in the back (n=4). The average intensity of pain that students reported after the class was 1,8 ± 1,5. The Wilcoxon test showed a significant difference between the intensity of reported pain in children before and after the class (p = 0,04) (Dockrell et al., 2010).

According to a University of Surrey research (Great Britain), students spend about 38% of their time using computers on average, and 28,91% of students have a flexed torso position and even 33,50% of students have considerable neck flexion (Kabali et al., 2015). A BBC programme confirmed the alarming data, showing that because of inadequate sitting position, about 25% of British students complained about back and neck pain, headache and loss of concentration. The research showed that non-ergonomic body position in an extended sitting position creates muscle pain and manifests itself in various musculoskeletal disorders (Kim et al., 2015).

The students spend about 92% of their working time in a static sitting position, 3% in active walking and 2% in a standing position. The international standards of the World Health Organisation and its instructions for sitting on a chair for a long period of time with proper body position causes significant stress for the lumbar spine (Murphy et al., 2003).

In the period of growth and development, between the ages of 6 and 18, the children are exposed to different health problems including the proper body position problem (Troussier, 1999). It is shown that the pain in the lumbar part of the spine in school children occurs from 20% to 51 % of the total population of school children. The back pain is also connected with extended sitting, the weakness of certain muscle groups and bad posture (Cardon et al., 2004).

The period of the most intense growth and development of boys is between 11 and 12 years old, and the acquired data shows that in this period there is a gradual violation of the postural status. A statistically significant difference in the postural status was confirmed in respondents of both sexes, aged 14 to 15 (p=0,011; Z=-2,487). Furthermore, it can be confirmed that boys have a worse posture condition at this age as well (Bogdanović & Milenković, 2008).

In the period from 2013/2014 it was confirmed that 25,6% of children, 11 to 15 years old, reach the recommended values of the World Health Organisation from 60 of moderate to intense physical activity during the day, but the fact is that boys are significantly more active than girls (32,1% compared to 19,1%) (Lafond et al., 2007).

Most children fulfilled the daily need for movement (99,3%) and sleeping (82,1%), but the recommendation related to time spent in front of the computer fulfilled only 15,2% of the children (Protić-Gava, 2015).

The research on a sample of 347 two-year-old children shows that the children who were wearing accelerometer for two days, a minimum of 400 minutes a day, gain the results that show that children spend most of their time in the sedentary position (85,6% of them) (WHO, 2016).

The study shows that for most of the children the custom-made furniture is not available neither in Europe nor in the world. In the last 50 years, the height of the children of the same age has increased. The average height of children of 7 to 10 years old was increased from 5-7 cm on average, while the height of the children of 11 to 14 years old was increased from 7 to 10 cm (Carson et al., 2017).

The epidemiological study conducted in The Republic of Korea showed that 18,8% of smartphone users have musculoskeletal disorders at least in one part of the body, especially in the neck, upper part of the torso and the upper extremities (Wijtzes et al., 2013), while in another Korean study that also includes smart-

phones, it was discovered that the most painful part of the body due to smartphone use, was in the cervical spine (55,8%) (Domljan & Grbac, 2008).

DISCUSSION

By identifying the results of the RULA test, we came to the conclusion that the ergonomic risk in smartphone users is high, and that is a result of two key factors: body posture and muscle use. The position of the neck, back and lower extremities had a combined effect on the musculoskeletal system of the neck. The results of the RULA test showed that there is a high risk of pain in the musculoskeletal system if the ergonomic measures are not applied (Namwongsa et al., 2018).

The type of the computer task influenced the posture of the children.16% of the children reported pain, especially when using the mouse. These results show that children at the age of 9 can develop musculoskeletal symptoms in the period of computer use for a short time (Breen et al., 2007).

The current findings suggest the possibility that a sedentary way of life and low physical activity lead to higher musculoskeletal disorders. Based on the evidences, it is important to understand that new technologies and their use carry a big risk for children's health (Howie et al., 2017).

By means of a quantitative analysis of the sedentary posture in school children, it is confirmed a higher head flexion while carrying a laptop in contrast with a desktop computer. It is also confirmed that head flexion is significantly smaller in younger children compared to older children. The type of IT technology that a child uses to communicate, as well as their age and sex affect the child's posture. The children that were reading from books have a smaller angle of head and flexion while watching compared to reading from a laptop. Reading from a laptop was connected with bigger head bending, neck bending and a bigger angle of watching compared to reading from a desk computer (Briggs et al., 2004).

In non-conditioned logistic regression analyses adjusted to the age, gender, and race, frequent users of desktop computers (daily or almost daily) had NUE symptoms (neck or upper extremity), i.e. a higher degree of neck and upper extremities pain in contrast with users who used the computer less frequently. Those who used computers for a long time without a break had higher NEU (neck or upper extremity) symptoms. Obesity and wearing glasses or contact lenses also were connected with the symptoms (Gillespie, 2006).

As the use of the internet becomes intensive at school and at home, the consequences of the disbalance of furniture and children's posture became more serious. To teach children about healthy computer habits will protect them from future painful disorders. Future worker is in schools nowdays. Because of that, certain attention must be payed to their work surface that will help in preventing problems connected with information and communication technologies in the future (Patel et al., 2015).

Musculoskeletal disorders connected with the use of a child computer are not only a concern for young people, but also affects the potential for higher musculoskeletal disorders in adults (Harris et al., 2005).

The respondents that usually watched TV till noon and late at night during the weekend have a bigger chance to be intense IT device users. 24% of girls and 10% of boys in the "intense" categories of IT devices were at a higher health risk that can be connected with a metabolic syndrome and cardiovascular diseases (Straker & Pollock, 2005).

There is more and more evidence that psychosocial factors connected with home and work environment play the leading role in musculoskeletal disorder development. Psychosocial factors that are connected with musculoskeletal disorders of the upper extremities include: an increase in labour demands, monotonous work, dissatisfaction, low social support, and conditions such as depression, stress and anxiety (Kelly et al., 2009).

A lot of changes in children's behaviour that parents see simply show normal distancing that adolescents mostly show when they are teenagers. Computer addiction can be viewed as a phase of intensive

computer use and its potential that all IT devices produce. A lot of children will pass this phase and will integrate IT device use in everyday life (Straker & Pollock, 2005).

The Body Discomfort Chart (BDC) and the Visual Analogous Scale (VAS) showed that the majority of respondents (65%) were at the level of 2.30% at the level of 3, and 5% at the level of 4. There was a statistically significant increase in reported discomfort from the beginning to the end of the computer class. A longer teaching process (80 minutes) did not result in a higher number of reports of discomfort than in a shorter teaching process (40 minutes). The problems are reflected in the lack of ergonomic considerations in the design and layout of computer workstations, both in schools and at home (Kelly et al., 2009).

The relationships between the computer work environment, the keyboard, and musculoskeletal disorders are significant, but they suggest that students without ergonomically designed furniture are more likely to have musculoskeletal disorders. Risk factors associated with computer use and discomfort are also significant. (Jacobs & Baker, 2002).

Particular computing activities, such as using a joystick or mouse, significantly predict musculoskeletal problems by means of multiple logistic regression. Many parents report difficulty removing their children from the computer (46%) and that their children spend less time outdoors (35%) (Burke & Peper, 2002).

Adjusting the height of the computer screen and the height of the table resulted in an increase in head tilting, neck flexion, viewing angle, activity of the cervical spine and a trend in the activity of the right upper trapezius. Greater head flexion represents the normative values of the child's inclination of the cervical spine (Straker et al., 2002).

The lowest level of muscular activity in children was found when they used a desktop computer. The cervical erector spinae and the upper trapezius muscle were found to be larger on the left side when using the book compared to higher levels of right side muscle activity. The three types of IT devices had different effects on the activities of the cervical erector spinae and upper trapezius muscle, suggesting different risks associated with different types of IT. The levels of activity were often above 5% of the maximum EMG (electromyography). Children are potentially at risk of health consequences associated with the use of IT devices (Greig et al., 2005).

CONCLUSION

By researching risk factors od musculoskeletal disorder development in children connected with long-time information and communication technology use, the outlined evidence from the discussion of the attitudes and opinions of other authors lead to the conclusion that a lot of risk factors affect children's health because of an ever-increasing and more frequent use of computers, consoles, tablets and mobile phones.

It can be concluded from this paper that using modern technology considerably more presents a detriment to children in the field of health than it presents a benefit to them.

By a means of a multidisciplinary approach, using ergonomic preventive measures when using computers, different educational content, as well as with various physical activities as a part of various school activities, and by following scientific achievements, it will be possible to enable children to have a comfortable, cheerful, painless, and most importantly a healthier way of life while using information and communication technology as an indispensable factor of modern life.

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Professional Paper

Comparative Overview of the Quality of Life in Serbia and North Macedonia Analyzed According to Numbeo Database

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ABSTRACT: In economic theory and practice, the term standard of living has emerged in recent decades. It was created as a suitable response to problems related to people's lives, regional inequalities in the level of development and served as an acceptable concept for more complex valorization of development potentials, especially in rural areas. The subject of the research is a comparative analysis of the quality of life in Serbia and Northern Macedonia according to Numbeo database. The aim of this paper is to point out the importance of living standards from both economic and sociological aspects, as well as to review the position of Serbia and Northern Macedonia in relation to other countries in the region based on the analysis of collected data and research. The reason for the comparative presentation of Serbia and Northern Macedonia is that the quality of life is at an approximate level. The salary of employees in education in these countries represents an average income that is sufficient for a satisfactory quality of life. The standard of living of a country depends on a number of factors such as political factors, economic factors, demographic, environmental and cultural factors.

Keywords: standard of living, Serbia, North Macedonia, economy, quality of life

JEL classification: F14, F15

INTRODUCTION

As a rule, the standard of living is higher in developed countries, which is logical. Indicators of living standards are Gross domestic product per capita, income earned by companies and other institutions, salaries of employees, unemployment, life expectancy, environmental quality, climate, political and religious freedom, security of the population, prices of products and services. The standard of living of a country is influenced by numerous and various factors that originate from the economy itself, but also from other parts of society with which the economy is connected, for example, health and education. With the process of globalization, technological progress is especially important for economic development. Its importance increases over time. What is characteristic for Serbia and Northern Macedonia is unfavorable demography, migration of the population from rural to urban areas, brain drain, insufficient domestic investments and mismatch of employment and wages, which contributes to the stratification of the population into rich and poor.

These changes were conditioned by changes in the political system, as well as the development of socio-political relations. The justification for changing the standard of living has always been the need to provide funds for strengthening state independence and its defense power, strengthening the state economy, material and cultural uplift and social security of citizens.

LITERATURE REVIEW

At the same time, globalization reveals the existence of social and political ones problems that transcend national borders and become a concern of the whole world: some of these problems are accelerated demographic growth, exploitation of nature, poverty, control of atomic weapons, terrorism, oppression of the people (Avramović, 2012). Many countries and international organisations are becoming increasingly aware of the vast consequences that population ageing may have on societies and problem of longterm care for old people and ageing population have been examined in a lot a number of papers (Arsenović et al., 2011). Migration flows are observed in the context of semi-peripheral position of Serbia in the global system, and hindered transformation and development (Bobić & Babović, 2013). As with other populations, the current age structure in Serbia and North Macedonia is formed under the direct influence of all three components of population change (fertility, mortality and migration), but also under the strong influence of the inherited age structure, manifested by the population momentum.

Living standard it was based on changes in ownership of the means of production and then on the existing political, educational, health, social and cultural subsystems. This meant creating a new class and new layers of the structure of society, whose interests were woven into the concept of transition and privatization (Maksimović & Novaković, 2020).

In essence, basic living standard measures, such as GDP per capita, are often used to define the differences between more and less developed countries. The influence of transnational actors in Serbia and Northern Macedonia is visible in a wide range of economic and social policies, and in this paper the research focuses on reforms in the field of creating policies to reduce poverty and social exclusion, especially those living on the margins. The transformation of the social and political systems of nation-states in the former socialist countries, at the end of the 20th and the beginning of the 21st century, took place under the strong influence of international organizations, as one of the main actors of globalization (Maksimović & Novaković, 2020).

Economic growth over the past years, has been the main focus when analyzing the well-being of a country (Hysa & Mansi, 2020). Even though that seems to be one reason, we notice different results in our two cases. GDP per capita, and other quality variables do in fact positively impact the levels of happiness in European Union countries (Hysa & Mansi, 2020).

Having a higher education degree significantly reduces the risk of poverty. As the level of education of the household head increases, the poverty index decreases to 5.4% (high school), 2.5% (high school) and 1.6% (university education) (Matković et al., 2010). The concept of poverty has been challenged due to its focus on meeting and depriving material needs, while recent research shows that in the most developed countries in recent decades a large part of the population lives in material well-being and that postmaterialist needs and values come to the fore (Janković et al., 2020). Over 70% of urban and 50% of rural families own the Internet, which was unthinkable only a few years earlier. Possession of mobile phones is even more common and imposes itself as a kind of consumer imperative, both in urban and rural areas (Janković et al., 2020). Recognizing the negative experiences of the past and the external sociospatial effects of social housing residualization (segregation and ghettoization, discrimination, unemployment, crime, housing collapse, etc.), international guidelines for sustainable housing 74 51-2020 AU policies recognize the role of urban and architectural practice in building long-term sustainable housing stock for this purpose (Njegić, 2020).

The law provides for an increase in sanctions imposed for violating the provisions of the law on food safety, in order to increase the efficiency of control over their implementation (Kirov, 2020). All the countries of the Western Balkans have a permanent and mild, but also a continuous increase in HDI indicators, which will lead to further progress in human development. In order to ensure the comprehensive growth of all HDI

components, the countries of the Western Balkans must continue to adopt global strategies and laws, realistic action plans, roadmaps for their implementation and the use of knowledge that encompasses a set of skills, competencies, and interests aimed at expanding people's choices and general welfare (Dasic et al., 2020).

On the other hand, only GDP per capita and Education seemed to positively impact Happiness, with other variables having a negative impact on it. does not imply higher levels of Happiness, in fact it had the opposite impact (Hysa & Mansi, 2020). Individuals with a higher education level generally have higher expectations which are harder to fulfill and less satisfied with their work (Hysa & Mansi, 2020). However, this appeared not to be the case in developing countries such as Western Balkans where Education appeared to have a positive impact, due to the fact that higher levels of education interpret in higher income and the population is focused more on it that in other sectors of life satisfaction (Hysa & Mansi, 2020).

Quality of life in Serbia and North Macedonia in relation to other countries in the region

Emerging market economies usually see an increase in living standards over time through so-called industrialized economies. We will observe the quality of life index in Serbia and Northern Macedonia through indices of purchasing power, security, health care, climate, cost of living, property and income prices, travel time to work and pollution index. The index is determined based on the minimum and maximum value of the measurement.

The quality of life index in Belgrade, Serbia in March 2021 for each of the following items is (https://www.numbeo.com/cost-of-living/rankings.jsp):

- *Purchasing power index* 35.74 very low;
- *Safety index* 61.96, high;
- *Health care index* 51.54 moderate;
- *Climate index* 83.23 very high;
- *Cost of living index* 37.86 very low;
- *The ratio of property price and income* 16.29 is very high;
- *Travel time index* 30.90 low;
- *Pollution index* 61.44 high.

The minimum value of the measurement is: 271, while the maximum value is: 704. In March 2021, when we summarize the above values, we come to the data that the Quality of Life Index in Belgrade, Serbia is 117.15, which is assessed as high and is proof that Serbia is still a country in transition.

Western Balkan countries—Albania, Bosnia and Herzegovina, Montenegro, North Macedonia and Serbia—have already realized that reforms such as creating a market economy and increasing the role of the citizen in the society are the guarantee for a new future with peace, stability, prosperity, and freedom. In the last decades, the EU has set the same goals and has supported its activities in the same principles, while recently, it is widely supporting the efforts of the Western Balkan countries by planning to accept them as member states once they meet the conditions for such a thing (Feruni et al., 2020).

Economic freedom has a significant positive impact on the economic development of both the Western Balkan countries and the EU countries, but the Western Balkans benefit more from economic freedom (Feruni et al., 2020).

The quality of life index in quality of life in Skopje, North Macedonia in March 2021. for each of the following items is (https://www.numbeo.com/cost-of-living/rankings.jsp):[1]

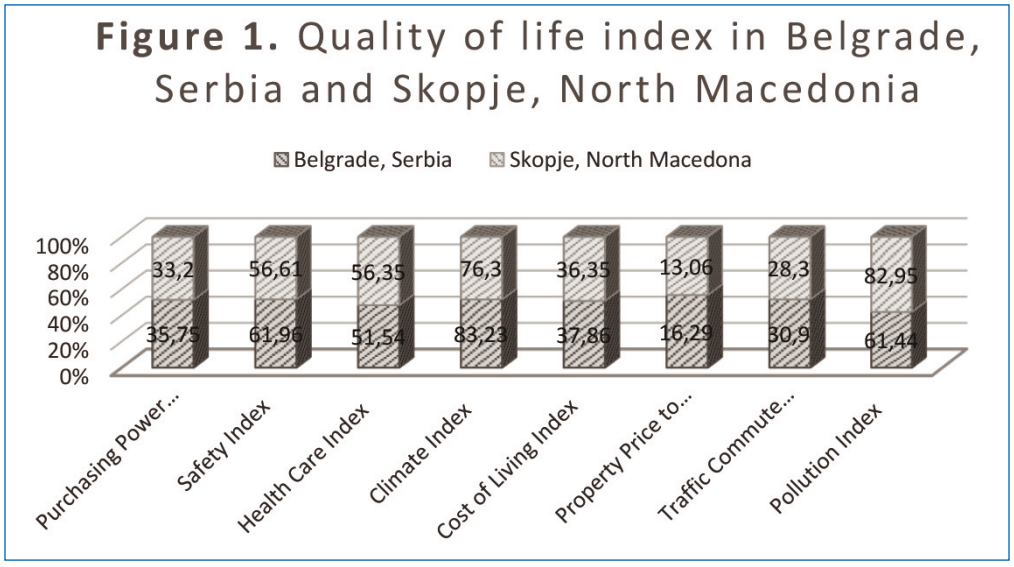
- *Purchasing Power Index* 33.20 very low;
- *Safety Index* 56.61 moderate;
- *Health Care Index* 56.35 moderate;

[1] The scale consists of the variables Very High, High, Moderate, Very Low and Low.

- *Climate Index* 76.30 high;
- *Cost of Living Index* 36.35 very low;
- *Property Price to Income Ratio* 13.06 high;
- *Traffic Commute Time Index* 28.30 low;
- *Pollution Index* 82.95 very high.

Minimum contributors for an underlying section: 46; Maximum contributors for an underlying section: 204; n March 2021, when we summarize the above values, we come to the data that the Quality of Life Index in Skopje, North Macedonia is 103.41 which is assessed as high and is proof that North Macedonia is still a country in transition.

We can illustrate it as follows:



Source: Autor

In the analysis of living standards in the Balkans, we will take a sample from the Numbeo database[2] for the capitals of 10 countries, including Serbia and Northern Macedonia. The sample was taken from a database representing 595 cities with the Cost of Living Index, Rent Index, Cost of Living Plus Rent Index, Groceries Index, Restaurant Price Index and Local Purchasing Power Index. Based on Table 1. when it comes to the cost of living index we can see that the best ranked capital of Skopje, in North Macedonia is worth 36.35, which ranks it 150th on the list of 595 countries, while the highest cost index has the capital of Ljubljana, Slovenia in the value of 51.38. Unlike Northern Macedonia, the cost of living index in Serbia is higher and amounts to 41.52, which is why Serbia has positioned itself at 200 positions in relation to Northern Macedonia.

[2] *Numbeo* is a collection of Web pages containing numerical and other itemizable data about cities and countries, designed to enable anyone to contribute or modify content. Numbeo uses the wisdom of the crowd to obtain the most reliable information possible. Numbeo then provides you with a statistical analysis of the data collected. In addition, Numbeo provides a variety of systematic research opportunities for its readers with its compilation of worldwide information. *6,876,935 prices in 10,012 cities entered by 572,406 contributors*

Table 1. Comparative overview of the Cost of Living Index in the countries in the region for March 2021.

Number	Rank	City	Cost of Living Index	Rent Index	Cost of Living Plus Rent Index	Groceries Index	Restaurant Price Index	Local Purchasing Power Index
1	150	**Skopje**, North Macedonia	36.35	9.15	23.69	29.37	27.14	33.20
2	176	**Sarajevo**, Bosnia And Herzegovina	38.89	9.21	25.07	31.65	27.00	49.99
3	197	**Podgorica**, Montenegro	41.30	12.31	27.80	32.39	32.86	34.72
4	200	**Belgrade**, Serbia	41.52	12.88	28.19	30.10	35.19	35.59
5	210	**Bucharest**, Romania	42.23	15.24	29.66	34.75	41.21	46.72
6	216	**Sofia**, Bulgaria	43.31	14.61	29.95	36.40	37.35	45.22
7	217	**Budapest**, Hungary	43.38	16.70	30.96	35.34	36.16	51.16
8	320	**Zagreb**, Croatia	51.38	17.87	35.78	42.69	42.84	49.21
9	296	**Athens**, Greece	58.94	16.50	39.18	46.49	58.04	41.12
10	300	**Ljubljana**, Slovenia	60.09	23.60	43.11	50.23	54.83	54.94

Source: (https://www.numbeo.com/cost-of-living/rankings.jsp)

From the countries of the Western Balkans, Croatia, and Montenegro fall under the category Very high human development. Their HDI is below the average for the specified group of countries to which they belong. Serbia, Albania, Bosnia, and Herzegovina have HDI above the average for that group of countries to which they belong, while North Macedonia has HDI which is the same as the average for this group of countries (Dasic et al., 2020).

METHODOLOGY

The following methods were applied in the research process: method of analysis and synthesis, method of comparison, statistical method, method of description and historical method. Using the methods of analysis and synthesis, the data will be processed and arranged into one harmonious whole. In addition to these two basic methods, a comparison method will be used to compare the data. The method of description is also used, which is intertwined throughout the paper. Also, one of the methods used is the statistical method, where data are sorted and displayed for easier comparison and understanding. Historical research is very important for the research of this paper, because with this method we can examine historical events and compare them with today's. In finding a survey of satisfaction with the employed quality of life in the education system in Serbia and North Macedonia, we took a sample of 40 respondents, professors at the elementary school in Belgrade and Skopje. Target research is that through indices of purchasing power, security, health care, climate, cost of living, property and income prices, travel time to work and pollution index, we get results on the quality of life in these places. We hired employees with the intention that their salary is on average with other occupations in both Serbia and North Macedonia. When it comes to Serbia and the countries of the former Yugoslavia, a Serbian teacher receives the lowest salary, even lower than teachers in BiH, Montenegro and Macedonia. Teachers in Serbia earn around 7,000€ gross annually, while a teacher in BiH earns around 9,700€, and their colleagues in Montenegro around 10,500€. The salary of a teacher in Macedonia is a little over 9,000€ while for example, a teacher in Greece earns about 25,000€ a year (http://www.fbg.org.rs/). Today, the initial salary of a teacher for the 7th level of expertise in Serbia is

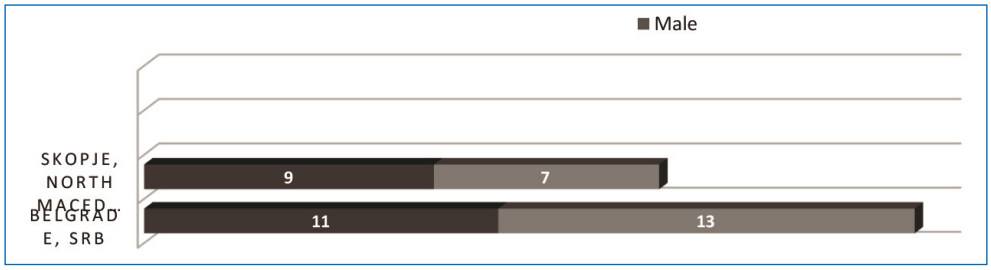
59,095 RSD (502,59€) while in Kosovo and Metohija, with the addition of 98,188 RSD (835,07€) dinars for the same worker.[3]

Questions and discussion

1. Your gender?

a) Male 7 (Skopje, North Macedonia) 11 (Belgrade, Serbia)

b) Female 13 (Skopje, North Macedonia) 9 (Belgrade, Serbia)



Of the 40 respondents, 20 were from Belgrade (Serbia) and 20 from Skopje (Northern Macedonia). In Belgrade, 11 males and 9 females were examined. While in Skopje there are 7 male respondents and 13 female respondents. With this question, our goal is to establish what is the satisfaction with the quality of life of respondents of different genders.

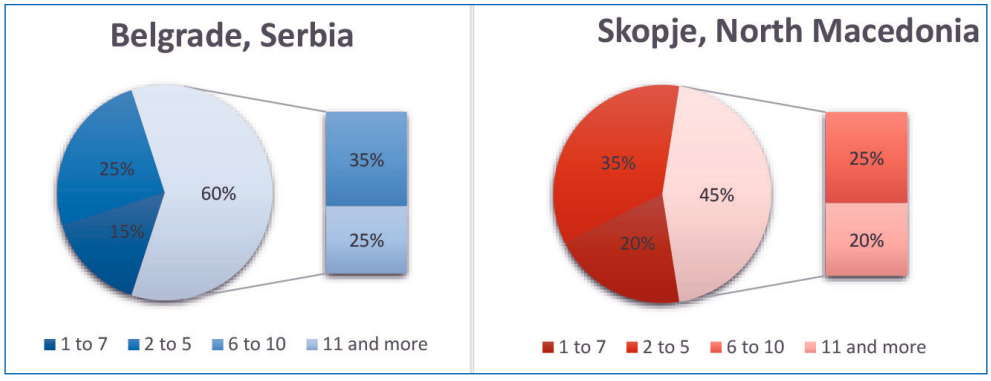
2. How many years of service do you have?

a) 1 – 3 years 4 (Skopje, North Macedonia) 3 (Belgrade, Serbia)

b) 2-5 – 7 years 7 (Skopje, North Macedonia) 5 (Belgrade, Serbia)

c) 6-10 – 7 years 5 (Skopje, North Macedonia) 7 (Belgrade, Serbia)

d)11 and more 3 years 4 (Skopje, North Macedonia) 5 (Belgrade, Serbia)

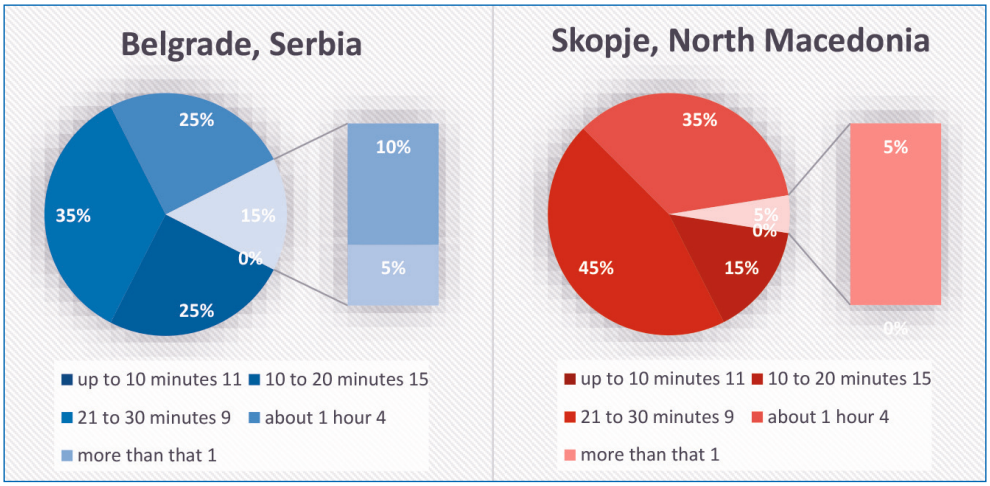


When it comes to the work experience of the respondents out of 20 respondents from Belgrade, 7 of them had work experience in the interval from 6 to 10, 5 respondents each had work experience from 2 to 5 years, in more than 11 years, while with the least work experience 1 to 3 years there were 3 respondents. From Skopje, most respondents had a work experience of 2 to 5 years (7 respondents), followed by 6 to 10 years of work experience (5 respondents) and 4 respondents with a work experience of 1 to 3 or 11 or more years.

[3] According to the middle exchange rate of the euro on March 20, 2021. in the amount of 117.58 RSD for 1€

3. How long does it take you to get to work?

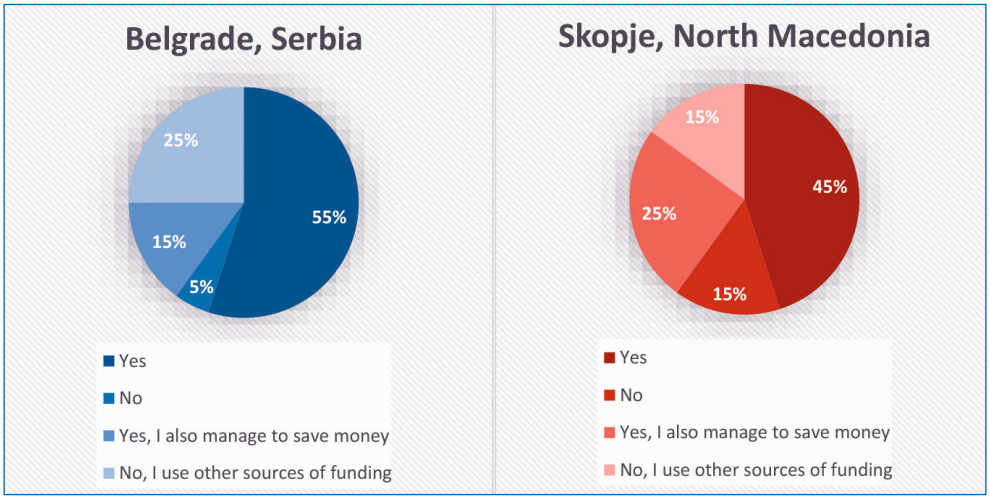
a) up to 10 minutes 3 (Skopje, North Macedonia) 5 (Belgrade, Serbia)
b) 10 to 20 minutes 9 (Skopje, North Macedonia) 7 (Belgrade, Serbia)
c) 21 to 30 minutes 7 (Skopje, North Macedonia) 5 (Belgrade, Serbia)
d) about 1 hour 1 (Skopje, North Macedonia) 2 (Belgrade, Serbia)
e) more than that 0 (Skopje, North Macedonia) 1 (Belgrade, Serbia)



Another indicator of quality of life is the travel time to work, so in accordance with that, our respondents came to the conclusion that respondents from Serbia need more time to come to work. 3 respondents from Skopje stated that they need less than 10 minutes to get to work, 9 respondents need approximately 11 to 20 minutes, while 7 respondents come to work on average from 21 to 30 minutes. In Belgrade, out of 20 respondents, 5 arrive at work in an interval of 10 minutes, 9 respondents arrive at work in an average of 11 to 20 minutes, 5 respondents in an interval of 21 to 30 minutes, about an hour of travel is needed for the two of them, while one respondent travels for more than an hour.

4. Do you manage to pay your dues with your monthly income?

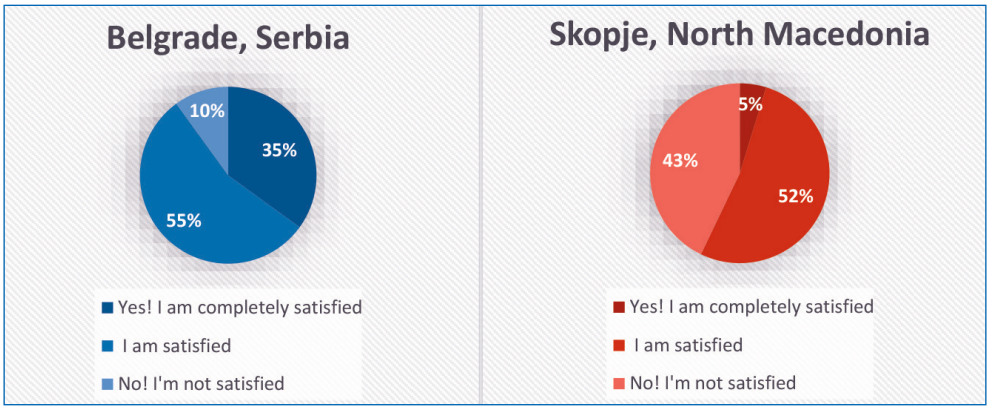
a) Yes 9 (Skopje, North Macedonia) 11 (Belgrade, Serbia)
b) No 3 (Skopje, North Macedonia) 1 (Belgrade, Serbia)
c) Yes, I also manage to save money 5 (Skopje, North Macedonia) 3 (Belgrade, Serbia)
d) No, I use other sources of funding 3 (Skopje, North Macedonia) 5 (Belgrade, Serbia)



The next indicator we examined was purchasing power index and cost of living. In Skopje, 9 respondents answered in the affirmative, that they manage to pay their expenses with a monthly salary, 5 respondents manage to save money, 3 respondents fail to cover their expenses, ie they need additional funds, probably respondents who do not have full fund of classes or family people. In Belgrade, 11 respondents answered that they manage to settle their expenses with monthly income, 3 respondents manage to save money, while 1 respondent fails to settle monthly salary obligations, 5 respondents stated that they need additional funds.

5. Are you satisfied with your health care?

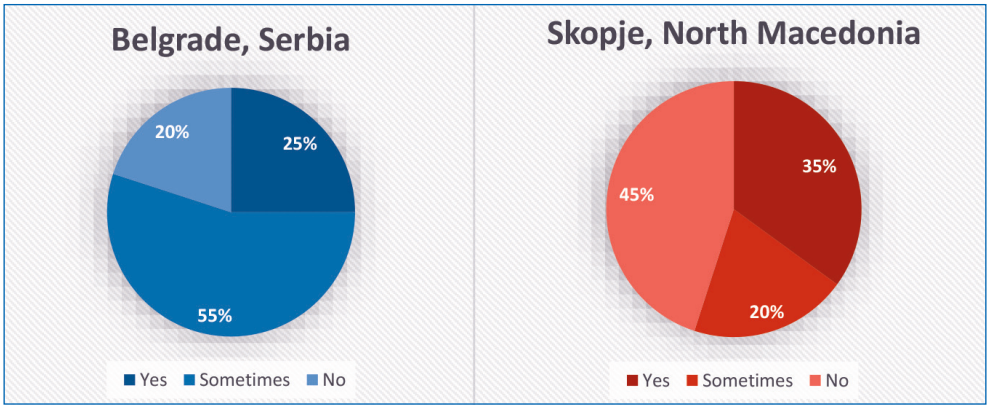
Yes! I am completely satisfied 1 (Skopje, North Macedonia) 7 (Belgrade, Serbia)
I am satisfied 11 (Skopje, North Macedonia) 11 (Belgrade, Serbia)
No! I'm not satisfied 9 (Skopje, North Macedonia) 2 (Belgrade, Serbia)



When it comes to the next indicator, which is satisfaction with health care, out of 20 respondents from Skopje, 11 of them are satisfied with health care, 1 respondent is completely satisfied, while 9 are not satisfied with health care. Respondents from Belgrade, 11 of them are also satisfied with health care, 7 of them are completely satisfied, while 2 respondents are not satisfied with health care. According to the conducted research, we can conclude that the respondents from Belgrade are more satisfied with the health care in relation to the respondents from Skopje.

6. Do you feel safe in your country?

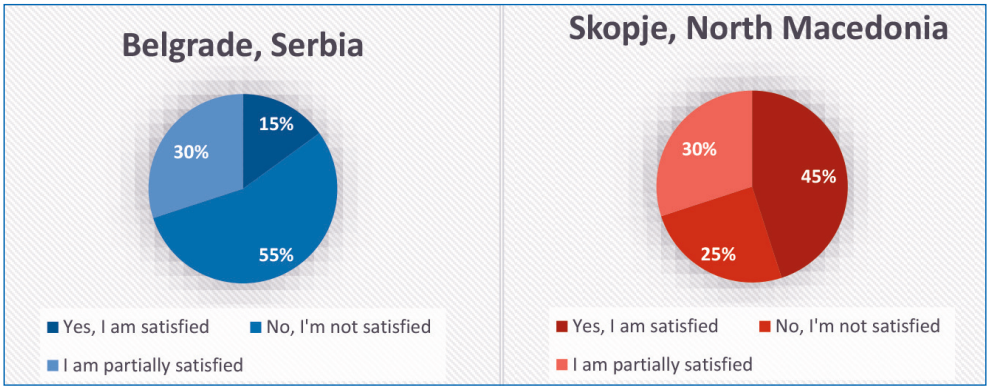
a) Yes 7 (Skopje, North Macedonia) 5 (Belgrade, Serbia)
b) Sometimes 4 (Skopje, North Macedonia) 11 (Belgrade, Serbia)
c) No 9 (Skopje, North Macedonia) 4 (Belgrade, Serbia)



When it comes to security, an indicator that is also crucial for quality of life, 7 respondents from Skopje feel safe in their country and surroundings, 4 of them sometimes feel safe, while 9 respondents do not feel safe in their environment. When it comes to respondents from Belgrade, 5 respondents feel safe in their environment, 11 respondents occasionally feel safe, while 4 of them said they do not feel safe in their environment.

7. Are you satisfied with the quality of the environment and the climate?

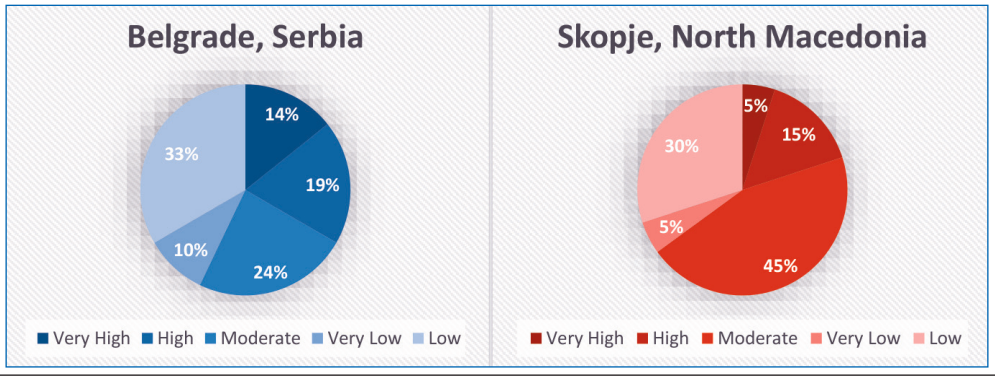
a) Yes, I am satisfied 9 (Skopje, North Macedonia) 3 (Belgrade, Serbia)
b) No, I'm not satisfied 5 (Skopje, North Macedonia) 11 (Belgrade, Serbia)
c) I am partially satisfied 6 (Skopje, North Macedonia) 6 (Belgrade, Serbia)



With the globalization of business, indicators such as climate and environment have crystallized, so we accordingly asked our respondents whether they are satisfied with the quality of the environment and the climate in their environment. Respondents from Skopje, 9 of them answered that they are satisfied with the quality of the environment and climate in Skopje, 5 respondents are not satisfied with the quality of the environment and climate, while 6 respondents are partially satisfied. In Belgrade, respondents are less satisfied with the quality of the environment and climate than respondents from Skopje. 11 respondents from Belgrade are not satisfied with the quality of the environment and climate, 3 respondents are satisfied, while 6 respondents are partially satisfied.

8. What is your quality of life?

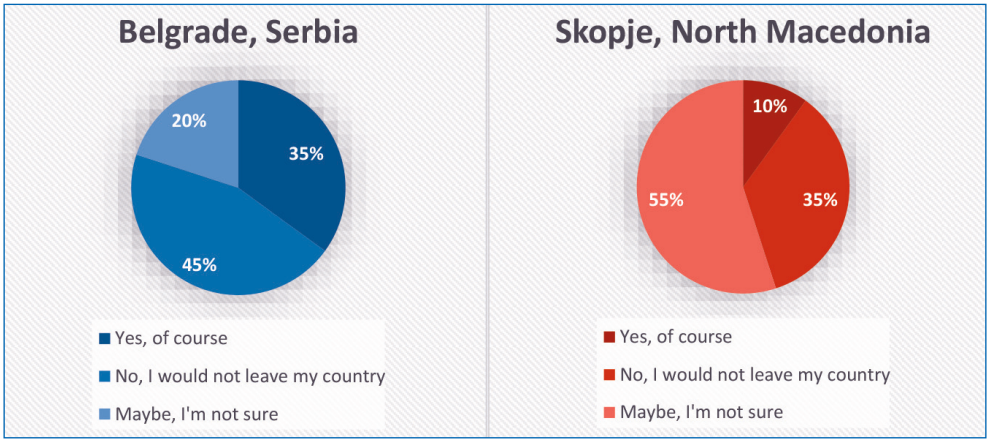
Very High 1 (Skopje, North Macedonia) 3 (Belgrade, Serbia)
High 3 (Skopje, North Macedonia) 4 (Belgrade, Serbia)
Moderate 9 (Skopje, North Macedonia) 5 (Belgrade, Serbia)
Low 6 (Skopje, North Macedonia) 6 (Belgrade, Serbia)
Very Low 1 (Skopje, North Macedonia) 2 (Belgrade, Serbia)



When it comes to the quality of life indicator, we applied the scale we stated at the beginning of the paper, from the variables *Very High, High, Moderate, Very Low* and *Low.* One of the twenty respondents from Skopje answered that it is very high, while on the other hand in Belgrade, three respondents answered that the quality of life is very high. Three respondents from Skopje answered that their quality of life is at a high level, four respondents from Belgrade gave the same answer. Nine respondents from Skopje answered that their quality of life is average or moderate, while in Belgrade five respondents answered the same. One respondent from Skopje and two from Belgrade answered that their quality of life was very low, while six respondents from Skopje and Belgrade answered that their quality of life was low.

9. If you had an offer to work for a higher salary and have a better quality of life, would you go abroad?

a) Yes, of course 2 (Skopje, North Macedonia) 7 (Belgrade, Serbia)
b) No, I would not leave my country 7 (Skopje, North Macedonia) 9 (Belgrade, Serbia)
c) Maybe, I'm not sure 11 (Skopje, North Macedonia) 4 (Belgrade, Serbia)



With this question, our goal was also to inform ourselves in a certain way about the satisfaction of the respondents with the standard of living, so with the intention to offer them the possibility of a higher salary, a better quality of life, we offered several possibilities for an answer. Two respondents from Skopje and seven from Belgrade would be willing to leave their country and work abroad, thus having a better quality of life, seven respondents from Skopje and nine respondents from Belgrade would not leave their country and work for such an offer, while eleven respondents from Skopje and four from Belgrade would consider the offer. Based on this last answer we can conclude that the respondents were realistic when answering the previous questions.

Table 2. Comparative overview of the Cost of Living Index in the countries

City	Travel time to work	Indices of purchasing power, cost of living, property and income prices	Health care	Security	Climate, pollution index	Total
Skopje, North Macedonia	5,41	2,8	2,4	2,2	3	15,81
Number, respondents	40	40	40	40	40	40
Belgrade, Serbia	7, 79	2,8	3,2	3,2	1,8	18,79

Source: Autor

From the attached we can conclude that the cost of living is higher in Belgrade (Serbia), while in Skopje (Northern Macedonia) are lower.

CONCLUSION

Based on the conducted research in primary schools in Belgrade and Skopje, based on the indicators from the Numbeo database, we came to the conclusion that the respondents from Serbia are more satisfied with health care compared to the respondents from Northern Macedonia. On the other hand, when it comes to the indicator Time to travel to work, respondents from Northern Macedonia need less time to come to work than respondents from Serbia. When it comes to the Security indicator, respondents from Serbia feel safer in their country compared to respondents from Northern Macedonia. When it comes to the indicator Climate and environment, based on the results of the research, we can conclude that the respondents from Northern Macedonia is more satisfied with the climate and the environment in relation to the respondents from Serbia. The problem in Serbia, especially in Belgrade, is air pollution, especially in winter days, but also a large number of landfills and the still underdeveloped environmental awareness of people. When it comes to the cost of living indicator, we can conclude that the closest indicators on this issue are the more money saved by respondents from Northern Macedonia. When it comes to the quality of life based on the scaling of variable values, we came to the result that people from Serbia are more satisfied with the quality of life compared to the respondents from Northern Macedonia. When asked whether, if there is a chance to work for a higher salary and have a better quality of life, the respondents would work abroad, we conclude that the respondents from Serbia are more willing to leave their country compared to the respondents from Northern Macedonia.

The standard of living refers to the quantity and quality of material goods and services available to a certain population for economic and demographic development and change can be said to be a complex process in which environmental, socio-economic, geographical, and other factors play an important role. Population movements can be natural, mechanical, spatial and social. Industrialization and development of other economic activities in Serbia and Northern Macedonia have led to major changes in the economic structure of the active population; population concentrations in urban and mixed settlements and to the spatial mobility of the population. Due to the demographic and socio-economic connection, there were new characteristics of the population of Serbia and Northern Macedonia, which are characteristic of the period after the demographic transition: low or moderate birth rate; low mortality rate and changed age structure and developed social and economic structure of the population. Serbia and Northern Macedonia are facing a steady aging population due to low fertility rates and increased life expectancy. The rate of economic activity is lower than in many other European countries. The population of Serbia and Northern Macedonia is declining due to negative natural growth and emigration. The consequences of the COVID-19 crisis can lead to the prevalence of national interests in the system of international economic relations and delay the solution of global security priorities, to actualize the danger of social unrest and contribute to the collapse of internal stability in some countries caused by locking the country.

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