AUGUST 26-30, 2019
PRIZREN, KOSOVO

ABSTRACTS & PROCEEDINGS BOOK

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NATURAL SCIENCE AND TECHNOLOGY

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Natural Science and Technology

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ABSTRACTS
&
PROCEEDINGS BOOK

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Evaluation of the Antioxidant Defense System Parameters in Furan-Induced Toxicity in Leydig cells

Buse Yilmaz[1], Banu Orta Yilmaz[1*]

Abstract: Furan is a compound formed during processing and conservation techniques, including heat treatment of food products. Furan is found in high amounts in food products such as coffee, baby food, fruit juices, jars and canned food. Therefore, it is quite significant to study the effects of this compound in the body. According to the studies, it has been determined that furan adversely affects human health and leads to toxicity. In previous studies, although furan causes disorders in testis, epididymis and prostate gland, no effect on sperm count and morphology. However, it was observed that apoptotic cells significantly increased in the testis. Nevertheless, limited number of studies have shown that furan exposure induces toxicity of the male reproductive system. In this study, low concentrations of furan (250 and 2500 μM) were applied to TM3 Leydig cell line for 24 hours. It was aimed to be understood the effects of furan on cytotoxicity and antioxidant defence system in Leydig cells and reveal the mechanisms underlying the toxicity in these cells. The results of this study indicated that furan significantly reduced cell viability in Leydig cells. In addition, it was found that antioxidant defense system parameters (catalase, superoxide dismutase, glutathione peroxidase, glutathione-S-transferase) which are one of the cells defence mechanisms against oxidative stress have been suppressed. As a result, it was concluded that the furan could disrupt the functioning of antioxidant enzymes and cause cellular damage in Leydig cells.

Keywords: Antioxidant defense system, cytotoxicity, furan, Leydig cell, oxidative damage.

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Fourier transform infrared (FTIR) and Energy Dispersive X-Ray Fluorescence (EDXRF) investigations of Ottoman Empire postage stamps printed in 1865-1913

Sevim Akyuz[1]

Abstract: Postage stamps are cultural heritage that shows the historical, economic, political and special development of a country and society. The first Ottoman Empire adhesive postage stamps were Tughra stamps, printed in 1863, followed by Duloz series of stamps, which were printed between 1865-1882. Since these stamps were prepared by the French artist Duloz, were known as the "Duloz" series. Following the Duloz series stamps, Crescent Stamps of Ottoman Empire were first issued in September 1876, after being a member of Universal Postal Union. Unlike the previous Duloz series postage stamps, Crescent stamps bears the name of the country and Western characters and values. From 1901 through 1913, the Ottoman Empire issued a number of stamps with similar designs including the Tughra of the reigning monarch and had a distinct Turkish appearance.
In this study, Ottoman Empire postage stamps, printed in 1865-1913, have been analyzed for the first time, non-destructively using Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) and Energy Dispersive X-Ray Fluorescence (EDXRF) spectrometry methods. The merging of data coming from ATR-FTIR and EDXRF techniques has allowed the characterization of the pigments used on the surface of each stamp and dispersed between the paper fibers. Lead chromate, Prussian blue, vermillion, calcium carbonate, gypsum, cellulose and oil were identified. Moreover, the paper of the stamps was also analyzed.

Keywords: FTIR, EDXRF, Ottoman Empire Postage Stamps, Pigments.

Fig 1. Investigated stamps and their dates of issue.

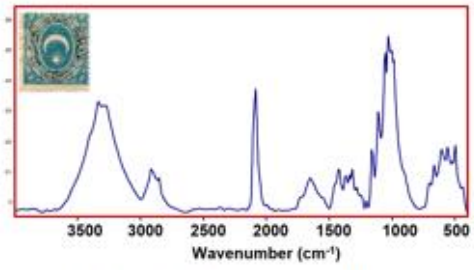

Fig. 2 ATR-FTIR spectrum of the Ottoman stamp shown.

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Investigations of the Neolithic Potteries of 6th Millennium BC from Göytepe-Azerbaijan by Spectroscopic and Chemometric Methods

Sevim Akyuz[1], Farhad Guliyev[2], Sefa Celik[3], Aysen E. Ozel[4], Valeh Alakbarov[2]

Abstract: Some Neolithic pottery fragments excavated in Göytepe-Azerbaijan were investigated using Fourier Transform Infrared (FTIR), micro-Raman, X-ray diffraction (XRD) and statistical chemometric techniques. The firing-temperature and -conditions were inferred from the mineral phases obtained from the FTIR and micro-Raman spectra of the samples. The XRD results confirmed the mineralogical composition determined by FTIR and micro-Raman analyses. Depending on the spectroscopic results, the firing temperatures of the investigated potteries were estimated to be between 600 oC and 750 oC in oxidizing atmosphere. As the chemometric methods, Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) were applied to FTIR spectral data in order to show similarities and dissimilarities of the samples and to extract the most discriminant features.

Keywords: Neolithic Pottery, FTIR, Raman, Spectroscopy, PCA-LDA, XRD

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Conformational Analysis and Vibrational Spectroscopic Investigation of a Biological Active Dipeptide

Sefa Celik[1], Volkan Durak[2], Aysen E. Ozel[3], Sevim Akyuz[4]

Abstract: A biological active dipeptide , which is a breakdown product of protein digestion or protein catabolism, has been investigated both theoretically and experimentally. Using the Chem3d program, the Alingers'MM2 force field was applied and 113 conformations were obtained by Molecular Dynamic Simulation. The energy values of these conformations determined by Molecular Dynamic Simulation are calculated using the ab-initio calculations with the Density Function Theory (DFT) method using B3LYP function with the basis set of 6-311 ++ G (d, p). Two possible conformers are determined. In addition, four different conformations were formed by using the geometric parameters of constructed amino acids taken from the literature. Optimized geometries and total energies of these four different conformations were calculated with the 6-31G(d, p), 6-31++G(d,p) and 6-311 ++G(d,p) basis sets using the DFT / B3LYP method. The vibration wave numbers of the two most stable conformation obtained were calculated by using the 6-311++G(d,p) basis set. The potential energy distribution (PED for the molecules were obtained using the MOLVIB program and the modes corresponding to each vibrational wavenumber were determined.

In the experimental part of the study, spectra of molecules were recorted using Jasco 300E FT-IR spectrometer (at 2 cm-1 resolution) and NRS 3100 Dispersive Micro Raman spectrometer. The obtained calculation results and experimental results are given in tabular form in comparasion with each other.

Keywords: Conformational analysis, Molecular Dynamic Simulation, DFT, FT-IR, Raman

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This work was supported by the Research fund of the University of Istanbul. Project numbers are BYP-2019-34276 and BYP-2018-32776.

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Conformational Analysis of a Molecule that has Anticancer Properties

Sefa Celik[1], Ali Tugrul Albayrak[2] , Sevim Akyuz[3], Aysen E. Ozel[4]

Abstract: The conformational analysis of the investigated molecule were performed in gas phase by PM3 and by molecular dynamic (MD) simulations. For MD simulations molecule was solvated in a cubic water box containing 1700 water molecule and subjected to a simulation time of 3 ns. The most stable conformations obtained by both methods were used for molecular docking studies. Molecular docking study was carried out to clarify the probable binding modes between the title compound and DNA. The active sites of the DNA were found to be the same for both conformationsWhen the most stable conformation obtained by PM3 calculations was used for docking of the molecule into DNA, a binding affinity of –6.9 kcal/mol was revealed, whereas -6.5 kcal/mol binding affinity was obtained for the most stable geometry obtained by MD simulations. Although the binding affinities were found to be different, the active sites of DNA obtained by molecular docking model using both optimized geometries were similar.

Acknowledgements

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Keywords: Conformational analysis, Molecular docking, MD simulations, PM3

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Vibrational Spectroscopic Investigations of Ancient Potteries and Glasses Excavated in Ancient Ainos (Enez)-Turkey

Sefa Celik[1], Sevim Akyuz[2], Ayşen E. Ozel[3], Sait Başaran[4]

Abstract: Ancient potteries and glasses are important source of materials on many aspects of the past such as civilization, trade and technology. ncient Ainos (Enez), in the Northern Coast of the Aegean sea, has been described as one of the most important archaeological sites in Turkey. The ancient city was established on the calcerous peninsula, belong to mid miocene, which was 25 meters high from the sea level. The city with two well-preserved harbors, was founded at the place where Antic Hebrus (Evros or Meric) river meets the sea, in the junction of seaways and highways that connect Balkans to Aegean and Anatolia. The river Hebrus (Meric) is the second largest river in the Balkans after the Danube. Until the 19th century, the river functioned as the major transportation artery between the north Aegean sea and regional cities like Edirne and Plovdiv,
In this study 20 fragments of potteries belonging to 4-6th Century BC and some glass bottles belonging to Roman, Byzantine and Ottoman periods, excavated in the archaeological site of ancient Ainos (Enez) have been investigated by micro-Raman, FTIR and EDXRF techniques, in order to obtain the ancient technology of the pottery and glass productions and to determine their chemical compositions.

Keywords: Micro-Raman, FTIR, EDXRF, Pottery, Glass

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The Future and Place of IGRs in IPM Programs

Sadettin Ünsal [1]*

Abstract: Broad-spectrum conventional insecticides were successful in controlling insect pests during the past six decades, minimizing thereby losses in agricultural yields. Unfortunately, many of these chemicals are harmful to man and beneficial organisms and cause ecological disturbances. Although considerable eftorts have been made to minimize the adverse environmental impact of pesticides and to maximize food production and health of the human population and domestic animals, there is today a great demand for safer and more selective insecticides aftecting specifically harmful pests, while sparing beneficial insect species and other organisms. Furthermore, the rapidly developing resistance to conventional insecticides provides the impetus to study new alternatives and more ecologically acceptable methods of insect control as part of integrated pest management (IPM) programs. One of these approaches which has captured worldwide attention is the use of analogs and antagonists of insect growth regulators (IGRs) such as juvenile hormones (JH), ecdysone agonists, chitin synthesis inhibitors. IGRs are a class of biorational compounds that disrupt the normal development of insects. IGRs affect the biology of the treated insects, for example, their embryonic and post-embryonic development, reproduction, behaviour and mortality. Abnormal morphogenesis is the observed effect of the action of IGRs on insects. Many of them are more potent than current insecticides, even against the eggs. Compared with conventional insecticides, IGRs do not exhibit quick knock-down effects on insects or cause mortality, but long-term exposure to these compounds largely stops population growth, as a result of the above-mentioned effects in both parents and progeny. IGRs are considered as a safer alternative to insecticides. These are non-toxic in nature and degrade rapidly. They also do not contaminate the groundwater and soil. The application of IGRs does not lead to harmful effects on advantageous soil microbes, animals, and humans. Numerous advantages of IGRs, such as lesser harmful impact on the environment and enhanced compatibility with pest management practices, make them attractive alternatives to insecticides. It must be understood that compounds of this type are also chemicals, but because of their low toxicity to mammals, their selective toxicity toward insect species, and their safety to the environment. They can assume a prominent role in the “integrated pest management (IPM)” program. This review is aimed at presenting an overview of this novel groups and compounds, with special emphasis on their modes of action and their importance to serve as components in IPM programs for the benefit of agriculture and the environment.

Keywords: Pests, Insect Growth Regulators (IGRs), Integrated Pest Management (IPM), Agriculture, Environmental Impact

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Determination of Environmental Conditions of Turkish Patented White Nectarine (Bayramiç Beyazı)

Akın Kıraç[1], Selçuk Birer[2], Mustafa Öğütcü[3]

Abstract: White nectarine (Bayramiç Beyazı) is one of the patented variety among the Turkish agriculture products, which originated in Çanakkale province district Bayramiç. The present study was to determine environmental condition effects on the cultivation of Turkish patented White Nectarine. Fifty-seven data were collected from different white nectarine farms in Çanakkale. Afterwards, the data analysed by MaxEnt (3.4.1v) software using with climatic data and topographic features. AUC values of the model were 0.952. Results of the present study demonstrated that the annual mean temperature (Bio 1), temperature seasonality (Bio 4), precipitation seasonality (Bio 15) and elevation influenced on the cultivation of white nectarine. According to these results, white nectarine annual mean temperature was 14 °C, temperature seasonality and precipitation seasonality were high and altitude was found between 100 and 200 m.
In conclusion, considering the whole Turkey map, habitat suitability map of the white nectarine showed that suitable areas of the white nectarine cultivation mainly in Çanakkale province, especially the Bayramiç district.

Keywords: White Nectarine, Habitat Suitability Model, MaxEnt, Çanakkale

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Experimental and Theoretical Vibrational Spectra and Electronic, Nonlinear Optical Properties of 1-(3-Pyridinyl)-Ethanone Molecule

Şenay Yurdakul[1] *, Sibel Çelik[2] , Meryem Alp[1]

Abstract: Using experimental and theoretical calculations, structural and some electronic properties of 1-(3-pyridinyl)-ethanone molecule were reported. Fourier transform infrared spectrum was obtained at room temperature in the region 4000 cm-1- 100 cm-1.In theoretical calculations, the B3LYP functional with 6-311++G(d,p) basis set was applied. The Fourier Transform Infrared (FT-IR) spectra was interpreted by using of normal coordinate analysis based on scaled quantum mechanical force field. The present work expands our understanding of the both the vibrational and structural properties as well as some electronic properties of the 1-(3-pyridinyl)-ethanone. Molecular electrostatic potential (MEP) distribution, frontier molecular orbitals, non-linear optical properties, thermodynamic parameters, charge analysis of the title molecule were also investigated. Some thermodynamic parameters of the molecule at different temperature were calculated, revealing the correlations between standard heat capacity, entropy, enthalpy changes and temperature.

Keywords: 1-(3-pyridyl)ethanone, infrared spectra, DFT, electronic properties.

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Natural Bond Orbital Analysis of Phenyltrichlorosilane

Saliha Ilican[1]*, Nihal Kus[1]

Abstract: Phenyltrichlorosilane (PClSi) used to make silicones for water repellents, heat resistant paints, insulating resins. Also it uses in industries for production of metals, in cosmetics, chemical manufacturing, etc. In this study, structure of the molecule was characterized using density functional theory (DFT) with B3LYP/6-311++G(d,p) level. Natural bond orbital (NBO) analysis was performed using NBO 3.1, as implemented in Gaussian09 program. Donor-acceptor interactions, stabilization energies, occupancy of the orbitals, natural and Mulliken charges for PClSi were analyzed with NBO method. The highest stabilization energy of PClSi was determined to be π-π* transition (Fig).

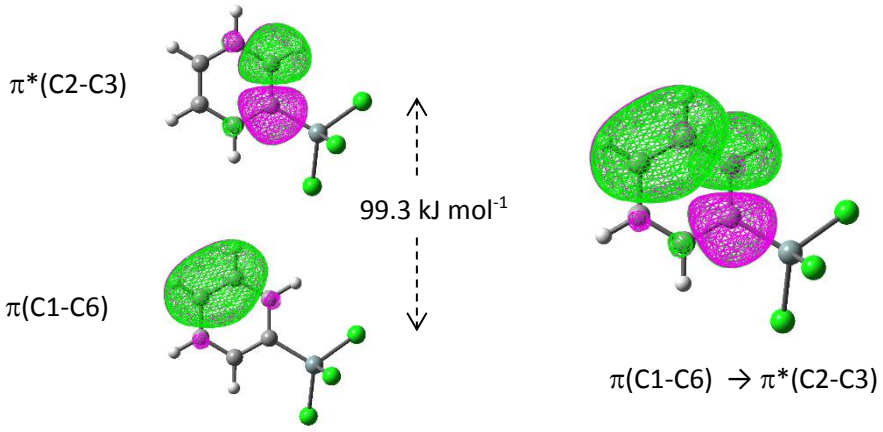

Figure. The orbital configuration of highest stabilization energy for PClSi.

Keywords: Phenyltrichlorosilane, DFT, NBO.

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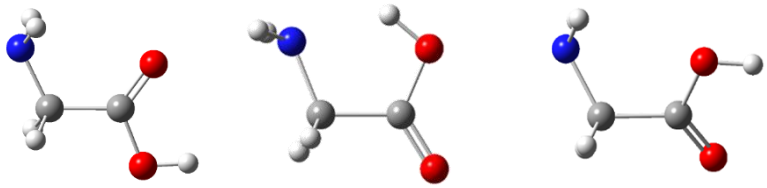
Conformational and Infrared Spectrum Analysis of Glycine

Saliha Ilican[1]*, Nihal Kus[1]

Abstract: Glycine (Gly) is an amino acid which forms the building block of protein. It's not a essential amino acid, and the body takes it from chemicals. Glycine is used for treating schizophrenia, stroke, sleep problems, metabolic syndrome, and metabolic disorders. Most importantly, it is also used in cancer prevention and memory development. Glycine has a wide application area and both theoretical and experimental studies are reported. In this study, molecular structure and conformational analysis of glycine were studied by DFT/B3LYP-6-311++g(d,p) method. The structure has seven conformers belong to calculations of N-C-C=O, H-O-C=O and C-C-N-H torsional motions, and three of them are main conformers (Fig.). Vibrational frequencies of Gly determined for all conformers. HOMO (highest occupied molecular orbital) - LUMO (lowest unoccupied molecular orbital) energy gaps for the main three conformers were calculated.



Gly_I **Gly_II** **Gly_III**

Figure. The main three conformers of glycine calculated by B3LYP/6-311++g(d,p) level.

Keywords: Glycine, Conformer, DFT, Vibrational frequency.

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Radical Transversal Lightlike Submanifolds of $\mathcal{A}$-constructed Sasakian Manifolds

Mehmet Gümüş[1]*, Çetin Camcı[2]

Abstract: Differantial geometry is an important branch of mathematical science. Especially in 19th century major works had been done by many mathematicians. In the second period of 20th century Blair defined contact manifolds and studied the general properties of contact manifolds in his lecture notes "Contact Manifolds in Riemannian Geometry" which published in 1976. Duggal and Bejancu studied the lightlike submanifolds of Semi-Riemannian Manifolds in their book "Lightlike Submanifolds of Semi-Riemannian Manifolds and Applications" in 1996 and in their paper "Lightlike submanifolds of indefinite Sasakian manifolds". Duggal and Şahin defined and investigated the geometry of lightlike submanifolds of indefinite Sasakian Manifolds. Gümüş defined the sliced almost contact manifolds in his Ph. D. thesis "A New Construction of Sasaki Manifolds in Semi-Riemann Space and Applications" as a wider class of almost contact manifolds in 2018. Gümüş and Camcı worked not only on the A-constructed Sasakian manifolds they also worked on the lightlike submanifolds of A-constructed Sasakian manifolds. They obtained similar results with the works done by Yildirim and Şahin in their paper "Transversal Lightlike Submanifolds of Indefinite Sasakian Manifolds" which published in 2010. In this worked Gümüş and Camci defined and worked the geometry of radical transversal lighlike submanifolds of A-constructed Sasakian manifolds.

Keywords: Sliced almost contact manifolds, A-constructed sasakian manifolds, lightlike submanifolds.

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On the Conditions of Commutative Rings

Didem K. Camcı[1]*

Abstract: In mathematics, a ring is one of the fundamental algebraic structures used in abstract algebra. There are many studies in the literature in which the commutativity of a ring is obtained. Because every commutative ring is a polynomial identity ring (PI-ring) satisfying the polynomial identity $xy - yx = 0$. Besides the relationships between derivations and the structure of rings has been studied by many authors in the last sixty years. The first work involving derivation related to the commutativity of a ring was prepared by Posner in 1957. In this study, we studied the conditions of being a commutative ring. We also developed the conditions for a commutative ring given in the literature.

Keywords: Ring, commutative ring, lie product, lie ideal.

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Antioxidant Enzyme Activities in Field Grown and Greenhouse Grown Marrow

Esma Hande Alici[1], Cengiz Cesko[2]*, Gulnur Arabaci[1]

Abstract: Plants are always exposed to several stress factors in cropland, which affect their production. These environmental problems usually give cause for accumulation of reactive oxygen species (ROS). ROS are highly reactive molecules which are produced mainly by the mitochondrial electron transport chain as a result of normal cellular metabolism. These reactive molecules can cause severe oxidative damage to plants. Plants have integrated enzymatic (SOD, POX, CAT, PPO, etc.) and non-enzymatic (vitamin C, vitamin E, β-carotene, uric acid, glutathione) antioxidant systems against oxidative damage that are activated during stress to regulate toxic levels of ROS. Thus, since environmental conditions can induce ROS production and ROS production activates the plant's antioxidant defense system, antioxidant enzyme levels may also be different in plants grown in different environmental conditions. In this study, the level of enzymatic antioxidants such as peroxidase (POX), superoxide dismutase (SOD), catalase (CAT) and polyphenol oxidase (PPO) of marrow (*Cucurbita pepo* L.) were determined. Two different marrow vegetables, which were harvested from a field and a greenhouse, were used as enzyme source. Their antioxidant enzyme levels were determined and the results were given comparatively. The antioxidant enzyme activities were measured spectrophotometrically. Enzyme activity levels were calculated by using the change in absorbance per unit of time, for each enzyme. According to the results, both of the sources showed SOD, POX, CAT and PPO activities. For all the enzymes tested, it was determined that the activities of antioxidant enzymes isolated from marrow grown in the field were higher than those isolated from marrow grown in the greenhouse.

Keywords: Catalase, *Cucurbita pepo* L., peroxidase, polyphenol oxidase, superoxide dismutase.

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Classification of The Monolithic Columns Produced in Troad and Mysia Region Ancient Granite Quarries in North-Western Anatolia via Soft Decision-Making

Serdar Enginoğlu[1]*, Murat Ay[2], Naim Çağman[3], Veysel Tolun[2]

Abstract: Ay and Tolun [An Archaeometric Approach on the Distribution of Troadic Granite Columns in the Western Anatolian Coasts. Journal of Archaeology & Art, 156, 2017, 119-130 (In Turkish)] have analysed the distribution in North-Western Anatolia of the monolithic columns produced in the ancient granite quarries, located in Troad Region and Mysia Region, by using archaeometric methods and have achieved some results by interpreting the prominent ones of the data obtained therein. In this study, we propose a new soft decision-making method called Monolithic Columns Classification Method (MCCM) constructed via fuzzy parameterized fuzzy soft matrices (*fpfs*-matrices) and Prevalence Effect Method (PEM). MCCM provides an outcome by interpreting all the results of the analysis mentioned above. We then apply the method to the monolithic columns classification problem. Finally, we discuss the need for further research.

Keywords: Ancient granite quarries, classification, *fpfs*-matrices, monolithic column, soft decision-making

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A New Concept for Mathematical Modelling of Problems with Further Uncertainty

Tuğçe Aydın*, Serdar Enginoğlu

Abstract: Recently, intuitionistic fuzzy sets, soft sets, and their hybrid versions have often used for modelling some problems containing uncertainties. Moreover, in the event that comes into question further uncertainty, using interval numbers are common. We, in this study, propose a new concept that allows for modelling of such uncertainties and which is called interval-valued intuitionistic fuzzy parameterized interval-valued intuitionistic fuzzy soft sets (*d*-sets). We then have applied this concept to the recruitment process of a company. This application has shown that *d*-sets can be successfully applied to the problems that contain further uncertainty. Finally, we discuss the need for further research. This study is a part of the first author's PhD dissertation.

Keywords: Fuzzy sets, soft sets, interval-valued intuitionistic fuzzy sets, *d*-sets, soft decision-making.

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Intuitionistic Fuzzy Parameterized Intuitionistic Fuzzy Soft Matrices

Serdar Enginoğlu*, Burak Arslan

Abstract: The concepts of fuzzy sets (Zadeh, 1965), soft sets (Molodtsov, 1999), and intuitionistic fuzzy sets (Atanassov, 1986) are among the known mathematical tools proposed to model problems that contain uncertainty. So far, their many general forms have been defined such as intuitionistic fuzzy soft sets (Maji et al., 2001), intuitionistic fuzzy parameterized soft sets (Deli and Çağman, 2015), intuitionistic fuzzy parameterized fuzzy soft sets (El-Yagubi and Salleh, 2013), and intuitionistic fuzzy parameterized intuitionistic fuzzy soft sets (Karaaslan, 2016). However, when the problems have a large amount of data, these concepts have a disadvantage in terms of time and complexity. Therefore, defining their matrix representations is significant. In this study, we define the concept of intuitionistic fuzzy parameterized intuitionistic fuzzy soft matrices (*ifpifs*-matrices) being one of these matrix representations. We then apply this concept to model the recruitment process in a company. Finally, we discuss the need for further research. This study is a part of the second author's master's thesis.

Keywords: Fuzzy sets, soft sets, intuitionistic fuzzy sets, soft matrices, *ifpifs*-matrices, soft decision-making

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Development of Reinforced Composites Containing Tea Tree Oil for The Treatment of Horse Nail Fractures

Tomasz Gozdek[1], Kamila Sobkowiak[1*]

Abstract: The aim of the study was the evaluation of properties of variously composed composite materials based on polyurethane filled with tea tree oil (TTO) and addition of other ingredients. The tea tree oil/cyclodextrin inclusion complex was prepared by using the 'Paste method' described in Shrestha, M and others. (2017). To analyse the properties of composite materials following testing methods were conducted: density, tensile strength, compression test, impact resistance. In the study, pursued in the Lodz University of Technology in Poland, thirteen materials with different percentile content of additives: TTO/β-CD, propolis, TTO/β-CD/Propolis, TTO were prepared and tested to establish the most favourable characteristics. Properties of sample containing Tea tree oil/ β-cyclodextrin/Propolis were the most satisfying and were assumed to be accurate in fulfilling the role of the hoof crack filler the best in the first study. With the higher amount of the additive the mechanical properties weakened preventing the use of the product in the hoof cracks.

Keywords: polyurethane, tea tree oil, cyclodextrin, propolis, encapsulation, hoof cracks.

Sobkowiak, K., Kocabıyık, A., & Karaboyacı, M. (2018). Development of Cyclodextrin Particle Reinforced Composites Containing Tea Tree Oil for The Treatment of Horse Nail Fractures. ICONST 2018, 888-893.

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Acknowledgements: This research is a continuation of the study conducted in the Suleyman Demirel University in Isparta, Turkey described in the article: Sobkowiak, K., Kocabıyık, A., & Karaboyacı, M. (2018). Development of Cyclodextrin Particle Reinforced Composites Containing Tea Tree Oil for The Treatment of Horse Nail Fractures.

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Global Trade of Forest Tree Seeds is a Potential Risk to Forest Biosecurity

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Abstract: Seeds are known to carry insect and pathogenic organisms both externally and internally. Therefore, the international trade of seed carries with it risks of inadvertent introduction of plant pests and pathogens which can establish in forests and landscapes. Tree seeds are generally considered safer for trade than live plants but the transport of infested/contaminated seed is known to be implicated in the introduction of several important and damaging forest pathogens to different regions of the world: such as the causal agents of pine pitch canker (*Fusarium circinatum*), Eucalyptus stem canker (*Teratosphaeria zuluensis*), pine shoot tip blight (*Diplodia sapinea*) and chestnut blight (*Cryphonectria parasitica*). Thus, our current understanding of this pathway may be underestimated in terms of its importance in the introduction and spread of potentially harmful pests and pathogens. Recent investigations revealed considerable proportions of potentially harmful fungi with biosecurity risks associated with routinely traded seeds. Improved detection protocols for potentially harmful pathogens associated with seeds, utilizing high throughput sequencing technologies, are required to screen for phytosanitary risks, along with improved measures to reduce or eliminate the risk.

Keywords: biosecurity, forest pathogens, seed trade, detection

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The Effect of Water Sources on the Formation of Adorabable Organic Halides in Swimming Pools

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Abstract: In general, tap water containing natural organic matter (NOM) is used for filling the swimming pool (SP) os accepted as precursors for disinfection by products (DBPs). Additionally SP revives the anthpogenic precursors such as hair, urine, etc from swimmers. Filling water (FW) entering the SP might be surface water (SW) or groundwater (GW). The main goal of this study to reduce DBPs precursors from the source water and impact of it on the formation of known and unknown DBPs.

For the experiments, two models of swimming pool water from two different sources of water were prepared. Sources water were brought to the same TOC level, then the body fluid analog (BFA) was added to increase the TOC to 1 mg/L for two models SP waters.

The results of two SP waters models indicate that there is a difference between using the SW and GW as FW on known DBPs and AOX formation, since NOM of SW represents a more potential precursors than NOM of GW.

Keywords: Water Sources, DBP, Formation, Swimming Pool.

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Isolation of *Pectobacterium Carotovorum*, Identification with 16S rRNA, Phytase Activity and Characterization of the Bacteria

Neslihan Dikbaş[1]*, Kağan Tolga Cinisli[1], Safa Mustafa Kılıç[1], Sevda Uçar[1], Emre Canca[1],

Abstract: Phytases can be produced by animals, plants and microorganisms. However, the most promising ones for commercial use and biotechnological applications are those of microbial origin. Phytases are also used in the preparation of myo-inositol phosphates in the food industry, soil remediation and in the paper industry. Biotechnology, along with the increased use of phytase enzymes, is a highly effective technology that is used today and will be used in the future to produce these enzymes and improve their properties.

The aim of this study was to conduct the molecular identification of *Pectobacterium carotovorum* strains isolated from lettuce to produce phytase from a new microbial source and the characterization of the enzyme. The activity and characterization of the phytase obtained from the bacterium was carried out. Isolation of strains was carried out following incubation at 26 ° C for 48 hours using Nutrient agar (Oxoid). The identification was performed using the 16S rRNA method. The phytase produced from *Pectobacterium carotovorum* showed the best activity at pH 8.0. The optimum temperature of the phytase obtained from *Pectobacterium carotovorum* was 60 ° C. In this study, enzymatic activity of phytase was investigated in *Pectobacterium carotovorum* for the first time. The results showed that it can be used in the industry due to the characteristics of the enzyme produced by *Pectobacterium carotovorum*.
Keywords: *Pectobacterium carotovorum*, 16S rRNA, Phytase, Characterization

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Determination of Chitinase Activity of *Lactobacillus Coryniformis* Obtained from Cheese and Its Effects on Alternaria Alternata

Neslihan Dikbaş[1*], Kağan Tolga Cinisli[1], Sevda Uçar[1], Selda Nur Hacıabdullahoğlu[1], Elif Tozlu[2], Özgür Kaynar[3], Recep Kotan [2]

Abstract: The use of bacteria in biotechnology has increased in the recent years. Various biotechnological studies on bacteria are carried out and various benefits and products can be obtained as a result of these studies. In the present study, the chitinase enzyme production from *L. coryniformis* and antifungal properties of *L. coryniformis* were investigated. Accordingly, chitinase enzyme production activities of *L. coryniformis* strains isolated from Cheese was tested and the suitability of its antifungal properties to industry was investigated by conducting a literature review. It was determined that the performed antifungal tests significantly inhibited the development of *A. alternata*. As a result, it was found that the extracellular chitinase enzyme produced by *L. coryniformis*, which is present in our culture collection and identified at 99% accuracy, had an optimum pH of 6 and an optimum temperature of 70°C. Our results confirmed that *L.coryniformis* can be use in the industry due to its wide pH range, its high optimum temperature and its superior antifungal properties against *A. alternata*.

Keywords: Bacteria, enzyme, antifungal

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Controlling Structural and Electronic Properties of ZnO NPs: Density-Functional Tight-Binding Method

Mustafa Kurban[1]*, Hasan Kurban[2,3], Mehmet Dalkılıç[2]

Abstract:

We carried out a thorough examination of the structural and electronic properties of undoped and Nitrogen (N)-doped ZnO nanoparticles (NPs) using the density-functional tight-binding (DFTB) method. By increasing the percent of N atoms in undoped ZnO NPs, the number of bonds, segregation phenomena and radial distribution function (RDF) of two-body interactions such as Zn-Zn, N-N, O-O, N-O etc. were investigated using novel algorithms. The results reveal that the number of Zn-Zn bonds is greater than that of N-N, N-O, O-O, and Zn-Zn bonds; thus, it appears that Zn atoms have a greater preference for N or O atoms. The RDFs of Zn and O atoms increase based on the increase in the content of N atoms. The segregation of Zn, O and N atoms shows that O and N atoms tend to co-locate at the center, whereas Zn atoms tend to reside on the surface. From the density of state (DOS) analysis, undoped and N-doped ZnO NPs demonstrate a semiconductor-like character which is compatible with experimental data. The HOMO-LUMO energy gap decreases from -4.717 to -0.853 eV. n increase in the content of N atoms contributes to the destabilization of ZnO NPs due to a decrease in the energy gap.

Keywords: NPs, N-doped ZnO, electronic structure, data science

1. Introduction

Nanoparticles (NPs), tiny objects whose sizes are lay between 1 and 100 nanometers, are finding use in diverse areas including energy, electronics, biomedical and optical fields due to their shape dependence properties as opposed to their bulk structure. More specifically, metallic NPs exhibit properties useful as both insulators and semiconductors and have been widely investigated (Wang, 2007; Yang, et al. 2008; Kushwaha, 2012). ZnO NPs, in particular, have been an area of intense scrutiny, because they have a wide bandgap and excellent optical properties for optoelectronics applications, being widely studied in various fields as photodetectors (Chang, et al. 2012), energetic materials (Barziniy, et al. 2019), and biomedical agents (Zhang, 2013).

In this work, we report the effect of Nitrogen (N) on ZnO NPs using the density-functional tight-binding (DFTB) method. Among the analyses we conduct are studies of the HOMO, LUMO and the frontier molecular orbital energy gap (E_g), total energy, density of states (DOS), radial distribution functions (RDFs), order parameter (R) to analyze the segregation phenomena of Zinc (Zn), Oxygen (O) and N atoms and the number of bonds of two-body interactions in the undoped and doped ZnO NPs. To supplement our work on

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structural analysis, we designed and implemented programs R (https://www.r-project.org/) to analyze the number of bonds, segregation phenomena, and RDF.

2. Material and Method

The structural and electronic properties of undoped and N-doped ZnO NPs have been examined using DFTB implemented in DFTB+ code (Aradi, et al. 2007) with the hyb-0-2 (Frauenheim, et al. 2003; Hajnal, et al. 2004) set of Slater Koster parameters. To make the program more accessible to non-computational scientists, we have also ensured that the programs are simple to use. Additionally, we have added functionality to include analysis of the number of bonds, segregation phenomena, and RDF of the ZnO NPs based on the N content. The code open source freely available online. Lastly, these programs include high-resolution visualizations to plot data, though our intent is broader than the scope of the work in this study, and a richer set of tools will be made in the future.

3. Results

3.1. Structural analysis

The initial structure of undoped ZnO NP with n = 258 atoms is indicated in Fig. 1. All of the ZnO NPs were characterized by 30×30×30 supercells of the hexagonal crystal structure (wurtzite, space group $P6_3mc$). All calculations have been performed at constant volume.

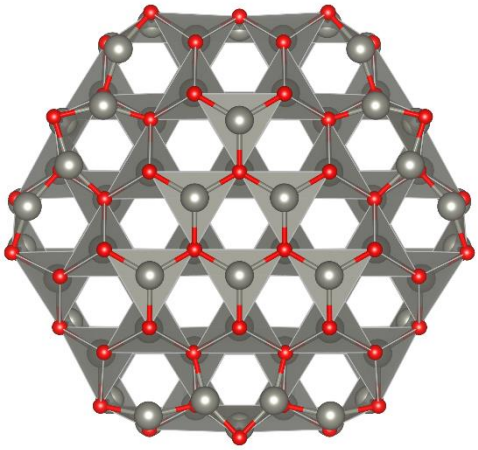

Figure 1. Initial structure (polyhedral) of undoped ZnO NP with 258 atoms. (Red is Oxygen, grey is Zinc).

The number of the nearest neighbor contacts (n_{ij}), that is the number of bonds, is generally adopted to distinguish the degree of packing, which is an important property of NPs. The number n_{ij} (Wu, et al. 2016) for the NPs is given by

$$n_{ij} = \sum_{i<j} \delta_{ij} \tag{1}$$

where $\delta_{ij} = \begin{cases} 1, r_{ij} \leq 1.2 r_{ij}^{(0)} \\ 0, r_{ij} > 1.2 r_{ij}^{(0)} \end{cases}$ $i, j =$ Zn, O or N, r_{ij} is the distance between atom i and j and $r_{ij}^{(0)}$ is a nearest neighbor criterion derived by fitting the experimental data (web page, 2019;

Czajkowski, et al. 1999). Fig. 2 shows the numbers of bonds in the undoped and doped ZnO NPs with 258 atoms. From the curve of ZnO NPs shown in Fig. 2, it is clear that the number of N-N and N-O bonds increase gradually in terms of increase in the content of N atoms in the ZnO NPs. Moreover, the number of Zn-Zn bonds is relatively smaller than total bonds, while N-N bonds are the smallest. This means that N atoms tend to form more bonds with O atoms: that Zn_2 tend to scatter on the surface can likewise be inferred. Moreover, the number of Zn-Zn bonds is larger than that of N-N, N-O, O-O and Zn-Zn bonds; thus, it appears that Zn atoms have a greater preference for N or O atoms (there is no experimental data on the Zn-O and Zn-N two body interactions, thus, Zn atoms probably adhere to N or O atoms) than for Zn atoms based on the increase of N content.

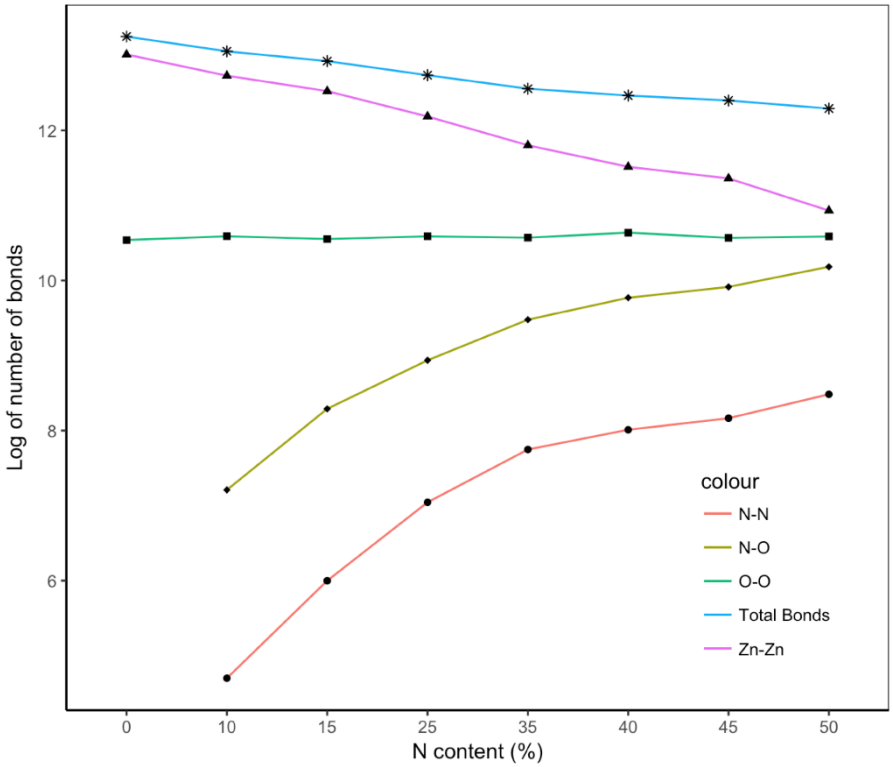

Figure 2. Variation of number of bonds of binary N-N, N-O, O-O and Zn-Zn interactions based on the content of N atoms in the ZnO NPs.

The order parameter (R_{T_i}) is calculated to determine the stable structure in the NPs by analyzing the distribution of the different types of atoms (Kurban, et al. 2016). R_{T_i} is identified by the average distance of a type T_i atoms in accordance with the center of a NP,

$$R_{T_i} = \frac{1}{n_{T_i}} \sum_{i=1}^{n_{T_i}} r_i \tag{2}$$

where n_{T_i} is the number T_i type atoms in the ternary ABC NPs, and r_i is the distance of the atoms to the coordinate center of the NP. We define a distance from the center of NP to a reference point as ϵ to indicate the location of atoms; if $R_{T_i} < \epsilon_{min}$ (a "small" value) , it means that the T_i type atoms are at the center, and if $R_{T_i} > \epsilon_{max}$ (a "large" value), it means

that the T_i type atoms are at the surface region of NP. If neither is true, *i.e.*, if $\epsilon_{min} \leq R_{T_i} \leq \epsilon_{max}$ (a "medium" value), it means a well-mixed NP.

Fig. 3 shows the behavior of R of Zn, O and N atoms in terms of the NP size. The segregation behavior of atoms in the undoped and doped ZnO NPs is performed using the R. The segregation of Zn, O and N atoms indicates that N atoms tend to locate at the center, while Zn atoms tend to occupy the surface as a general trend. The segregation of N atoms to the surface is due to its lower cohesive energy. The R shows different characteristics with the increase of the content of N atoms. For example, R_{Zn} values sharply increase after doping 35% N, and R_O smoothly decrease.

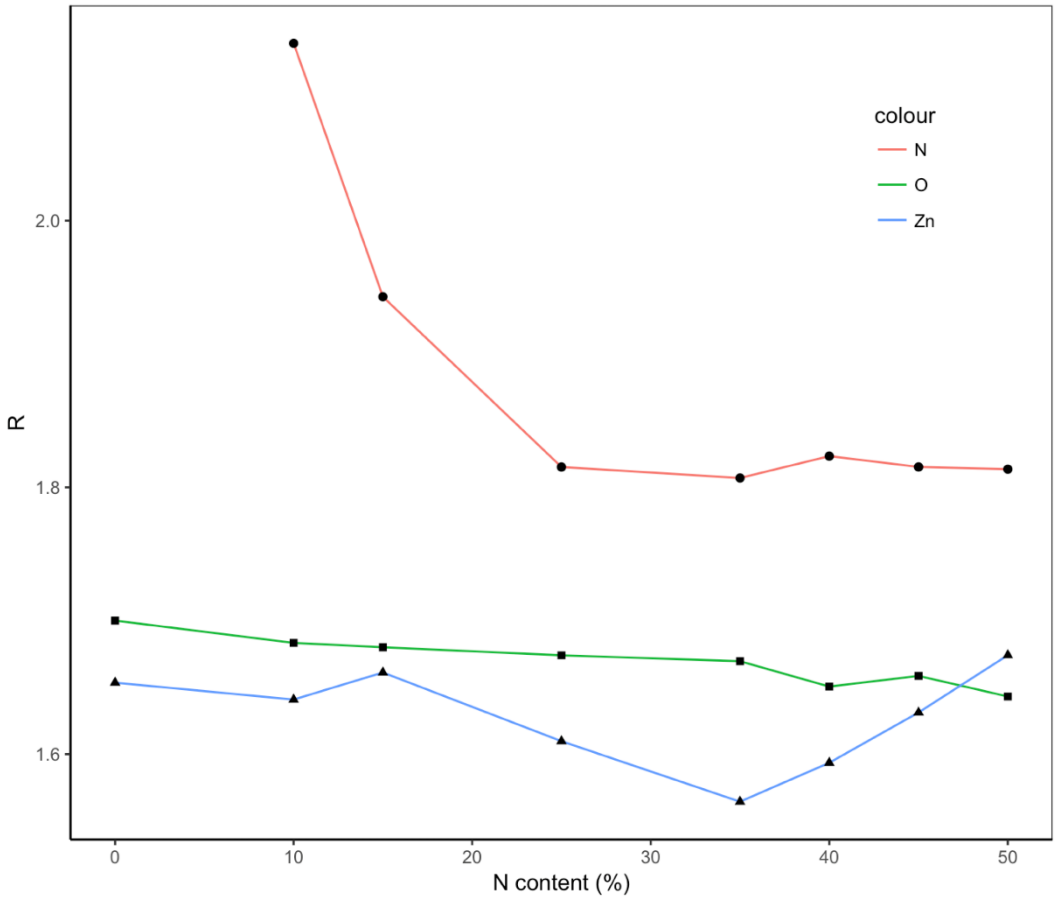

Figure 3. Variation of the order parameter of Zn, O and N atoms in the ZnO NPs.

The Radial Distribution Function (RDF) is an important structural characteristic that defines the probability of finding a particle at a distance r from another tagged particle. The RDF is mathematically defined as $g_{(r_i)} = n_{(r_i)}/(|\Delta| \times V_s \times V_d)$ where $n_{(r_i)}$ is the mean number of atoms in a shell of width dr at distance r_i, $|\Delta|$ represents total atom number and V_s is the volume of the spherical shell and V_d is the mean atom density.

Fig. 4 shows the RDF Zn-Zn, O-O and N-N binary interactions in the undoped and doped ZnO NPs. The RDFs are calculated for each atomic pair of optimized structures. Zn-Zn has a narrower and higher distribution than O-O interactions. With regards to N atoms, the peaks for both pairs increase with increasing the content of N atoms. Moreover, the fluctuations were observed in obvious peaks of N-N interactions with raising the content of N.

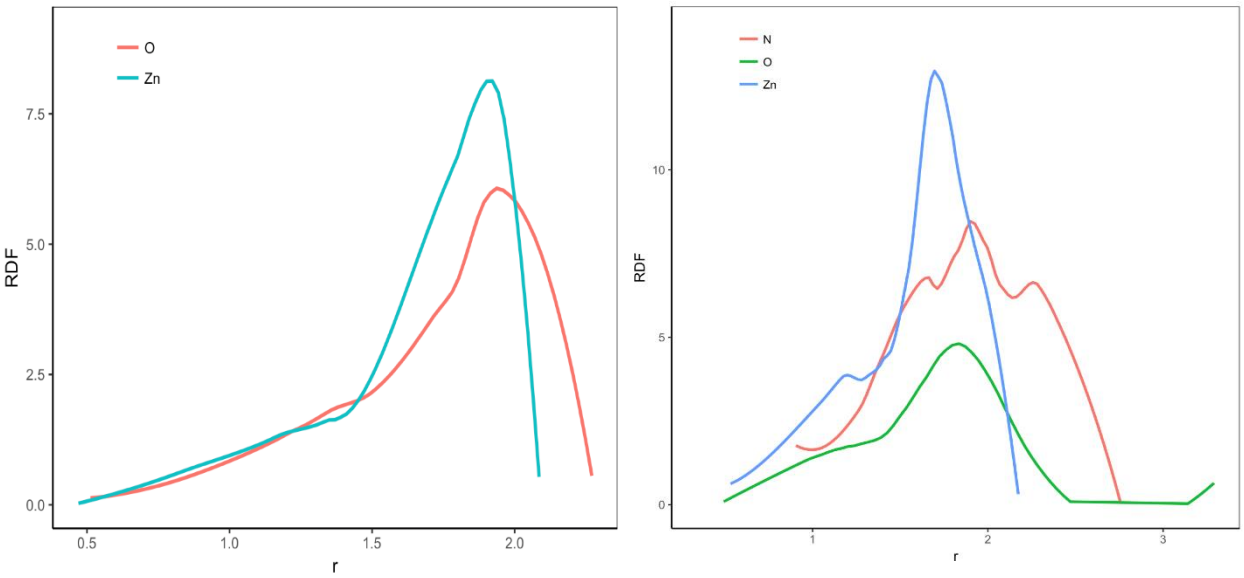

Figure 4. Radial distribution function of undoped (left) and doped (right) ZnO NPs.

3.2. Electronic structure

To obtain detailed information on electronic states in undoped and doped ZnO NPs, we report in this study the results of the electronic total DOS of different sizes as seen in Fig.5. The density of localized states decreases concomitantly with the content of N atoms where the greatest contribution comes from the undoped ZnO NPs. These fluctuations progressively disappear based on the increase in the content of N. The density of localized states has a sharply increasing tendency to occur in the region of between -10 and -15 eV. The DOS analysis also indicates that undoped and doped ZnO NPs have the energy gap, so, all the NPs show semiconductor character. There are both a decrease and an increase in HOMO, LUMO and Fermi energy with increasing the content of N.

The HOMO value for undoped ZnO NP is -7.89 eV wide, *i.e.*, about 0.97 eV greater than the 50% N-doped NP which has the lowest HOMO value (-6.91 eV) and is less reactive, while being more stable than the undoped and other NPs (see Fig. 6, Table 1). Fermi energy levels are found to be the middle of the valence and conduction band. The HOMO-LUMO energy gap of undoped ZnO NP is 4.71 eV, which decrease from -4.717 to -0.853 eV. It is clear then that an increase in the content of N atoms contributes to the destabilization of ZnO NPs due to a decrease in the energy gap.

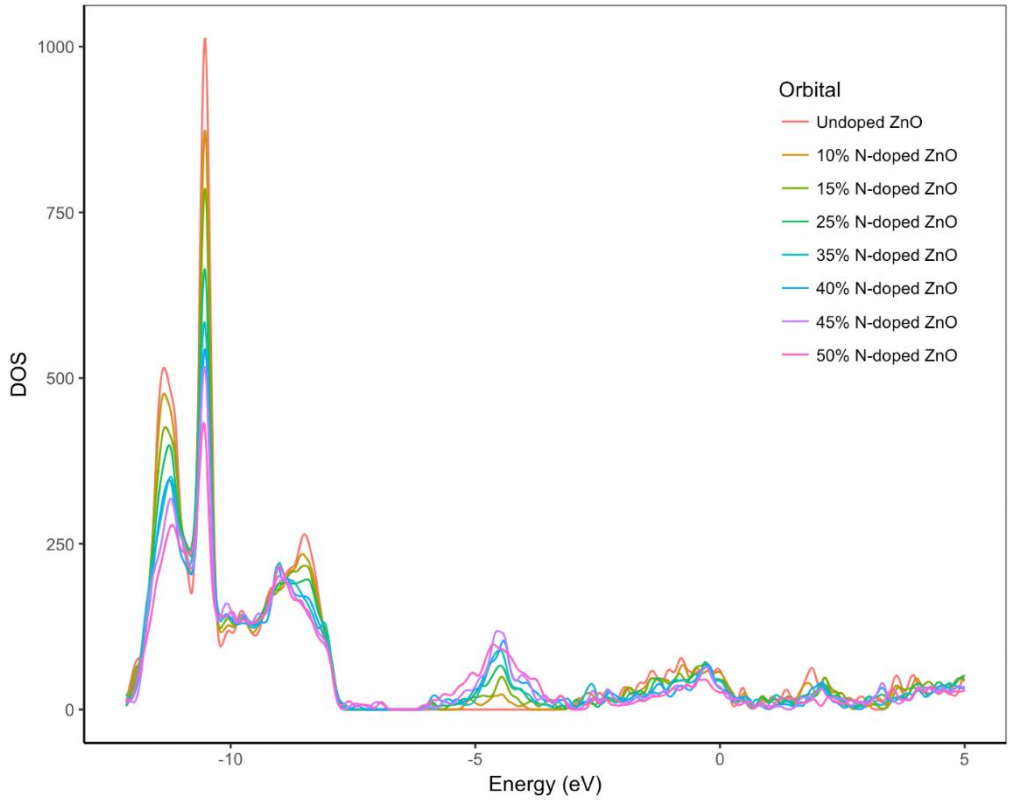

Figure 5. The total density of states (DOS) of undoped and N-doped ZnO NPs.

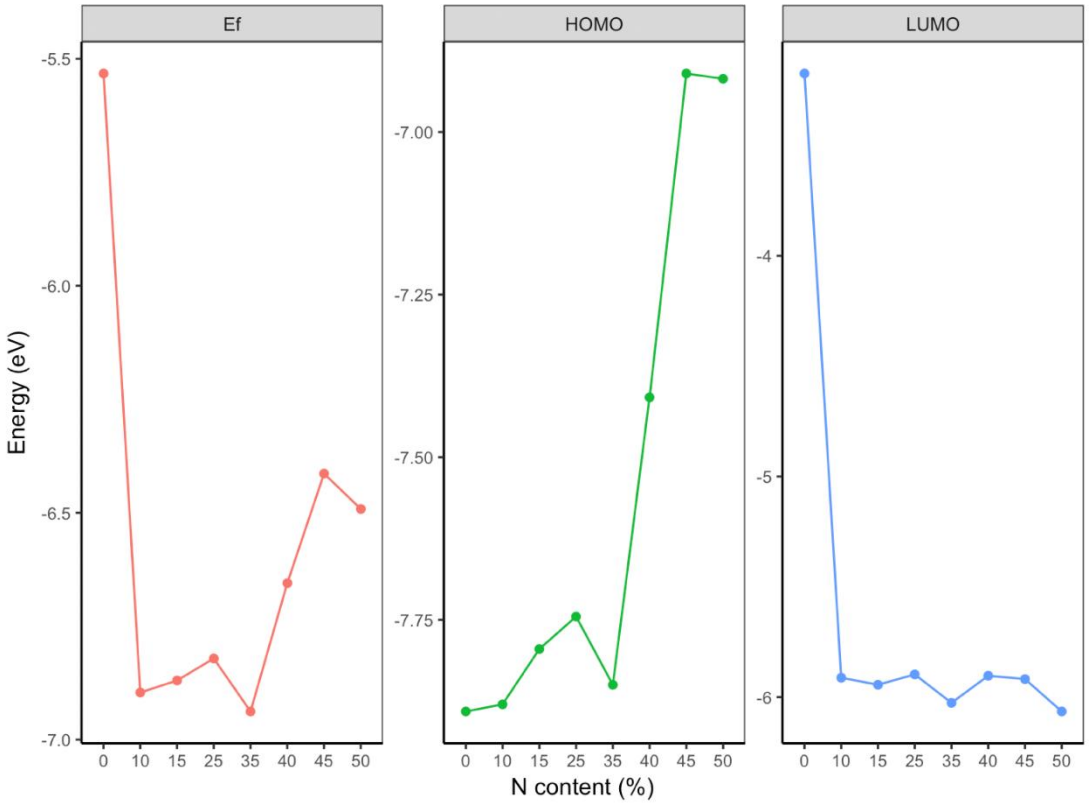

Figure 6. HOMO, LUMO and Fermi energies of undoped and N-doped ZnO NPs.

Table 1. The electronic structure data of undoped and N-doped ZnO NPs.

	HOMO	LUMO	Energy gap	Fermi energy
Undoped ZnO	-7.891	-3.174	4.7170	-5.5324
10% N-doped ZnO	-7.880	-5.912	1.9680	-6.8961
15% N-doped ZnO	-7.795	-5.944	1.8510	-6.8696
25% N-doped ZnO	-7.745	-5.897	1.8480	-6.8211
35% N-doped ZnO	-7.850	-6.026	1.8240	-6.9379
40% N-doped ZnO	-7.408	-5.903	1.5050	-6.6551
45% N-doped ZnO	-6.910	-5.918	0.9920	-6.4138
50% N-doped ZnO	-6.918	-6.065	0.8530	-6.4917

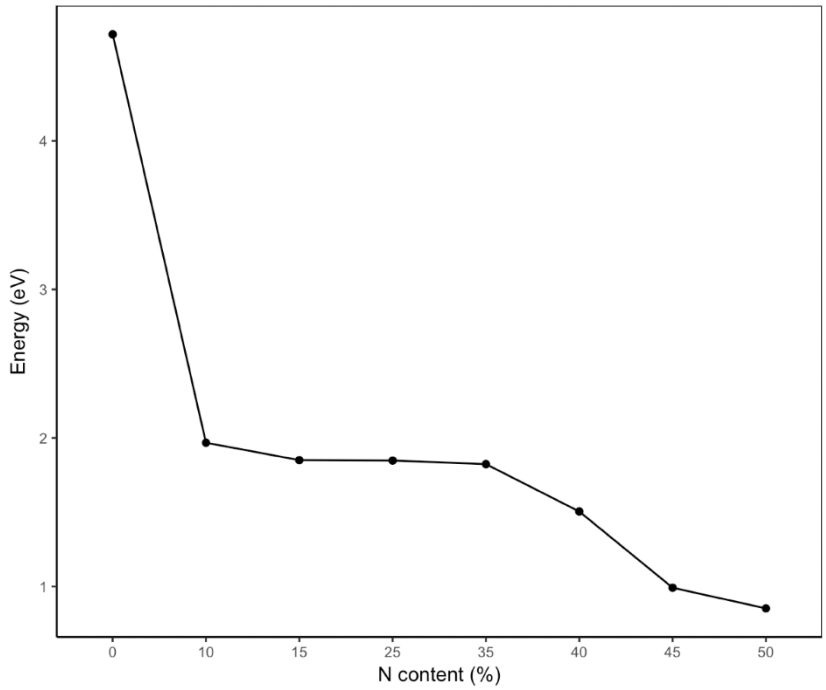

Figure 7. HOMO-LUMO energy gap of undoped and N-doped ZnO NPs.

4. Discussion and Conclusions

This work examines the structural and electronic properties of undoped and doped Nitrogen (N) ZnO NPs with 258 atoms, using the density functional tight binding (DFTB) approach. To perform structural analysis, we designed, implemented, and tested R code that analyzes the number of bonds, segregation phenomena, and RDFs of binary interactions in the ZnO NPs. From the results of our calculations, we found that the number of Zn-Zn bonds is larger than that of N-N, N-O, O-O, and Zn-Zn bonds; thus, it appears that Zn atoms have a greater preference for N or O atoms. The increase in the content of N atoms contributes to the stabilization of the ZnO NPs. The segregation of Zn, O and N atoms indicates that N atoms tend to locate at the center, while Zn atoms tend to occupy the surface as a general trend. The HOMO energy level decreases; however, the LUMO level increase, thus the HOMO-LUMO band gap decreases from -4.717 to -0.853 eV. The decrease in the HOMO levels contributes to the stabilization of the ZnO NPs. From the density of state (DOS) analysis, ZnO NPs exhibits a semiconductor-like character.

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The Effects of a Single Atom Substitution and Temperature on Electronic and Photophysical Properties F8T2 Organic Material

Mustafa Kurban[1]*

Abstract:

The changes in the electronic structure and photophysical properties of F8T2 organic semiconductor-based on a single atom substitution and temperature have been investigated using the self-consistent charge density-functional based tight-binding (SCC-DFTB) which is based on the density functional theory (DFT) and molecular dynamics (MD) methods. First of all, the heat treatment was carried out on the F8T2 from 50 K to 600 K. Later, the electronic and optical properties of F8T2 by substitution of some nonmetallic single atoms, such as Fluorine (F), Bromine (Br) and Iodine (I) was performed. The HOMO, LUMO and bandgap energies, dipole moments, and Fermi levels were investigated. Absorption spectral analysis has also been obtained by time-dependent (TD)-DFTB. The obtained results of F8T2 were compared to experimental results. The HOMO and LUMO energy levels of F8T2 were found -5.045 and -2.729 eV, respectively, which are compatible with experimental HOMO (-5.44 eV) and LUMO (-2.95 eV) energy levels. The band energy (2.32 eV) is also consistent with experimental findings (2.49 eV). The gap energy for F8T2 increased from 2.32 eV (at 0 K) to 3.03 K (at 663.38 K) which is about 0.71 eV wide than that of F8T2 at 0 K. The calculated maximum absorbance peak is 437 nm which is very well matched with experimental value (465 nm).

Keywords: F8T2, absorbance, electronic structure, TD-DFTB

1. Introduction

In recent years, organic semiconductors have been of significant attention in many applications such as electronic and photonic applications (Cheng, et al. 2019; Zhang, et al. 2018). Among them, poly[(9,9-dioctylfluorenyl-2,7-diyl)-co-bithiophene] (F8T2), especially, is a promising class in organic field effect phototransistors as the active material due to its high ionization potential (5.5 eV) (Whang, et al. 2010; Sirringhaus, et al. 2000). Besides, the transistors show highly stable and reproducible performance under heat treatment (Whang, et al. 2010).

The physical and optoelectronic properties of materials are considerably tunable as a function of temperature and an atom substitution (Kurban, 2018; Kurban, et al. 2016). In these regards, the changes in the bandgap and photophysical properties of F8T2 have been investigated using the self-consistent charge density-functional based tight-binding (SCC-DFTB) which is based on the density functional theory (DFT) and molecular dynamics (MD) methods in this study (Aradi, et al. 2007; Elstner, et al. 1998).First of all, the heat treatment was carried out on the F8T2 from 50 K to 600 K. Later, the electronic and optical properties

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of F8T2 by substitution of some nonmetallic single atoms, such as Fluorine (F), Bromine (Br) and Iodine (I), was performed. HOMO, LUMO and bandgap energies, dipole moments, and Fermi levels were investigated. Absorption spectral analysis has also been performed using time-dependent (TD)-DFTB.

2. Material and Method

The electronic structure and optical properties of undoped and Br-, I- and F-doped F8T2 have been examined using DFTB implemented in DFTB+ code (Aradi, et al. 2007) with the hyb-0-2 (Hanial, et al. 2003; Szűcs, et al. 2004) set of Slater Koster parameters. MD method was used to search temperature dependence properties in the frame of DFTB+ code. Absorption spectra have also been obtained by TD-DFTB calculations-based on the Casida's approach (Andersen, 1980).

3. Results

The different views of the optimized geometry of F8T2 organic molecule are indicated in Fig. 1.

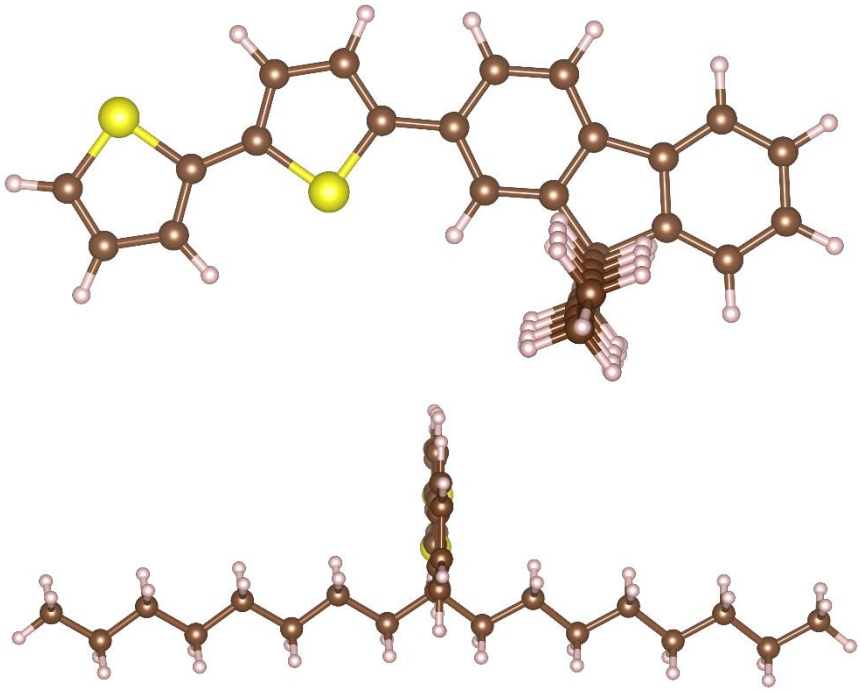


Figure 1. Different views of the optimized geometry of F8T2 organic molecule. (Yellow is Sulfur, purple is Hydrogen and brown is Carbon).

To obtain detailed information on electronic states in undoped F8T2 organic semiconductor, firstly, the results of the electronic total DOS of different temperatures and doped single atoms as seen in Fig. 2. The density of localized states decreases concomitantly with an increase in temperature where the greatest contribution comes from F8T2 at 0 K and Br-doped F8T2. These fluctuations progressively continue based on the increase in temperature, but there is a shift in energy values. The density of localized states has a sharply increasing tendency to occur in the region of between -8 and -7 eV. The DOS analysis also indicates that

F8T2 have the energy gap, so, all the nanoparticles show semiconductor character. There is an increase in HOMO, and a decrease in LUMO and Fermi energy is slightly increasing with increasing temperature in the range of 0-600 K.

The HOMO value for F8T2 organic semiconductor is -5.04 eV wide, *i.e.*, about 0.76 eV smaller than the 50% N-doped nanoparticle which has the lowest HOMO value (-5.80 eV) and is more reactive, while being less stable than F8T2 at high temperatures (see Fig. 3). Fermi energy levels are found to be the middle of the valence and conduction band. The HOMO-LUMO energy gap of F8T2 is 2.31 eV, which increases from 2.31 to 3.03 eV in the range of 0-600 K (see Fig. 4), because of the interatomic spacing increases. It is clear then that an increase in the temperature contributes to the stabilization of F8T2 due to an increase in the energy gap. The total energy (per/atom) also increases under heat treatment (see Fig. 4).

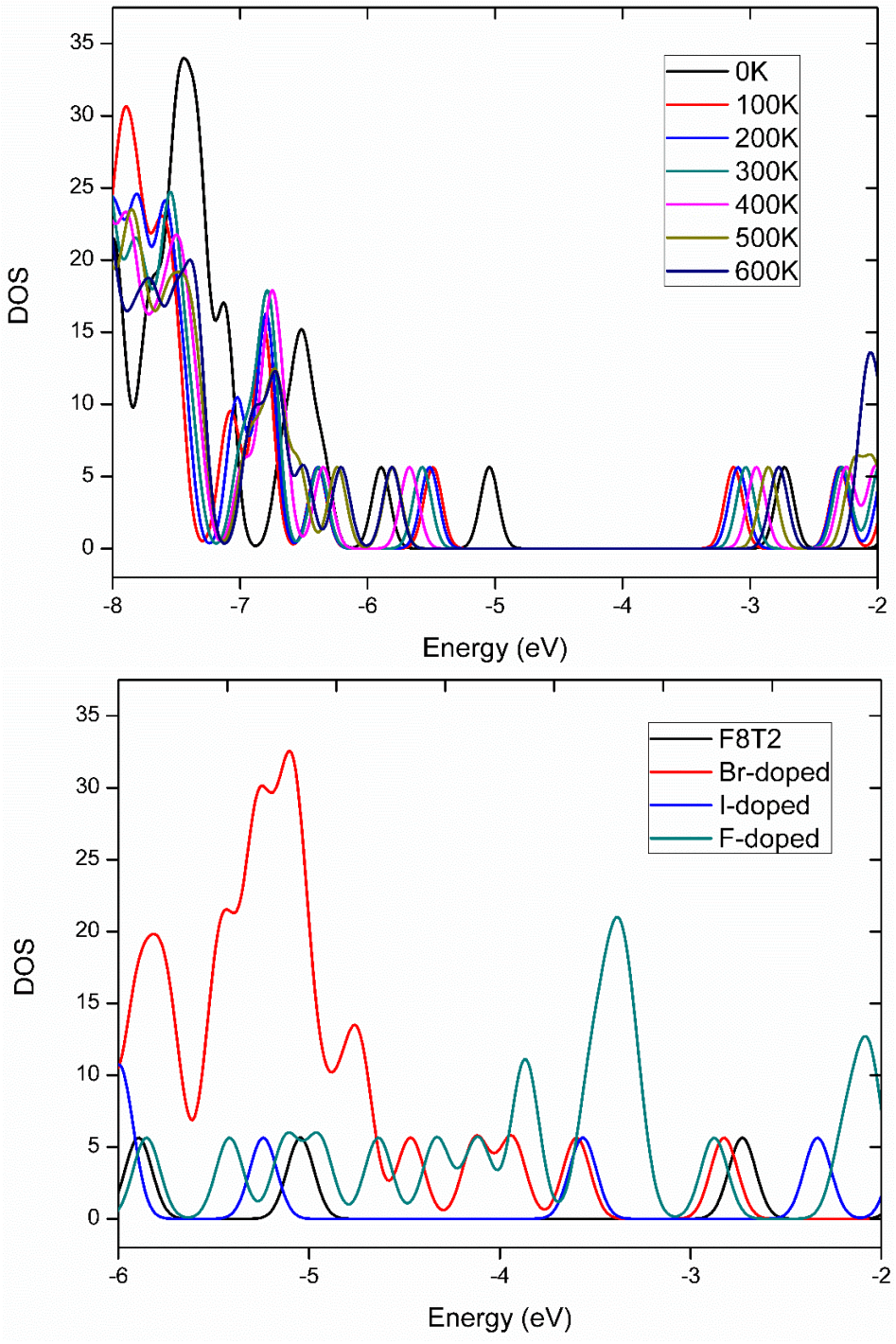


Figure 2. The total density of states (DOS) under heat treatment and atom doped F8T2.

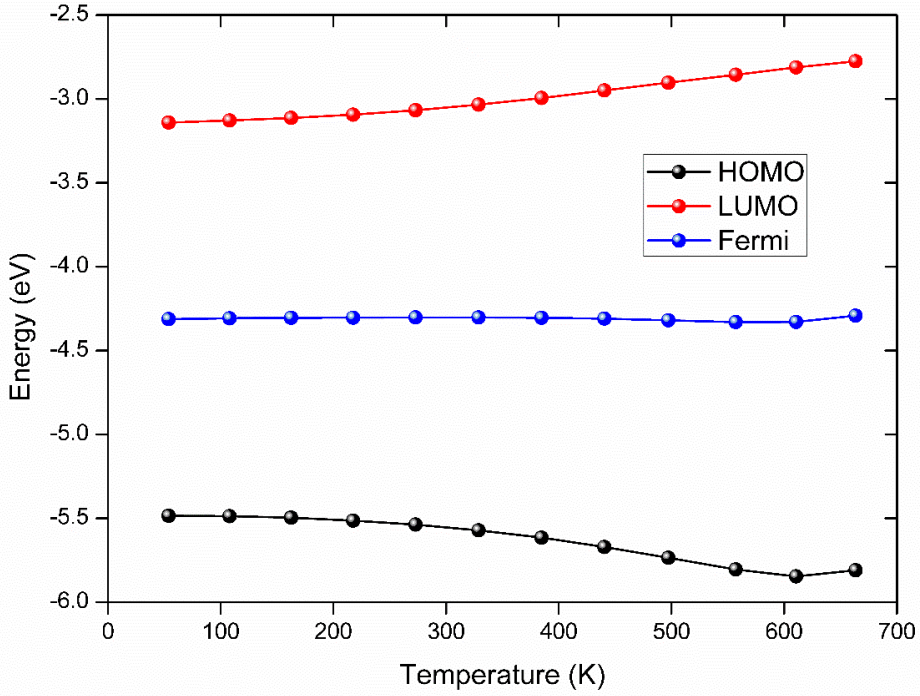


Figure 3. The HOMO, LUMO and Fermi energy levels of F8T2 under heat treatment.

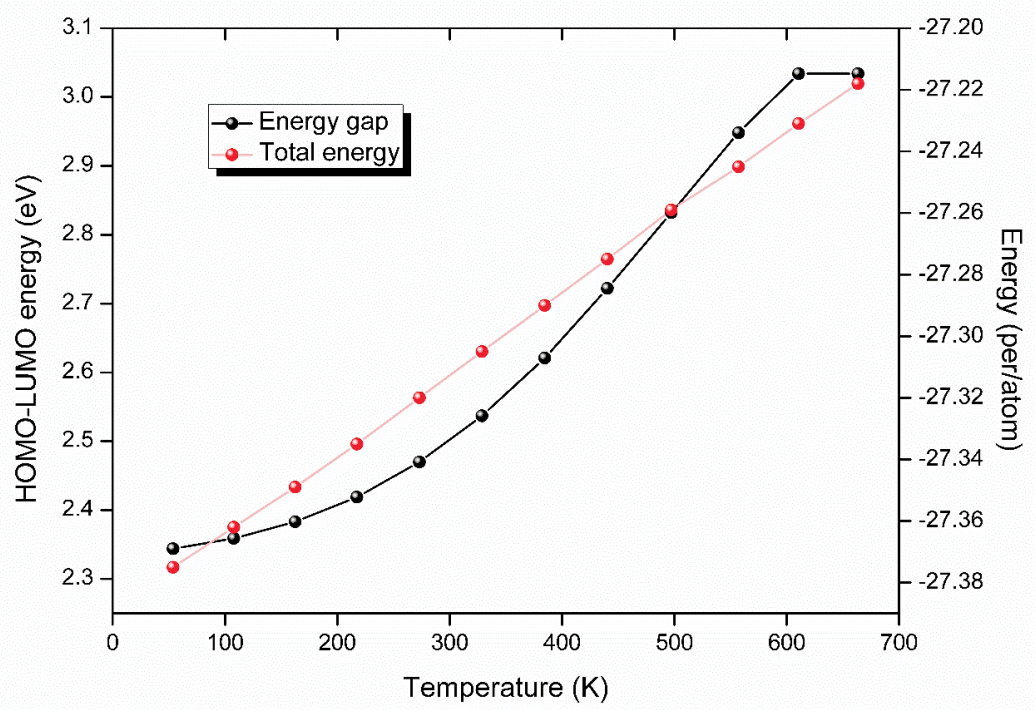


Figure 4. The variations of the HOMO-LUMO energy gap and total energy (per/atom) of F8T2 under heat treatment.

On the other hand, the energetic properties of Br, I and F doped-F8T2 have been investigated. The HOMO, LUMO, Fermi energy levels and HOMO-LUMO gap were tabulated in Table 1. The energy gap values of pure CNTs are found to be in the following decreasing order: F8T2> I-doped F8T2> F-doped F8T2> Br-doped F8T2 (see Table 1). Experimental energy gap value of F8T2 is 2.49 eV wide (Kettner, et al. 2016), i.e., about 0.17 eV greater than that of DFTB calculations which are very compatible with experimental data. The HOMO value for Br-doped F8T2 organic semiconductor is -3.78 eV wide, *i.e.*, about 1.26 eV smaller than that of undoped F8T2 (-5.04 eV). The HOMO value for I-doped F8T2 is -5.17 eV wide, *i.e.*, about 0.12 eV greater than undoped F8T2. This also indicates that Br-doped F8T2, compared to that of undoped and I and F-doped F8T2, allows easy excitation of electrons from HOMO to LUMO.

Table 1. The electronic structure data of undoped and Br-, I- and F-doped F8T2.

	HOMO	LUMO	Energy gap	Fermi energy
F8T2-DFTB	-5.045	-2.729	2.316	-3.8870
F8T2-Exp.	-5.440	-2.950	2.490	-
I-doped F8T2	-5.170	-3.495	1.675	-4.3324
F-doped F8T2	-4.797	-3.130	1.667	-3.9634
Br-doped F8T2	-3.784	-2.685	1.099	-3.2342

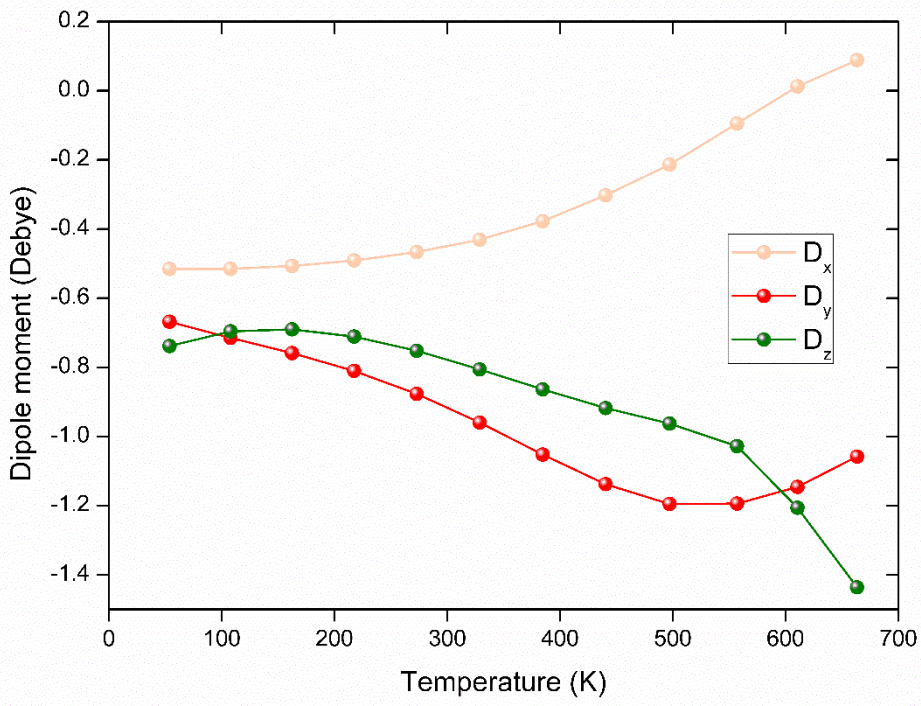
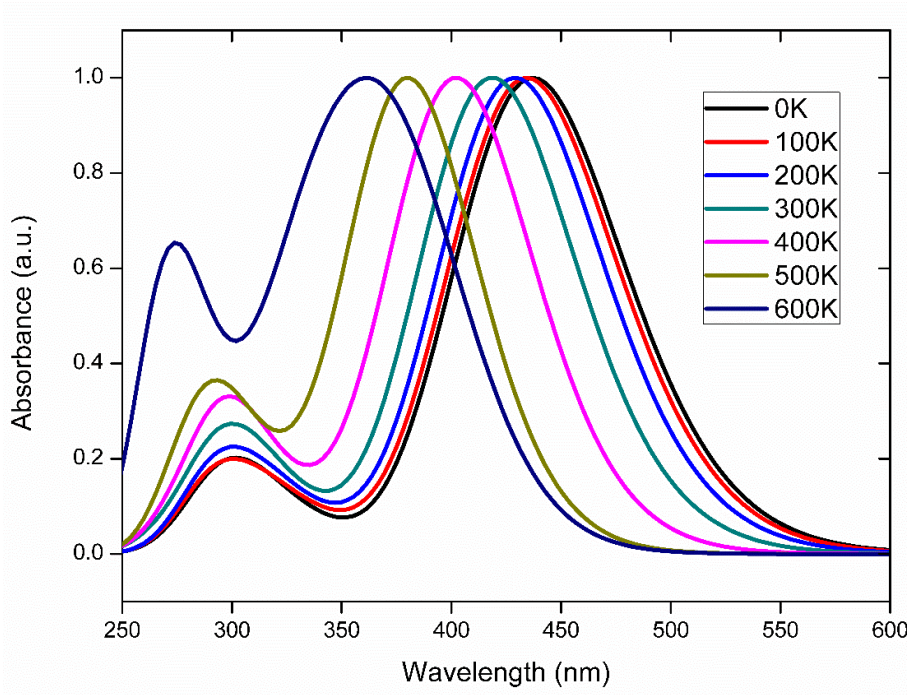


Figure 5. The variations of dipole moments of F8T2 in different x, y, z directions under heat treatment.

The dipole moment (D_M) results from differences in electronegativity. The bigger D_M means stronger intermolecular interaction. Herein, the x, y and z components of D_M under temperature are shown in Fig. 5. The component of D_M along the x-axis (-0.48 Debye) at 0 K for F8T2 gives rise to the largest negative charge separation in the z-direction. D_M decrease in

terms of temperature along x-directions; it increases along y and z directions. After 500 K, it started increasing up to almost 663 K. When it comes to Br, I and F doped F8T2, the biggest component of D_M for Br-doped F8T2 is found to be along the x-axis (-1.39 Debye) which means large negative charge separation in the x-direction. The biggest value of D_M for Br-doped F8T2 corresponds to stronger intermolecular interaction. These values are comparable with the gap energies because the lowest gap energy of Br-doped F8T2 means that electrons easily transfer from HOMO to LUMO. In this regard, there is a highly relevant correlation between D_M and the energy gap of the undoped and doped FT82. Thus, it can be concluded that the large D_M has small energy gap.



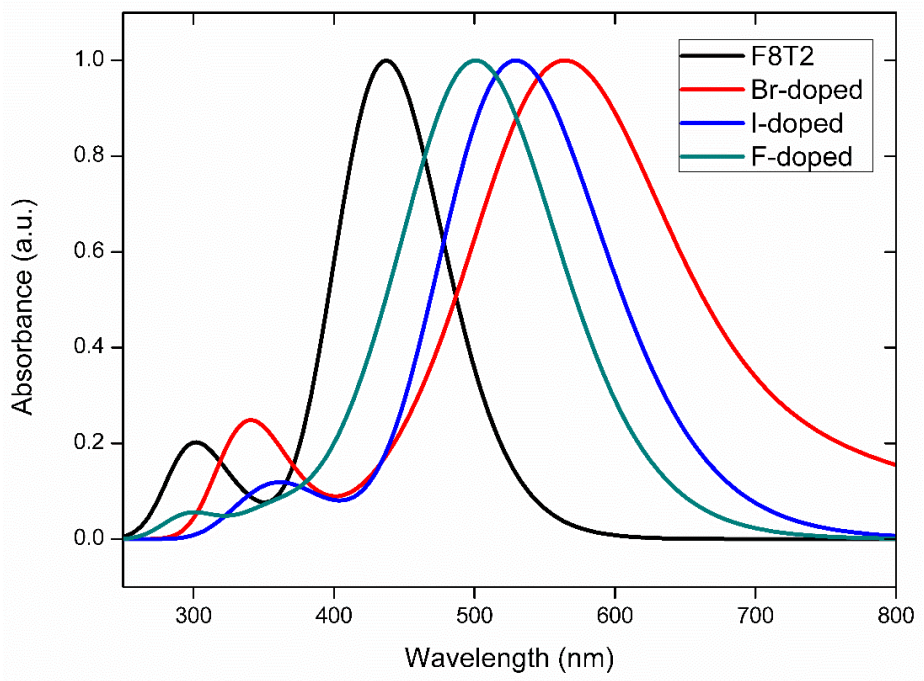


Figure 6. Absorbance spectra of under heat treatment and atom doped F8T2.

Absorbance spectra of F8T2 at different temperature and Br, I and F-doped F8T2 were depicted in Fig. 6. The F8T2 exhibits the maximum peaks 2.84 eV (436 nm) for undoped F8T2 corresponds to the ultraviolet (UV) region, which is very well matched with experimental data 2.66 eV (465 nm) (Kettner, et al. 2016). The absorbance spectrum of F8T2 decreases concomitantly with an increase in temperature where the maximum spectra of F8T2 (361 nm; 3.43 eV) are smallest at 600K. The absorption peaks are getting narrower and have smaller magnitude from 0 K to 600 K. It is also clear from the spectra that the structures are shifted towards higher energy in going from 0 K to 600 K. Absorbance spectra of Br-, I- and F-doped F8T2 are 2.20 eV (563 nm), 2.34 eV (529 nm) and 2.38 eV (501 nm), respectively. The obtained results show that a single atom substitution significantly improves the photophysical properties of F8T2.

4. Discussion and Conclusions

The electronic and photophysical properties of F8T2 organic semiconductor-based on a single atom substitution and temperature have been investigated using the density-functional tight-binding (DFTB) approach. The HOMO and LUMO energy levels of F8T2 were found -5.045 and -2.729 eV, respectively, which are compatible with experimental HOMO (-5.44 eV) and LUMO (-2.95 eV) energy levels. The band energy (2.32 eV) is also consistent with experimental findings (2.49 eV). The gap energy for F8T2 increased from 2.32 eV (at 0 K) to 3.03 K (at 663.38 K) which is about 0.71 eV wide than that of F8T2 at 0 K. The biggest component of dipole moment for Br-doped F8T2 is found to be along the x-axis (-1.39 Debye) which means large negative charge separation in the x-direction. there is a highly relevant correlation between D_M and the energy gap of the undoped and doped FT82. The calculated maximum absorbance peak is 437 nm which is very well matched with experimental value (465 nm). Br-, I- and F-doped on F8T2 significantly improve the photophysical properties of F8T2.

Acknowledgements

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Phytotoxicity from the Plants

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Abstract: Various pesticides have been developed to combat weeds, one of the biggest problems of agricultural areas. These medicines, classified as herbicides, are intended for the destruction of foreign plants, which are competitor of cultivated crops in agricultural areas, during the germination stage or for drying adult plants. Herbicides are used in more than 480,000 tons. These synthetic or semi-synthetic chemicals are harmful to the microbiology of the agricultural soil used, the plant biota that produces harmless biodiversity and the human health through the accumulation of plants. Allelopathy is a research area that investigates the negative effects of fungi, bacteria or plants to each other and their natural causes. In this review, the toxic effects of plant sources against each other were examined and the studies that used these sources against weeds were mentioned.

Keywords: Allelopathy, Botany, Phytotoxicity, Herbicide

1.Giriş

Tarım alanlarında yayılış gösteren yabancı otlardan kurtulmak için çeşitli yöntemler bulunmaktadır. Bunlardan biri de yabancı otları öldüren herbisitlerdir. Genetik olarak değiştirilmiş herbisite dirençi tarım bitkilerinin de ortaya çıkmasıyla herbisit kullanımı önemli ölçüde artmıştır. 2016 yılı verilerine göre dünya genelinde 480.000 tondan daha fazla herbisit kullanılmaktadır (FAO, 2018).

Herbisitler aminoasit sentezini bozarak, bitkilerde kloroz, nekroz ve büyüme noktalarında ölüme yol açarak, lipit sentezini engelleyerek, bazı protein ve enzim sentezlerini engelleyerek, klorofil sentezini engelleyerek veya klorofil yıkımını sağlayarak ve daha başka yollarla yabancı otlarda etkili olmaktadırlar (Sherman vd., 2018). Ancak toprağa karışan herbisitlerin potansiyel zararları ise hem tarım bitkisinin verimi hem insan sağlığı hem de bitkilerin evrimi açısından birçok zararı bulunmaktadır (Vyvyan 2002; Haig vd.2005). Günümüze gelindiğinde bu kadar yüksek oranda tüketilen herbisit kullanımının sürdürülebilir tarım için negatif etkileri üzerinde durularak son zamanlarda doğal yöntemlere dönüş yapılmaktadır.

Herbisitin aşırı kullanılması yabani otlarda bu ilaçlara karşı direnç geliştirilmesine yol açmaktadır. Bu nedenle dirençli yabancı otu ortadan kaldırmak için yeni herbistler geliştirilmek zorunda kalınmaktadır. Yapılan çalışmalarda herbisitlerin neden olduğu bu gibi problemlerin üstesinden gelmek için doğada yer alan kaynakların kullanılması üzerinde durulmuştur. Kullanılan bu kaynaklardan biri bitkilerin içerdiği bileşiklerdir. Bitkilerde bulunan ve diğer bitkilere zarar veren fitotoksik bileşikler ot öldürücü olarak kullanılmaktadır. Bu mekanizma, bitkilerin genellikle sekonder metabolitleri sayesinde diğer bitkiler üzerindeki olumsuz etkilerden yararlanmaya dayanmaktadır. Buna "allelopatik" etki denilmektedir.

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Bitkisel kaynakların herbisit gibi yabancı otların gelişimi engelleyecek şekilde kullanılması yeni değildir. Örneğin ceviz ağacı, salgıladığı bir madde olan *juglon* ile etrafta yabancı otların yetişmesini engellemek (Rietveld, 1983) ve bu sayede su ve besin olarak rakip olacak diğer bitkileri ortadan kaldırma stratejisi uygulamaktadır. Bundan yola çıkarak ceviz ağacının etken maddesi olan juglonun fitotoksisitesi, tahıl ve sebze gibi tarım ürünlerin yetiştirilmesinde önemli negatif etkileri olan yabancı otlardan kurtulmak için kullanılmaktadır (Terzi, 2008).

Ziraat mühendisleri gözlemledikleri buna benzer mekanizmalardan yola çıkarak sinerjik ve allelopatik bitkileri yanyana ekip tarım planlaması yapmakta ya da allelopatik etki gösteren kimyasalları tespit edip (ellolokimyasallar) tarım ilaçlanın bir bileşeni olarak kullanmaktadırlar (de Albuquerque, 2011). Dayan ve Duke (2014), yeni nesil herbist olarak kullanılabilecek, aralarında bitkilerin yanı sıra mantar ve bakterilerde bulunduğu 200.000'nin üzerinde potansiyel tür bulunduğuna değinmiştir. Örneğin Mitchell vd. (2001) *Callistemon citrinus'* tan izole edilen fitotoksik bileşikler olan "triketone*"* ve "leptospermone*"* ile doğal içerikli bir herbisit olan "mesotrion"ı geliştirmişlerdir.

Haig vd. (2005) ise 8 ay gözlem yaptıkları çalışmalarında 45 familyaya ait 150 den fazla yerel bitki türünün toz haline getirildikten sonra elde edilen ekstraktlarını bir yabancı ot olan *Lolium rigidum* Gaud. bitkisinin herbisiste direnç kazanmış üyelerinde uygulamışlar ve % 98.5 oranında büyümenin inhibe edildiğini göstermişlerdir. Tarım arazilerinde yerel çim olarak yetişip yabancı ot olarak sıkıntı veren bir arpa türü olan *Lolium rigidum* Gaud. bitkisine karşı lavantanın da (*Lavandula* spp.*)*, oldukça fitotoksik olduğu görülmüştür. Lavanta ekstraktları ile *Lolium* spp. üzerinde yapılan bir çalışmada kök büyümesini neredeyse % 100'e yakın inhibe ettiği ortaya çıkmıştır. Ayrıntılı incelemede bu fitotoksisitiye büyük ölçüde lavanta ekstraktının bileşiğinde yer alan "kumarin*"* bileşiğinin sebep olduğu bildirilmiştir (Haig vd., 2009).

Baharat olarak tüketilen birçok bitkinin esansiyel yağları nedeniyle ot öldürücü olarak kullanıldığı bilinmektedir. Tworkoski (2002) yaptığı çalışmada kırmızı kekik (*Thymus vulgaris* L.), geyik otu (*Satureja hortensis* L.), tarçın (*Cinnamomum zeylanicum* Blume); ve karanfil (*Syzygium aromaticum* (L.) Merr. & L.M.Perry); bitkilerinin esansiyel yağlarının ekim alanlarında yabancı ot olarak kabul edilen kaz ayağı (*Chenopodium album* L. CHEAL;), kanarya otu (*Ambrosia artemisiifolia* L.), kanyaş (*Sorghum halepense* L.) ve karahindiba bitkilerine karşı herbisit benzeri etki gösterdiğini kanıtlamıştır.

Pinaceae üyelerinin bulundukları alanlara dikkat edildiğinde aynı ortamda vejetasyonun oldukça zayıf olduğu gözlemlenmiştir. Bundan yola çıkarak araştırmacılar çamın allelopatik etkisini bir çok tür üzerinde test etmişlerdir. Örneğin Valera-Burgos vd.,(2012) Fıtık çamının (*Pinus pinea* L.) özütlerinin sulu çözeltilerinin *Halimium halimifolium*. (L.) Willk, *Cistus libanotis.* L. ve *Cistus salviifolius* L. türlerinin çimlenmesini baskıladığını bulmuşlardır.

Pinus densiflora Siebold & Zucc., *Pinus thunbergii* Parl. ve *Pinus rigida* Mill. türlerinin yapraklarından elde edilen ekstraklarla yapılan çalışmada *Leonurus sibiricus* L., *Aristolochia hirta* L. , *Erigeron annuus* (L.) Pers, *Aquilaria hirta* L. *Amaranthus mangostanus* L., *Saussurea gracilis* -Maxim., *Perilla frutescens* (L.) Britton. gibi orman türlerinin çimlenmesini etkilediğine değinilmiştir (Kil, 1992).

Bunun yanı sıra kırmızı çamın (*Pinus densiflora* Siebold & Zucc*)* tarım arazilerinde yabancı ot olarak görülebilecek tere, (*Lepidium sativum),* marul (*Lactuca sativa* L.), yonca (*Medicago sativa* L.), çim (*Lolium multiflorum* L.*)*, kelp kuyruğu (*Pheleum pratense* L.) ve *Digitaria*

sanguinalis L. bitkilerinde fitotoksik özellik gösterdiği bildirilmiştir. Burada etken olan maddenin ise "9 α ,13 β -Epidioxyabeit-8(14)en-18-oic acid" olabileceğine değinilmiştir (Kato-Noguchi vd. 2009).
Pinus halepensis Mill.'in fitotoksik etkisi üzerine yapılan bir çalışmada *Festuca arundinacea* Schreb., *Cynodon dactylon* (L.) Pers., *Avena sativa* L. bitkilerini fotosistem II üzerinden olumsuz etkilediğini bulunmuştur (Nektarios vd., 2005).

Bunun dışında Sharma vd., (2016) *Pinus roxburghii* Sarg.'den elde edilen ekstrakların bir çok olumsuz etkene dayanıklı olduğu bilinen Asteraceae'nın bir üyesi olan *Bidens pilosa* L. türüne karşı fitotoksik olduğu sonucuna varmışlardır.

Huang vd. (2010) uzun biber meyvesinden (*Piper longum* L.) elde edilen "sermentine" etki maddesinin marul (*Lactuca sativa* L.) üzerindeki fitotoksik özelliğini ortaya koymuşlarıdır.
Myrica gale L. meyvelerinin ihtiva ettiği " myrigalone A" allelokimyasalı ile tere bitkisi (*Lepidium sativum* L.) üzerinde yapılan çalışmada, bu bileşiğin çimlenme sırasında tohumda endosperm dokusunun kullanılmasını ve emriyonun gelişmesini engelleyerek fitotoksik etki gösterdiğini kanıtlanmıştır (Oracz vd., 2011).

Bitkilerden elde edilen kimyasalların bitkilerdeki moleküler etkileri üzerinde bir çok çalışma bulunmaktadır. Okyanus mersini olarak da bilinen *Leptospermum scoparium* J.R.Forst. & G.Forst. bitkisinin yapraklarının distilasyonu ile elde edilen esansiyel yağda bulunan "β-triketones" bileşiğinin marul üzerindeki fitotoksisitesi değerlendirilmiştir. Bu bileşik bitkilerde klorofil mekanizmasına zarar verip fotosentezi etkileyerek çimlenme aşamasında bitki ölümünü tetiklemektedir (Dayan vd., 2007).

Sorghum bicolor L. bitkisinin kök büyümesi üzerindeki allelopatik etkisi, uzun zamandan beri bilinmektedir (Lehle ve Putnam, 1983). Birçok bitki için etkili olan bu bitkinin bileşikleri kök hücrelerinde mineral madde geçişinde etkili H^+ - ATPase yolaklarında hasara neden olarak etki mekanizmasını çalıştırmaktadır (Hejl ve Koster 2004a).

Cevizden elde edilen bir allelokimyasal olan juglonun, soya ve mısır üzerindeki çalışmalarda, etki mekanizması olarak kök hücrelerinde proton pompalarında hasara yol açtığını su ve mineral alımını etkileyerek bitki gelişiminin önüne geçtiğini görülmektedir (Hejl ve Koster 2004b).
Morre ve Grieco (1999) soya (*Glycine max* (L.) Merrill), arabidopsis (*Arabidopsis thaliana* (L.) Heynh.), domates (*Lycopersicum esculentum* L.) ve sorgum (*Sorghum vulgare* Pers.) üzerindeki fitotoksik etkiyi belirlemek üzere yaptıkları moleküler çalışmada, *Castela polyandr* bitkisiden elde edilen "Glaucarubolone" etkin maddesinin, bitki hücre zarındaki NADH okisidazını etkiledğini ve ayrıca hücrelerde aşırı büyümeye yol açarak toksik etki oluşturduğunu bildirmişlerdir. Aynı çalışmada tropikal bitki olan *Quassia africana* (Baill.) Baill.' dan elde edilen "Simalikalactone D" etkin maddesinin de oksin tetikleyici NADH oksidazı üzerinde etkin olarak fitotoksik özellik gösterdiği belirlenmiştir.

Limon otu (*Cymbopogon citratus* (DC.) Stapf) gibi aromatik bileşik içeren çeşitli bitkilerde yer alan "sitral" terponoidinin buğday (*Triticium aestivum* L.), siyah hardal (*Brassica nigra* L.), *Amaranthus palmeri* gibi bitkiler için tohum çimlenmesinin engelleyici özellik gösterdiği bilinmektedir (Dudai et al., 1999).

Chaimovitsh vd., (2010) sitralin bitki germinasyonundaki olumsuz etkilerini *Arabidopsis thaliana* (L.) Heynh. hücreleri üzerinde yaptıkları deneyle anlamaya çalışmışlardır. Çalışma

sonucunda sitralin gaz fazında mikromolar düzeydeki konsantrasyonlarının hücre iskeleti, hücre bölünmesi, hücreler arası iletişim gibi görevlerden sorumlu olan mikrotübüllerin yapısını bozduğunu bulmuşlardır.
Küstüm otundan (*Mimosa* spp.*)* elde edilen "mimosin" etken maddesinin fitotoksik özelliği üzerinde araştırma yapan Perennes vd. (1993) bileşiğin, petunya (*Petunia hybrida* hort. ex Vilm.) hücre döngüsünde etken bir enzimi etkileyerek toksisite gösterdiğini bulmuşlardır.

Bunlar gibi bitki gelişiminde negatif etkili olan bir çok bileşik mevcuttur. Tablo 1'de bitkilerden elde edilen bazı fitotoksik bileşikleşiklere ve kaynağı olan bitkilere yer verilmiştir. Herbisitler aynı zamanda tohumu tüketilen tarım bitkileri üzerinde kullanılmaktadır. Tohumlanmış bitkilerin kolay hasadının yapılabilmesi için tüm bitkinin kuruması sağlanmalıdır. Bitki kaynaklı "kaprilik asit" ve Itır (*Pelargonium*) bitikisinde bulunan "pelargonik asit" etken maddeleri bu amaçla kullanılan birer fitotoksik bileşiktir (Coleman ve Penner 2006).

Tablo 1. Fitotoksik allelokimyasallar (Putnam, 1988; Zanardo vd. 2009; Kato-Noguchi vd., 2009; Dayan ve Duke,2014).

ALLELOKİMYASAL	İZOLE EDİLEN BİTKİ	REFERANS
4-dihydroxy-1,4(2H)-benzoxazin-3- one (DIBOA)	*Acanthus mollis* L.	Wolf vd., 1985
1,3,7-trimethylxanthine	*Camellia sinensis* (L.) Kuntze	Rizvi vd., 1981
1,3,7-trimethylxanthine	*Coffee arabica* L.	Rizvi vd.,1987
9 α ,13 β - Epidioxyabeit-8(14)en-18-oic acid	*Pinus densiflora* Siebold & Zucc.	Kato-Noguchi vd. 2009
Benzoxazinones	Acanthaceae, Poaceae, Ranunculaceae, ve Scrophulariaceae	Barnes ve Putnam, 1983;1986
Cinnamik asit türevleri	*Cinnamomum verum* J.Presl ve birçok bitki	Schreiner ve Reed 1908
Esculin	*Phleum pratense* L.	Avers, C. J., and R. H. Goodwin. 1956
Etilen	Elma *(Malus sylvestris* Mill.)	Eplee 1975.
Ferulic asit	*Ferula foetida* (Bunge) Regel	Holappa ve Blum, 1991
Glaucarubolone	*Castela polyandra* Moran & Felger	Morre ve Grieco, 1999
Hyoscyamine	*Datura stramonium* L.	Levitt vd., 1984; Lovett vd., 1981
Juglon	Ceviz *(Juglans nigra* L.*)*	Davis, 1928.
Kafein	*Coffee arabica* L.	Waller vd.,1986
Kaprilik asit	biber ve birçok bitki	Coleman ve Penner, 2006
Leptospermone	*Callistemon citrinus* (Curtis)	Mitchell vd., 2001
Mimosin	*Mimosa* spp	Perennes vd., 1993
Myrigalone A	*Myrica gale* L.	Oracz vd., 2011

p-coumaric asit	*Lavandula* spp. ve birçok bitki	Zanardo vd. 2009
pelargonik asit	*Pelargonium*	Coleman ve Penner, 2006
Salisilik asit	Salicaceae	Barkosky ve Einhellig, 1993
Scopolin	*Nicotiana tabacum* L. *Helianthus annuus* L. ve bir çok bitkide	Rice, 1984
Sermentine	*Piper longum* L.	Huang vd., 2010
Simalikalactone D	*Quassia africana* (Baill.)	Morre ve Grieco, 1999
Sitral	*Cymbopogon citratus* (DC.) Stapf)	Dudai et al., 1999; Chaimovitsh vd., 2010
Sorgoleone	*Sorghum bicolor* L.	Hejl ve Koster, 2004b
Tricin	Ayrık otu *(Agropyron repens* (L.) Beauv.)	Weston vd. 1987
Triketone	*Callistemon citrinus* (Curtis) Skeels	Mitchell vd., 2001
Vitexin ve isovitexin	Maş fasülyesi *(Vigna radiata* (L.) Wilczek*)*	Tang ve Zhang, 1986
β-triketones	*Leptospermum scoparium* J.R.Forst. & G.Forst.	Dayan vd., 2007

Bunların dışında elma gibi meyvelerin olgunlaşması sırasında etkili olan "etilen hormonu" dormansi sırasında toprağa enjekte edildiğinde canavar otu (*Striga*) tohumlarında intihar etkisi oluşturduğu rapor edilmiştir (Eplee, 1975). Görüldüğü gibi yabancı otlardan kurtulmak için birçok bitkilerin bileşiklerinden yararlanılan bir çok yöntem bulunmaktadır.

2. Sonuç ve Öneriler

Birçok bitki ve bunlara ait kimyasallar fitotoksik etki göstererek diğer bitkilerin gelişmesini durdurmaktadır. Aynı zamanda bitkilerden elde edilen bileşikler moleküler düzeyde bir çok yolakta etkili olarak ziraat mühendislerinin olduğu kadar modern farmakognozinin de konusu olmaya devam etmektedir.

Herbisit kullanımının azaltılması ve topraktaki kalış süresinin düşürülmesi tarımın sürdürülebilirliği için önemlidir. Kaynağı canlılar olan allelokimyasallar ise bu konuya alternatif olması bakımından oldukça değerli bir çalışma alanıdır. Bu anlamda günümüzde etken maddenin salgılanmasını artıracak genetiği değiştirilmiş organizmalar üretilmektedir (Duke, 2003; Duke et al., 2001; de Albuquerque vd.,2011). Böylece az sayıda bitkiden çok miktarda allelokimyasal üretilerek geniş alanlara uygulamada kolaylık sağlanabilecektir.

Bu anlamdaki genetik çalışmaların başka bir konusu ise yabancı otları öldürmek için kullanılan herbistlerin sadece yabancı otları değil tarım bitkilerinin kendisini de etkilemesi sebebiyle, günümüzde özgürce herbisit kullanabilmek için herbisite dayanıklı genetiği değiştirilmiş tarım bitkileri üretilmesidir. Bu açıdan bakıldığında doğal kaynaklı da olsa fazlaca kullanılacak olan allelokimyasala karşı bitki ve toprak biyotasının direnç kazanması mümkün olabilir. Direnç kazanan türlerden ise başka türlere gen geçişi olabileceğinden her türlü herbisit ve benzeri maddenin kullanımında kontrol gerekmektedir.

Ayrıca bitkinin herbiste dayanıklı olması, bitki tarafından toplanan veya bitki yüzeyinde tutulan herbisitin insana zararsız olacağı anlamına gelmez. Bunun dışında toprak herbisitleri sahip olduğu mikroorganizmalarla bu kimyasalları başka bileşiklere dönüştürerek olduğundan daha zararlı hale getirebilir.

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Investigation of Antioxidant and Antimicrobial Properties of Different Plant Species Extracts Growing in Shar Mountains

Gulnur Arabaci[1*], Busra Tosun[1] Cengiz Cesko[2]

Abstract: The aim of this study was to determine the antioxidant and antimicrobial activities of methanol extracts of different plant species (*Datura stramonium* seed, *Datura stramonium* leaf, *Verbascum thapsus*, *Rosmarinus officinalis* and *Thymus vulgaris*) grown in Shar Mountains, Kosovo. Three different methods (DPPH radical scavenging capacity, ferrous ion chelating activity and reducing power) were used to determine the antioxidant activities of the plant extracts. Antimicrobial activity was investigated by agar well diffusion method. According to the antioxidant results, *Thymus vulgaris* extract had the highest DPPH radical scavenging activity with the IC_{50} value of 6271.43 ± 0.03 mg/L. The chelating property of iron ions was observed with the highest activity in *Thymus vulgaris* and *Verbascum thapsus*. *Datura stramonium* leaf showed the highest reducing power activity among the other plant species. Overall, the results showed that most plants have good antioxidant activities. Trolox, a water-soluble analog of BHT, ascorbic acid, EDTA and α-tocopherol, was used as standard in the antioxidant experiments. In this work, it had been also investigated the antimicrobial activity of the plant species against *Staphylococcus aureus* (ATCC 29213), *Escherichia coli* (ATCC 25922), *Saccharomyces cerevisiae* (SBT8), *Bacillus subtilis* (ATCC 6051) and *Bacillus subtilis* (ATCC 6633). As a result of the research, it was determined that plant extracts have antibacterial activities against all bacteria tested. Among the extracts, *Rosmarinus officinalis* and *Thymus vulgaris* showed the highest antibacterial activity against bacteria.

Keywords: Antimicrobial, antioxidant, *Rosmarinus officinalis*, *Thymus vulgaris*, *Datura stramonium*, *Verbascum thapsus*.

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A Configuration of Five of the Soft Decision-Making Methods via Fuzzy Parameterized Fuzzy Soft Matrices and Their Application to a Performance-Based Value Assignment Problem

Tuğçe Aydın[1]*, Serdar Enginoğlu[1]

Abstract: Fuzzy sets, soft sets, and their hybrid versions have become the preferred mathematical tools for modelling uncertainties. Moreover, it is of great importance their matrix representations to transfer data to the computer environment. Being one of these matrix representations, the concept of fuzzy parameterized fuzzy soft matrices (*fpfs*-matrices) is the most favoured among them. In this study, to improve the skills of modelling of the methods constructed by fuzzy soft sets, we configure these methods via *fpfs*-matrices, faithfully to the original. We then apply the methods to the problem that a performance-based value assignment to some filters used in noise removal. Finally, we discuss the need for further research.

Keywords: Fuzzy sets, soft sets, soft matrices, *fpfs*-matrices, soft decision-making

1. Introduction

The standard mathematical tools are generally inadequate to model decision-making problems involving uncertainty in the real world. In order to cope with such problems, many decision-making methods constructed by soft sets (Molodtsov, 1999), fuzzy soft sets (Maji et al., 2001), fuzzy parameterized soft sets (Çağman et al., 2011), and fuzzy parameterized fuzzy soft sets (*fpfs*-sets) (Çağman et al., 2010) have been proposed. Moreover, the matrix representations of these concepts are of great importance for transferring data to the computer environment. Therefore, the concepts of soft matrices (Çağman and Enginoğlu, 2010), fuzzy soft matrices (Çağman and Enginoğlu, 2012), and fuzzy parameterized fuzzy soft matrices (*fpfs*-matrices) (Enginoğlu, 2012; Enginoğlu and Çağman, In Press) have been put forward. Here, the concept of *fpfs*-matrices is most favoured among them.

Recently, Enginoğlu and Memiş (2018a) and Öngel (2019) have configured some of the soft decision-making methods via *fpfs*-matrices, faithfully to the original. These two studies are pioneering studies on this subject. Also, Enginoğlu and Memiş (2018b) have illustrated that some methods have same ranking order and drawn attention simplification problem in terms of time and complexity of the configured methods (Enginoğlu and Memiş, 2018c; Enginoğlu et al., 2018a, b).

In this paper, we take into account the methods provided in (Feng, 2010; Kalayathankal and Singh, 2010; Kuang et al., 2010; Kong et al., 2011; Sun and Ma, 2011). Feng (2010) has used fuzzy soft sets in the problem of determining the most attractive phone. Kalayanthankal and

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Singh (2010) have proposed an algorithm using fuzzy soft sets to predict the potential flood in a region. Kuang et al. (2010) have applied the algorithm to the problem of choosing the best project. Kong et al. (2011) have developed a new algorithm constructed by fuzzy soft sets and based on the grey relational analysis. Sun and Ma (2011) have used fuzzy soft sets to obtain a decision on the house purchase problem.

In Section 2 of the present paper, we give the concept of *fpfs*-matrices. Besides, we present some of the configured soft decision-making algorithms in (Enginoğlu and Memiş, 2018a; Öngel, 2019) required in the next sections. In Section 3, we configure five of the soft decision-making methods constructed by fuzzy soft sets via *fpfs*-matrices, faithfully to the original. In Section 4, we apply the methods to a performance-based value assignment to some filters used in noise removal, so that we can order them in terms of performance. Finally, we discuss the need for further research.

2. Preliminaries

In this section, firstly, we present the concept of *fpfs*-matrices (Enginoğlu, 2012; Enginoğlu and Çağman, In Press). Throughout this paper, let E be a parameter set, $F(E)$ be the set of all fuzzy sets over E, and $\mu \in F(E)$. Here, a fuzzy set is denoted by $\left\{{}^{\mu(x)}x \mid x \in E\right\}$ instead of $\{(x, \mu(x)) \mid x \in E\}$.

Definition 2.1. (Çağman et al., 2010; Enginoğlu, 2012) Let U be a universal set, $\mu \in F(E)$, and α be a function from μ *to* $F(U)$. Then, the set $\left\{\left({}^{\mu(x)}x, \alpha\left({}^{\mu(x)}x\right)\right) \mid x \in E\right\}$ being the graphic of α is called a fuzzy parameterized fuzzy soft set *(fpfs*-set) parameterized via E over U (or briefly over U).

In the present paper, the set of all *fpfs*-sets over U is denoted by $FPFS_E(U)$. In $FPFS_E(U)$, since the $graph(\alpha)$ and α generated each other uniquely, the notations are interchangeable. Therefore, as long as it does not cause any confusion, we denote an *fpfs*-set $graph(\alpha)$ by α.

Example 2.1. Let $E = \{x_1, x_2, x_3, x_4\}$ and $U = \{u_1, u_2, u_3, u_4, u_5\}$. Then,

$$\alpha = \{({}^{0.5}x_1, \{{}^{0.6}u_2, {}^{0.4}u_3, {}^{0.3}u_4, {}^{0.9}u_5\}), ({}^{0.1}x_2, \{{}^{0.7}u_1, {}^{0.4}u_5\}), ({}^{0}x_3, \{{}^{0.8}u_2, {}^{1}u_4, {}^{0.5}u_5\}), ({}^{0.2}x_4, \{{}^{0.3}u_3, {}^{0.8}u_4\})\}$$

is an *fpfs*-set over U.

Definition 2.2. (Enginoğlu, 2012; Enginoğlu and Çağman, In Press) Let $\alpha \in FPFS_E(U)$. Then, $[a_{ij}]$ is called the matrix representation of α (or briefly *fpfs*-matrix of α) and is defined by

$$[a_{ij}] \coloneqq \begin{bmatrix} a_{01} & a_{02} & a_{03} & \cdots & a_{0n} & \cdots \\ a_{11} & a_{12} & a_{13} & \cdots & a_{1n} & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mn} & \cdots \\ \vdots & \vdots & \vdots & \ddots & \vdots & \ddots \end{bmatrix}$$

such that for $i \in \{0,1,2,\cdots\}$ and $j \in \{1,2,\cdots\}$,

$$a_{ij} \coloneqq \begin{cases} \mu(x_j), & i = 0 \\ \alpha\left({}^{\mu(x_j)}x_j\right)(u_i), & i \neq 0 \end{cases}$$

Here, if $|U| = m - 1$ and $|E| = n$, then $[a_{ij}]$ has order $m \times n$.

From now on, the set of all *fpfs*-matrices parameterized via E over U is denoted by $FPFS_E[U]$.

Example 2.2. Let us consider the *fpfs*-set α provided in Example 2.1. Then, the *fpfs*-matrix of α is as follows:

$$[a_{ij}] = \begin{bmatrix} 0.5 & 0.1 & 0 & 0.2 \\ 0 & 0.7 & 0 & 0 \\ 0.6 & 0 & 0.8 & 0 \\ 0.4 & 0 & 0 & 0.3 \\ 0.3 & 0 & 1 & 0.8 \\ 0.9 & 0.4 & 0.5 & 0 \end{bmatrix}$$

Secondly, since they are used in some of the algorithms in Section 3, we give three of the configured algorithms provided in (Enginoğlu and Memiş, 2018a; Öngel, 2019). Throughout this paper, $I_n = \{1,2,3,\cdots,n\}$ and $I_n^* = \{0,1,2,3,\cdots,n\}$.

MBR01 (Enginoğlu and Memiş, 2018a)

Step 1. Construct an *fpfs*-matrix $[a_{ij}]_{m\times n}$

Step 2. Obtain $[b_{ik}]_{(m-1)\times(m-1)}$ defined by

$$b_{ik} \coloneqq \sum_{j=1}^{n} a_{0j}\chi(a_{ij}, a_{kj}), \quad i,k \in I_{m-1}$$

such that

$$\chi(a_{ij}, a_{kj}) \coloneqq \begin{cases} 1, & a_{ij} \geq a_{kj} \\ 0, & a_{ij} < a_{kj} \end{cases}$$

Step 3. Obtain $[c_{i1}]_{(m-1)\times 1}$ defined by

$$c_{i1} \coloneqq \sum_{k=1}^{m-1} b_{ik}, \quad i \in I_{m-1}$$

Step 4. Obtain $[d_{i1}]_{(m-1)\times 1}$ defined by

$$d_{i1} \coloneqq \sum_{k=1}^{m-1} b_{ki}, \quad i \in I_{m-1}$$

Step 5. Obtain the score matrix $[s_{i1}]_{(m-1)\times 1}$ defined by

$$s_{i1} \coloneqq c_{i1} - d_{i1}, \quad i \in I_{m-1}$$

Step 6. Obtain the decision set $\left\{{}^{\mu(u_k)}u_k | u_k \in U\right\}$ such that $\mu(u_k) = \frac{s_{k1} + \left|\min_i s_{i1}\right|}{\max_i s_{i1} + \left|\min_i s_{i1}\right|}$

Lately, this method has been mathematically simplified by Enginoğlu and Memiş (2018c). Thus, the simplified version of MBR01, denoted by sMBR01, is more advantages in terms of running time and complexity.

MRB02 (Enginoğlu and Memiş, 2018a)

Step 1. Construct an *fpfs*-matrix $[a_{ij}]_{m\times n}$

Step 2. Obtain the score matrix $[s_{i1}]_{(m-1)\times 1}$ defined by

$$s_{i1} \coloneqq \sum_{j=1}^{n} a_{0j}a_{ij}, \quad i \in I_{m-1}$$

Step 3. Obtain the decision set $\left\{{}^{\mu(u_k)}u_k | u_k \in U\right\}$ such that $\mu(u_k) = \frac{s_{k1}}{\max\limits_i s_{i1}}$

M11 (Öngel, 2019)

Step 1. Construct an *fpfs*-matrix $[a_{ij}]_{m\times n}$

Step 2. Obtain $[b_{ik}]_{(m-1)\times(m-1)}$ defined by

$$b_{ik} \coloneqq \sum_{j=1}^{n} a_{0j}(a_{ij} - a_{kj}), \quad i,k \in I_{m-1}$$

Step 3. Obtain the score matrix $[s_{i1}]_{(m-1)\times 1}$ defined by

$$s_{i1} \coloneqq \sum_{k=1}^{m-1} b_{ik}, \quad i \in I_{m-1}$$

Step 4. Obtain the decision set $\left\{{}^{\mu(u_k)}u_k | u_k \in U\right\}$ such that $\mu(u_k) = \frac{s_{k1}+\left|\min\limits_i s_{i1}\right|}{\max\limits_i s_{i1}+\left|\min\limits_i s_{i1}\right|}$

3. Five of the Soft Decision-Making Algorithms

In this section, to improve the skills of modelling of the methods constructed by fuzzy soft sets and which are provided in (Feng, 2010; Kalayathankal and Singh, 2010; Kuang et al., 2010; Kong et al., 2011; Sun and Ma, 2011), we configure these methods via *fpfs*-matrices (Enginoğlu, 2012; Enginoğlu and Çağman, In Press), faithfully to the original.

Algorithm 1 F10(z)

Step 1. Construct an *fpfs*-matrix $[a_{ij}]_{m\times n}$

Step 2. Obtain a fuzzy-valued row matrix $[\lambda_j]_{1\times n}$ defined by

$$\lambda_j \coloneqq \sum_{i=1}^{m-1} a_j^i b_i, \quad j \in I_n$$

and

$$b_i \coloneqq f\left(\frac{i}{m-1}\right) - f\left(\frac{i-1}{m-1}\right), \quad i \in I_{m-1}$$

f is a function defined by $f(x) = x^{\frac{1-z}{z}}$ for a $z \in [0,1]$

Here, a_j^i denotes i^{th} largest value of the elements with index nonzero in j^{th} column.

Step 3. Obtain $[c_{ij}]_{m\times n}$ defined by

$$c_{ij} \coloneqq \begin{cases} a_{0j}, & i = 0 \\ 1, & i \neq 0 \; and \; a_{ij} \geq \lambda_j \\ 0, & i \neq 0 \; and \; a_{ij} < \lambda_j \end{cases}$$

such that $i \in I_{m-1}^*$ and $j \in I_n$

Step 4. Apply MRB02 to $[c_{ij}]$ and obtain the z-decision set

Algorithm 2 KS10

Step 1. Apply MBR01

That is, KS10 and MBR01 are same. Therefore, we will prefer the notation MBR01.

Algorithm 3 KSM10

Step 1. Construct an *fpfs*-matrix $[a_{ij}]_{m\times n}$

Step 2. Obtain the *fpfs*-matrix $[b_{ij}]_{m\times n}$ defined by

$$b_{ij} \coloneqq \begin{cases} \frac{1}{n-1}\left(1 - \frac{c_j}{\sum_{k=1}^n c_k}\right), & i = 0 \\ a_{ij}, & i \neq 0 \end{cases}$$

such that

$$c_j \coloneqq \begin{cases} d_1, & j = 1 \\ \frac{d_{j-1} + d_j}{2}, & j \in \{2,3,\dots,n-1\} \\ d_{n-1}, & j = n \end{cases}$$

and

$$d_j \coloneqq \frac{1}{m-1}\sum_{i=1}^{m}\left(a_{0(j+1)}a_{i(j+1)} - a_{0j}a_{ij}\right), \quad j \in I_{n-1}$$

Step 3. Apply M11 to $[b_{ij}]$

Algorithm 4 KWW11(w,z)

Step 1. Construct an *fpfs*-matrix $[a_{ij}]_{m\times n}$

Step 2. Apply MBR01 and MRB02 to $[a_{ij}]$ and obtain the score matrices $[s_{i1}^1]_{(m-1)\times 1}$ and $[s_{i1}^2]_{(m-1)\times 1}$, respectively

Step 3. Obtain $[b_{i1}]_{(m-1)\times 1}$ and $[c_{i1}]_{(m-1)\times 1}$ defined by

$$b_{i1} \coloneqq \frac{s_{i1}^1 - \min\limits_{k\in I_{m-1}} s_{k1}^1}{\max\limits_{k\in I_{m-1}} s_{k1}^1 - \min\limits_{k\in I_{m-1}} s_{k1}^1}, \quad i \in I_{m-1}$$

and

$$c_{i1} \coloneqq \frac{s_{i1}^2 - \min\limits_{k\in I_{m-1}} s_{k1}^2}{\max\limits_{k\in I_{m-1}} s_{k1}^2 - \min\limits_{k\in I_{m-1}} s_{k1}^2}, \quad i \in I_{m-1}$$

Step 4. Obtain $[d_{i1}]_{(m-1)\times 1}$ and $[e_{i1}]_{(m-1)\times 1}$ defined by

$$d_{i1} \coloneqq \max_{k\in I_{m-1}} b_{k1} - b_{i1}, \quad i \in I_{m-1}$$

and

$$e_{i1} \coloneqq \max_{k\in I_{m-1}} c_{k1} - c_{i1}, \quad i \in I_{m-1}$$

Step 5. For $w \in [0,1]$, obtain $[f_{i1}]_{(m-1)\times 1}$ and $[g_{i1}]_{(m-1)\times 1}$ defined by

$$f_{i1} \coloneqq \frac{\min\limits_{k\in I_{m-1}} \{d_{k1}, e_{k1}\} + w \max\limits_{k\in I_{m-1}} \{d_{k1}, e_{k1}\}}{d_{i1} + w \max\limits_{k\in I_{m-1}} \{d_{k1}, e_{k1}\}}, \quad i \in I_{m-1}$$

and

$$g_{i1} \coloneqq \frac{\min\limits_{k\in I_{m-1}} \{d_{k1}, e_{k1}\} + w \max\limits_{k\in I_{m-1}} \{d_{k1}, e_{k1}\}}{e_{i1} + w \max\limits_{k\in I_{m-1}} \{d_{k1}, e_{k1}\}}, \quad i \in I_{m-1}$$

Step 6. For $z \in [0,1]$, obtain the score matrix $[s_{i1}]_{(m-1)\times 1}$ defined by

$$s_{i1} \coloneqq zf_{i1} + (1-z)g_{i1}, \quad i \in I_{m-1}$$

Step 7. Obtain the (w,z)-decision set $\left\{^{\mu(u_k)}u_k | u_k \in U\right\}$ such that $\mu(u_k) = \frac{s_{k1}}{\max\limits_i s_{i1}}$

Algorithm 5 SM11

Step 1. Construct an *fpfs*-matrix $[a_{ij}]_{m\times n}$

Step 2. Obtain a fuzzy-valued row matrix $[\lambda_j]_{1\times n}$ defined by

$$\lambda_j \coloneqq \max_{i\in I_{m-1}} \{a_{0j}a_{ij}\}, \quad j \in I_n$$

Step 3. Obtain $[b_{i1}]_{(m-1)\times 1}$ defined by

$$b_{i1} \coloneqq \min\left\{\max_{j\in I_n}\{1 - a_{0j}a_{ij}, \lambda_j\}\right\}, \quad i \in I_{m-1}$$

Step 4. Obtain $[c_{i1}]_{(m-1)\times 1}$ defined by

$$c_{i1} \coloneqq \max\left\{\min_{j\in I_n}\{a_{0j}a_{ij}, \lambda_j\}\right\}, \quad i \in I_{m-1}$$

Step 5. Obtain the score matrix $[s_{i1}]_{(m-1)\times 1}$ defined by

$$s_{i1} \coloneqq b_{i1} + c_{i1}, \quad i \in I_{m-1}$$

Step 6. Obtain the decision set $\left\{^{\mu(u_k)}u_k | u_k \in U\right\}$ such that $\mu(u_k) = \frac{s_{k1}}{\max\limits_i s_{i1}}$

4. An Application of the Configured Methods

In this section, we apply the configured methods to performance-based value assignment problem for some filters used in image denoising. We first give the performance values of Progressive Switching Median Filter (PSMF) (Wang and Zhang, 1999), Decision Based Algorithm (DBA) (Pattnaik et al., 2012), Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF) (Esakkirajan et al., 2011), Noise Adaptive Fuzzy Switching Median Filter (NAFSMF) (Toh and Isa, 2010), and Different Applied Median Filter (DAMF) (Erkan et al., 2018) obtained by using the mean Structural Similarity (SSIM) (Wang et al., 2004) results for the 15 traditional images ranging in noise densities from 10% to 90% and which are provided in (Erkan et al., 2018). We then obtain the ranking order of these filters via the methods mentioned in Section 3.

Table 1. The mean SSIM results for the 15 traditional images

Filters	10%	20%	30%	40%	50%	60%	70%	80%	90%
PSMF	0.9028	0.8715	0.8018	0.6988	0.4903	0.1882	0.0633	0.0318	0.0139
DBA	0.9079	08664	0.8097	0.7376	0.6521	0.5552	0.4567	0.3623	0.2937
MDBUTMF	0.8841	0.7994	0.7443	0.7657	0.7963	0.7880	0.7501	0.6443	0.3052
NAFSMF	0.9147	0.8916	0.8669	0.8409	0.8124	0.7796	0.7403	0.6872	0.5736
DAMF	**0.9253**	**0.9113**	**0.8946**	**0.8752**	**0.8523**	**0.8244**	**0.7892**	**0.7398**	**0.6572**

Suppose that the success of the filters mentioned above at high-noise density is more important than in their success at the other noise densities. In that case, the values in Table 1 can be represented with an *fpfs*-matrix constructed in the first steps of algorithms as follows:

$$[a_{ij}] = \begin{bmatrix} 0.1 & 0.2 & 0.3 & 0.4 & 0.5 & 0.6 & 0.7 & 0.8 & 0.9 \\ 0.9028 & 0.8715 & 0.8018 & 0.6988 & 0.4903 & 0.1882 & 0.0633 & 0.0318 & 0.0139 \\ 0.9079 & 0.8664 & 0.8097 & 0.7376 & 0.6521 & 0.5552 & 0.4567 & 0.3623 & 0.2937 \\ 0.8841 & 0.7994 & 0.7443 & 0.7657 & 0.7963 & 0.7880 & 0.7501 & 0.6443 & 0.3052 \\ 0.9147 & 0.8916 & 0.8669 & 0.8409 & 0.8124 & 0.7796 & 0.7403 & 0.6872 & 0.5736 \\ 0.9253 & 0.9113 & 0.8946 & 0.8752 & 0.8523 & 0.8244 & 0.7892 & 0.7398 & 0.6572 \end{bmatrix}$$

Secondly, we give a performance ranking order of the filters for each method.

Performance Ranking of Filters via F10(z)

Step 2. For $z = 0.8$, a fuzzy-valued row matrix $[\lambda_j]_{1\times n}$ is as follows:

$$[\lambda_j] = [0.9188 \quad 0.8964 \quad 0.8696 \quad 0.8430 \quad 0.8097 \quad 0.7638 \quad 0.7189 \quad 0.6619 \quad 0.5580]$$

Step 3. The matrix $[c_{ij}]$ is as follows:

$$[c_{ij}] = \begin{bmatrix} 0.1 & 0.2 & 0.3 & 0.4 & 0.5 & 0.6 & 0.7 & 0.8 & 0.9 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Step 4. If MRB02 to $[c_{ij}]$ is applied, then the score matrix and 0.8-decision set are as

follows:

$$[s_{i1}] = [0 \quad 0 \quad 1.3 \quad 3.5 \quad 4.5]^T$$

and

$$\{^{0}\text{PSMF}, {}^{0}\text{DBA}, {}^{0.2889}\text{MDBUTMF}, {}^{0.7778}\text{NAFSMF}, {}^{1}\text{DAMF}\}$$

Performance Ranking of Filters via MBR01

Step 2. The matrix $[b_{ik}]$ is as follows:

$$[b_{ik}] = \begin{matrix} 4.5 & 0.2 & 0.6 & 0 & 0 \\ 4.3 & 4.5 & 0.6 & 0 & 0 \\ 3.9 & 3.9 & 4.5 & 1.3 & 0 \\ 4.5 & 4.5 & 3.2 & 4.5 & 0 \\ 4.5 & 4.5 & 4.5 & 4.5 & 4.5 \end{matrix}$$

Step 3. The matrix $[c_{i1}]$ is as follows:

$$[c_{i1}] = [5.3 \quad 9.4 \quad 13.6 \quad 16.7 \quad 22.5]^T$$

Step 4. The matrix $[d_{i1}]$ is as follows:

$$[d_{i1}] = [21.7 \quad 17.6 \quad 13.4 \quad 10.3 \quad 4.5]^T$$

Step 5. The score matrix is as follows:

$$[s_{i1}] = [-16.4 \quad -8.2 \quad 0.2 \quad 6.4 \quad 18]^T$$

Step 6. The decision set is as follows:

$$\{^{0}\text{PSMF}, {}^{0.2384}\text{DBA}, {}^{0.4826}\text{MDBUTMF}, {}^{0.6628}\text{NAFSMF}, {}^{1}\text{DAMF}\}$$

Performance Ranking of Filters via KSM10

Step 2. The *fpfs*-matrix $[b_{ij}]$ is as follows:

$$[b_{ij}] = \begin{matrix} 0.0838 & 0.0861 & 0.0902 & 0.0968 & 0.1094 & 0.1171 & 0.1205 & 0.1399 & 0.1561 \\ 0.9028 & 0.8715 & 0.8018 & 0.6988 & 0.4903 & 0.1882 & 0.0633 & 0.0318 & 0.0139 \\ 0.9079 & 0.8664 & 0.8097 & 0.7376 & 0.6521 & 0.5552 & 0.4567 & 0.3623 & 0.2937 \\ 0.8841 & 0.7994 & 0.7443 & 0.7657 & 0.7963 & 0.7880 & 0.7501 & 0.6443 & 0.3052 \\ 0.9147 & 0.8916 & 0.8669 & 0.8409 & 0.8124 & 0.7796 & 0.7403 & 0.6872 & 0.5736 \\ 0.9253 & 0.9113 & 0.8946 & 0.8752 & 0.8523 & 0.8244 & 0.7892 & 0.7398 & 0.6572 \end{matrix}$$

Step 3. If M11 to $[b_{ij}]$ is applied, then the score matrix and decision set are as follows:

$$[s_{i1}] = [-1.3331 \quad -0.3207 \quad 0.2229 \quad 0.6046 \quad 0.8262]^T$$

and

$$\{^{0}\text{PSMF}, {}^{0.4689}\text{DBA}, {}^{0.7206}\text{MDBUTMF}, {}^{0.8974}\text{NAFSMF}, {}^{1}\text{DAMF}\}$$

Performance Ranking of Filters via KWW11(w,z)

Step 2. If MBR01 and MRB02 to $[a_{ij}]$ is applied, then the score matrices $[s_{i1}^1]$ and $[s_{i1}^2]$ are as follows:

$$[s_{i1}^1] = [-16.4 \quad -8.2 \quad 0.2 \quad 6.4 \quad 18]^T$$

and

$$[s_{i1}^2] = [1.2250 \quad 2.3351 \quad 2.9640 \quad 3.3244 \quad 3.5498]^T$$

Step 3. The $[b_{i1}]$ and $[c_{i1}]$ matrices are as follows:

$$[b_{i1}] = [0 \quad 0.2384 \quad 0.4826 \quad 0.6628 \quad 1]^T$$

and

$$[c_{i1}] = [0 \quad 0.4775 \quad 0.7480 \quad 0.9030 \quad 1]^T$$

Step 4. The $[d_{i1}]$ and $[e_{i1}]$ matrices are as follows:

$$[d_{i1}] = [1 \quad 0.7616 \quad 0.5174 \quad 0.3372 \quad 0]^T$$

and

$$[e_{i1}] = [1 \quad 0.5525 \quad 0.2520 \quad 0.0970 \quad 0]^T$$

Step 5. For $w = 0.6$, the $[f_{i1}]$ and $[g_{i1}]$ matrices are as follows:

$$[f_{i1}] = [0.3750 \quad 0.4406 \quad 0.5369 \quad 0.6402 \quad 1]^T$$

and

$$[g_{i1}] = [0.3750 \quad 0.5345 \quad 0.7042 \quad 0.8609 \quad 1]^T$$

Step 6. For $z = 0.3$, the score matrix is as follows:

$$[s_{i1}] = [0.3750 \quad 0.5064 \quad 0.6541 \quad 0.7947 \quad 1]^T$$

Step 7. The (0.6,0.3)-decision set is as follows:

$$\{^{0.3750}\text{PSMF}, ^{0.5064}\text{DBA}, ^{0.6541}\text{MDBUTMF}, ^{0.7947}\text{NAFSMF}, ^{1}\text{DAMF}\}$$

Performance Ranking of Filters via SM11

Step 2. The fuzzy-valued row matrix is as follows:

$$[\lambda_j] = [0.0925 \quad 0.1823 \quad 0.2684 \quad 0.3501 \quad 0.4262 \quad 0.4946 \quad 0.5524 \quad 0.5918 \quad 0.5915]$$

Step 3. The $[b_{i1}]$ matrix is as follows:

$$[b_{i1}] = [0.7205 \quad 0.6669 \quad 0.5272 \quad 0.5322 \quad 0.5054]^T$$

Step 4. The $[c_{i1}]$ matrix is as follows:

$$[c_{i1}] = [0.2795 \quad 0.3331 \quad 0.5251 \quad 0.5498 \quad 0.5918]^T$$

Step 5. The score matrix is as follows:

$$[s_{i1}] = [1 \quad 1 \quad 1.0523 \quad 1.0820 \quad 1.0972]^T$$

Step 6. The decision set is as follows:

$$\{^{0.9114}\text{PSMF}, {}^{0.9114}\text{DBA}, {}^{0.9591}\text{MDBUTMF}, {}^{0.9861}\text{NAFSMF}, {}^{1}\text{DAMF}\}$$

Thirdly, we present performance results of filters for five algorithms in Table 2. We then give the ranking order of filters for these algorithms in Table 3. The results show that DAMF outperforms the others at all algorithms. DAMF is the most successful filter than the others, even if the ranking order of some filters herein is change.

Table 2. Performance Results of Filters for Algorithms

Algorithms/Filters	PSMF	DBA	MDBUTMF	NAFSMF	DAMF
F10(0.8)	0	0	0.2889	0.7778	**1**
MBR01	0	0.2384	0.4826	0.6628	**1**
KSM10	0	0.4689	0.7206	0.8974	**1**
KWW11(0.6,0.3)	0.3750	0.5064	0.6541	0.7947	**1**
SM11	0.9114	0.9114	0.9591	0.9861	**1**

Table 3. The Ranking Orders of the Filters for Algorithms

Algorithms	Ranking Orders
F10(0.8)	$\text{PSMF} = \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} \prec \text{DAMF}$
MBR01	$\text{PSMF} \prec \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} \prec \text{DAMF}$
KSM10	$\text{PSMF} \prec \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} \prec \text{DAMF}$
KWW11(0.6,0.3)	$\text{PSMF} \prec \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} \prec \text{DAMF}$
SM11	$\text{PSMF} = \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} \prec \text{DAMF}$

Consequently, the intuitional results have confirmed the results obtained by the methods mentioned above. In Table 4, the z-decision sets and the ranking orders of the algorithm F10(z) for ten different z-values are given. The results show that the success of the filters to performance-based value assignment problem depends on the z-value.

Table 4. The z-decision sets and the ranking orders of the algorithm F10(z) for ten different z-values

Algorithms	The Decision Sets	Ranking Orders
F10(0.1)	$\{^{0.1333}\text{PSMF}, {}^{1}\text{DBA}, {}^{0.8667}\text{MDBUTMF}, {}^{1}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} \prec \text{MDBUTMF} \prec \text{DBA} = \text{NAFSMF} = \text{DAMF}$
F10(0.2)	$\{^{0.1333}\text{PSMF}, {}^{1}\text{DBA}, {}^{0.8667}\text{MDBUTMF}, {}^{1}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} \prec \text{MDBUTMF} \prec \text{DBA} = \text{NAFSMF} = \text{DAMF}$
F10(0.3)	$\{^{0.1333}\text{PSMF}, {}^{0.9111}\text{DBA}, {}^{0.8667}\text{MDBUTMF}, {}^{1}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} \prec \text{MDBUTMF} \prec \text{DBA} \prec \text{NAFSMF} = \text{DAMF}$
F10(0.4)	$\{^{0.0667}\text{PSMF}, {}^{0.1333}\text{DBA}, {}^{0.8667}\text{MDBUTMF}, {}^{1}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} \prec \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} = \text{DAMF}$
F10(0.5)	$\{^{0.0444}\text{PSMF}, {}^{0.0222}\text{DBA}, {}^{0.5778}\text{MDBUTMF}, {}^{1}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} \prec \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} = \text{DAMF}$
F10(0.6)	$\{^{0}\text{PSMF}, {}^{0}\text{DBA}, {}^{0.5778}\text{MDBUTMF}, {}^{1}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} = \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} = \text{DAMF}$
F10(0.7)	$\{^{0}\text{PSMF}, {}^{0}\text{DBA}, {}^{0.5778}\text{MDBUTMF}, {}^{0.9778}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} = \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} \prec \text{DAMF}$
F10(0.8)	$\{^{0}\text{PSMF}, {}^{0}\text{DBA}, {}^{0.2889}\text{MDBUTMF}, {}^{0.7778}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} = \text{DBA} \prec \text{MDBUTMF} \prec \text{NAFSMF} \prec \text{DAMF}$
F10(0.9)	$\{^{0}\text{PSMF}, {}^{0}\text{DBA}, {}^{0}\text{MDBUTMF}, {}^{0}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} = \text{DBA} = \text{MDBUTMF} = \text{NAFSMF} \prec \text{DAMF}$
F10(1)	$\{^{1}\text{PSMF}, {}^{1}\text{DBA}, {}^{1}\text{MDBUTMF}, {}^{1}\text{NAFSMF}, {}^{1}\text{DAMF}\}$	$\text{PSMF} = \text{DBA} = \text{MDBUTMF} = \text{NAFSMF} = \text{DAMF}$

5. Conclusion

In this study, we have configured five of the soft decision-making methods, faithfully to the original via fpfs-matrices. We then have applied the methods to order the filters in terms of performance. It can be seen that the configuration of the soft decision-making methods via *fpfs*-matrices have increased the availability ratio of the methods. Considered this modelling ability of the *fpfs*-matrices, the necessity of configuration of the soft decision-making methods has been better understood. However, the absence of the name of these methods leads to some difficulties. To overcome this problem, we use a notation in which the first letters of the authors' names and the last two digits of the publication years are used (see Enginoğlu and Memiş, 2018a). When all potential configurations occur, it will be possible to compare these methods.

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An Application of Fuzzy Parameterized Fuzzy Soft Matrices in Data Classification

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Abstract: In this paper, we propose a classification method based on Chebyshev pseudo-similarity of fuzzy parameterized fuzzy soft matrices (*fpfs*-matrices). We then compare the proposed method with Fuzzy Soft Set Classifier (FSSC), FussCyier, and Fuzzy Soft Set Classification Using Hamming Distance (HDFSSC) in terms of the performance criterions (accuracy, precision, recall, and F-measure) and running times by using four medical data sets in the UCI machine learning repository. The results show that the proposed method outperforms FSSC, FussCyier, and HDFSSC for "Cryotherapy", "Diabetic Retinopathy", "Hepatitis", and "Immunotherapy" data sets. Finally, we discuss the need for further research.

Keywords: Fuzzy sets, soft sets, *fpfs*-matrices, similarity measure, data classification

1. Introduction

The concept of soft sets (Molodtsov, 1999) is a useful mathematical tool used for modelling uncertainties, and a wide range of studies have been conducted on this concept (Çağman and Deli, 2012a, b; Deli and Çağman, 2015; Enginoğlu et al., 2015; Şenel, 2016; Zorlutuna and Atmaca, 2016; Atmaca, 2017; Çıtak and Çağman, 2017; Riaz and Hashmi, 2017; Atmaca, 2018; Riaz and Hashmi, 2018; Riaz et al., 2018; Çıtak, 2018; Şenel, 2018a, b; Jana et al., 2019; Karaaslan, 2019a, b; Sezgin et al., 2019a, b). So far, its many general forms have been conducted such as fuzzy soft sets (Maji et al., 2001; Çağman et al., 2011b), fuzzy parameterized soft sets (Çağman et al., 2011a), and fuzzy parameterized fuzzy soft sets (*fpfs*-sets) (Çağman et al., 2010). Moreover, the matrix representations of these sets have been defined (Çağman and Enginoğlu, 2010, 2012; Enginoğlu, 2012; Enginoğlu and Çağman, In Press). Being one of these matrix representations, fuzzy parameterized fuzzy soft matrices (*fpfs*-matrices) have become prominent because of the success of modelling the problems in which the parameters and objects have uncertainties.

The rest of the paper is organised as follows: In Section 2, we present definitions of *fpfs*-sets (Çağman et al., 2010; Enginoğlu, 2012), *fpfs*-matrices (Enginoğlu, 2012; Enginoğlu and Çağman, In Press), and Chebyshev pseudo-similarity of *fpfs*-matrices. In Section 3, we propose Fuzzy Parameterized Fuzzy Soft Chebyshev Classifier (FPFSCC) using Chebyshev pseudo-similarity of *fpfs*-matrices. In Section 4, we compare FPFSCC with Fuzzy Soft Set Classifier (FSSC) (Handaga et al., 2012), FussCyier (Lashari et al., 2017), and Fuzzy Soft Set Classification Using Hamming Distance (HDFSSC) (Yanto et al., 2018) in terms of the performance criterions (accuracy, precision, recall, and F-measure) and running times by using four medical data sets in the UCI machine learning repository (Dua and Graff, 2019). The results show that the proposed method outperforms FSSC, FussCyier, and HDFSSC for

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"Cryotherapy", "Diabetic Retinopathy", "Hepatitis", and "Immunotherapy" data sets. Finally, we discuss the need for further research. This study is a part of the first author's PhD dissertation.

2. Preliminaries

In this section, firstly, the concept of *fpfs*-matrices (Enginoğlu, 2012; Enginoğlu and Çağman, In Press) have been presented. Throughout this paper, let E be a parameter set, $F(E)$ be the set of all fuzzy sets over E, and $\mu \in F(E)$. Here, a fuzzy set is denoted by $\left\{{}^{\mu(x)}x : x \in E\right\}$ instead of $\{(x, \mu(x)) : x \in E\}$.

Definition 2.1. (Çağman et al., 2010; Enginoğlu, 2012) *Let U be a universal set, $\mu \in F(E)$, and α be a function from μ to $F(U)$. Then, the set $\{({}^{\mu(x)}x, \alpha({}^{\mu(x)}x)) : x \in E\}$ being the graphic of α is called a fuzzy parameterized fuzzy soft set (fpfs-set) parameterized via E over U (or briefly over U).*

In the present paper, the set of all *fpfs*-sets over U is denoted by $FPFS_E(U)$. In $FPFS_E(U)$, since the $graph(\alpha)$ and α generated each other uniquely, the notations are interchangeable. Therefore, as long as it does not cause any confusion, we denote an *fpfs*-set $graph(\alpha)$ by α.

Example 2.1. *Let $E = \{x_1, x_2, x_3, x_4\}$ and $U = \{u_1, u_2, u_3, u_4, u_5\}$. Then,*

$$\alpha = \{({}^{0.9}x_1, \{{}^{0.4}u_1, {}^{0.2}u_2, {}^{0.7}u_4\}), ({}^{0}x_2, \{{}^{0.1}u_1, {}^{0.8}u_3, {}^{1}u_5\}), ({}^{0.5}x_3, \{{}^{0.7}u_1, {}^{0.3}u_4\}), ({}^{1}x_4, \{{}^{0.6}u_1, {}^{0.9}u_5\})\}$$

is an fpfs-set over U.

Definition 2.2. (Enginoğlu, 2012; Enginoğlu and Çağman, In Press) *Let $\alpha \in FPFS_E(U)$. Then, $[a_{ij}]$ is called the matrix representation of α (or briefly fpfs-matrix of α) and is defined by*

$$[a_{ij}] := \begin{bmatrix} a_{01} & a_{02} & a_{03} & \dots & a_{0n} & \dots \\ a_{11} & a_{12} & a_{13} & \dots & a_{1n} & \dots \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \dots & a_{mn} & \dots \\ \vdots & \vdots & \vdots & \ddots & \vdots & \ddots \end{bmatrix}$$

such that for $i \in \{0,1,2,\cdots\}$ and $j \in \{1,2,\cdots\}$,

$$a_{ij} := \begin{cases} \mu(x_j), & i = 0 \\ \alpha({}^{\mu(x_j)}x_j)(u_i), & i \neq 0 \end{cases}$$

Here, if $|U| = m - 1$ and $|E| = n$, then $[a_{ij}]$ has order $m \times n$.

Throughout this paper, the set of all *fpfs*-matrices parameterized via E over U is denoted by $FPFS_E[U]$.

Example 2.2. *Let us consider the fpfs-set α provided in Example 2.1. Then, the fpfs-matrix of α is as follows:*

$$[a_{ij}] = \begin{bmatrix} 0.9 & 0 & 0.5 & 1 \\ 0.4 & 0.1 & 0.7 & 0.6 \\ 0.2 & 0 & 0 & 0 \\ 0 & 0.8 & 0 & 0 \\ 0.7 & 0 & 0.3 & 0 \\ 0 & 1 & 0 & 0.9 \end{bmatrix}$$

Secondly, we present the Chebyshev pseudo-similarity of *fpfs*-matrices.

Definition 2.3. *Let* $[a_{ij}], [b_{ij}] \in FPFS_E[U]$. *Then, the Chebyshev pseudo-similarity of* $[a_{ij}]$ *and* $[b_{ij}]$ *is defined by*

$$s([a_{ij}], [b_{ij}]) \coloneqq 1 - \min_{i \in I_{m-1}} \left\{ \max_{j \in I_n} \{ |a_{0j}a_{ij} - b_{0j}b_{ij}| \} \right\}$$

such that $I_{m-1} \coloneqq \{1,2, \dots, m-1\}$ *and* $I_n \coloneqq \{1,2, \dots, n\}$.

3. An Application of Fuzzy Parameterized Fuzzy Soft Matrices in Data Classification

3.1. Fuzzy parameterized fuzzy soft Chebyshev classifier (FPFSCC)

In this subsection, firstly, we give some basic notations. Let $u, v \in \mathbb{R}^n$. Then, the Pearson correlation coefficient between u and v is defined by

$$P(u,v) \coloneqq \frac{n\sum_{i=1}^{n} u_i v_i - (\sum_{i=1}^{n} u_i)(\sum_{i=1}^{n} v_i)}{\sqrt{[n\sum_{i=1}^{n} u_i^2 - (\sum_{i=1}^{n} u_i)^2][n\sum_{i=1}^{n} v_i^2 - (\sum_{i=1}^{n} v_i)^2]}}$$

Throughout this paper, let $[dm]$ be a data matrix having order $m \times n$, $[\widetilde{dm}]$ be the feature fuzzification of $[dm]$, the last column of $[\widetilde{dm}]$ be the class column, $[tm]$ be a training matrix which is a submatrix of $[dm]$, $[tm^r]$ be a submatrix of $[tm]$ whose values of the last column are equal to r, and $[tm]^j$ be j^{th} column of $[tm]$.

Secondly, we propose FPFSCC classification algorithm. FPFSCC's steps are as follows:

FPFSCC's Algorithm Steps

Step 1. Read a nonempty $[dm]$

Step 2. Calculate the feature weight vector $[fw_{1j}]$ based on the Pearson correlation coefficient between feature vectors and class vector defined by

$$fw_{1j} \coloneqq P([dm]^j, [dm]^n), for\ j \in \{1,2, \dots, n-1\}$$

Step 3. Obtain $[\widetilde{dm}]$ such that for $i \in \{1,2, \dots, m\}$ and $j \in \{1,2, \dots, n\}$,

$$\widetilde{dm}_{ij} \coloneqq \begin{cases} \dfrac{dm_{ij}}{\max\limits_{k} dm_{kj}}, & j \neq n \\ dm_{ij}, & j = n \end{cases}$$

Step 4. Obtain $[tm]$ from the $[\widetilde{dm}]$

Step 5. Obtain $[tm^r]$ for all r

Step 6. Calculate the cluster centre matrix $[e_{rj}]$ such that for $i \in \{1,2,\dots,k_r\}$ and $j \in \{1,2,\dots,n-1\}$,

$$e_{rj} \coloneqq \frac{1}{k_r}\sum_{i=1}^{k_r} tm_{ij}^r$$

Here, k_r is row number of $[tm^r]$.

Step 7. Obtain the train *fpfs*-matrices $\left[a_{ij}^r\right]$ such that for all r, $a_{0j}^r = fw_{1j}$ and $a_{1j}^r = e_{rj}$

Step 8. Obtain the unknown class data $[u_{1j}]$ from the test data

Step 9. Obtain the test *fpfs*-matrix $\left[b_{ij}\right]$ such that $b_{0j} = fw_{1j}$ and $b_{1j} = u_{1j}$

Step 10. Compute S_r for all r defined by

$$S_r \coloneqq s\left(\left[a_{ij}^r\right],[b_{ij}]\right) = 1 - \min_{i\in I_{m-1}}\left\{\max_{j\in I_n}\left\{\left|a_{0j}a_{ij} - b_{0j}b_{ij}\right|\right\}\right\}$$

Step 11. Obtain c such that $S_c = \max_r S_r$

Step 12. Assign the data $[u_{1j}]$ without class to class c

Step 13. Repeat Step 9-12 for all data $[u_{1j}]$ without class in test data

3.2. Simulation criteria

In this subsection, in Table 1, we present the details of the "Cryotherapy", "Diabetic Retinopathy", "Hepatitis", and "Immunotherapy" datasets provided in UCI Machine Learning Repository (Dua and Graff, 2019). Also, we give the definitions of the performance four performance criterions: accuracy, precision, recall, and F-measure, as follows:

$$Accuracy \coloneqq \frac{TP+TN}{TP+TN+FP+FN} \qquad Precision \coloneqq \frac{TP}{TP+FP}$$

$$Recall \coloneqq \frac{TP}{TP+FN} \qquad F-Measure \coloneqq \frac{2(Precision \times Recall)}{Precision + Recall} = \frac{2TP}{2TP+FP+FN}$$

where TP: True positive, FP: False positive, TN: True negative, and FN: False negative.

Here, the accuracy of a classifier is calculated by dividing the total correctly classified positives and negatives by the total number of samples, the precision of a classifier is calculated by dividing correctly classified positives by the total positive count, the recall of a classifier is calculated by dividing correctly classified positives by total true positive class, and the F-measure of a classifier is harmonic mean of precision and recall values.

Table 1. Description of The UCI data sets

No.	Name	Instances	Attributes	Class
1	Cryotherapy	90	6	2
2	Diabetic Retinopathy	1151	19	2
3	Hepatitis	155	19	2
4	Immunotherapy	90	7	2

3.3. Simulation results

In this subsection, we first compare the proposed method FPFSCC with three methods FSSC, FussCyier, and HDFSSC by using "Cryotherapy", "Diabetic Retinopathy", "Hepatitis", and "Immunotherapy" datasets and four performance criterions: accuracy, precision, recall, and F-measure provided in Subsection 3.2.

Secondly, in Table 2 and 3, we present the performance results of the algorithms for "Cryotherapy" and "Diabetic Retinopathy" data sets, and for "Hepatitis" and "Immunotherapy" data sets, respectively. In Figures 1-4, we give the figures of Table 2 and 3. In Table 4 and Figure 5, we give the running times of algorithms for all medical data sets mentioned above. We use MATLAB R2019a and a workstation with I(R) Xeon(R) CPU E5-1620 v4@3.5 GHz and 64 GB RAM for simulation. All simulation results are obtained at random 100 independent runs. A split of data 80 per cent is a training set, and 20 per cent is a testing set. The performance results are obtained by averaging the performance values of each class.

Table 2. The results (%) of the methods for "Cryotherapy"and "Diabetic Retinopathy" data sets

	Cryotherapy				Diabetic Retinopathy			
Classifier	**Accuracy**	**Precision**	**Recall**	**F-Measure**	**Accuracy**	**Precision**	**Recall**	**F-Measure**
FSSC	82.00	82.74	82.50	81.36	57.95	58.15	58.15	57.87
FussCyier	77.22	77.44	76.93	76.14	57.59	57.88	57.86	57.51
HDFSSC	82.72	82.88	82.65	81.95	57.27	57.44	57.44	57.19
FPFSCC	**85.06**	**85.75**	**85.52**	**84.55**	**59.54**	**59.53**	**59.55**	**59.41**

Table 3. The results (%) of the methods for "Hepatitis" and "Immunotherapy" data sets

	Hepatitis				Immunotherapy			
Classifier	**Accuracy**	**Precision**	**Recall**	**F-Measure**	**Accuracy**	**Precision**	**Recall**	**F-Measure**
FSSC	64.19	65.16	61.57	59.75	62.28	61.15	65.84	56.69
FussCyier	64.97	65.47	62.71	61.46	68.00	63.48	68.12	60.99
HDFSSC	65.13	64.76	64.17	63.58	67.89	62.98	68.09	60.78
FPFSCC	**69.23**	**69.26**	**69.27**	**68.42**	**70.67**	**66.75**	**73.17**	**64.60**

Table 4. The mean running time of the methods for the data sets (In Seconds)

Classifier	Cryotherapy	Diabetic Retinopathy	Hepatitis	Immunotherapy
FSSC	0.00037	0.00192	0.00050	0.00039
FussCyier	0.00039	0.00112	0.00046	0.00041
HDFSSC	0.00032	0.00133	0.00041	0.00036
FPFSCC	0.00062	0.00597	0.00114	0.00069

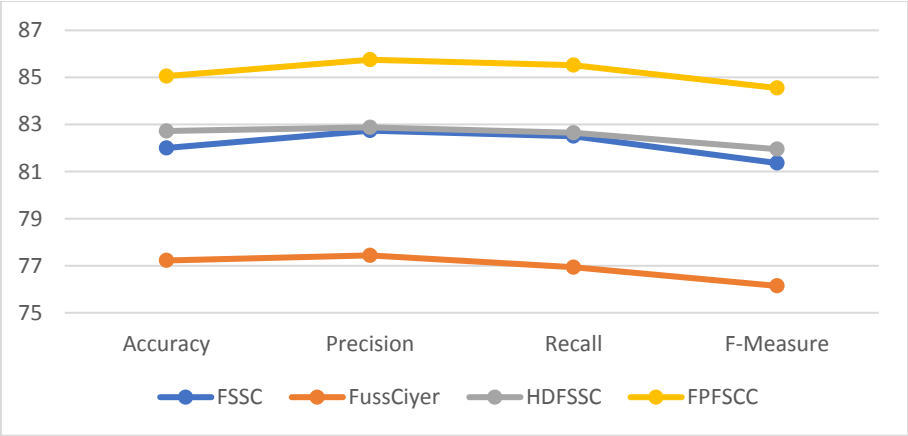

Figure 1. The Figure of the average accuracy, precision, recall, and F-measure results (%) of algorithms for "Cryotherapy" dataset in Table 2

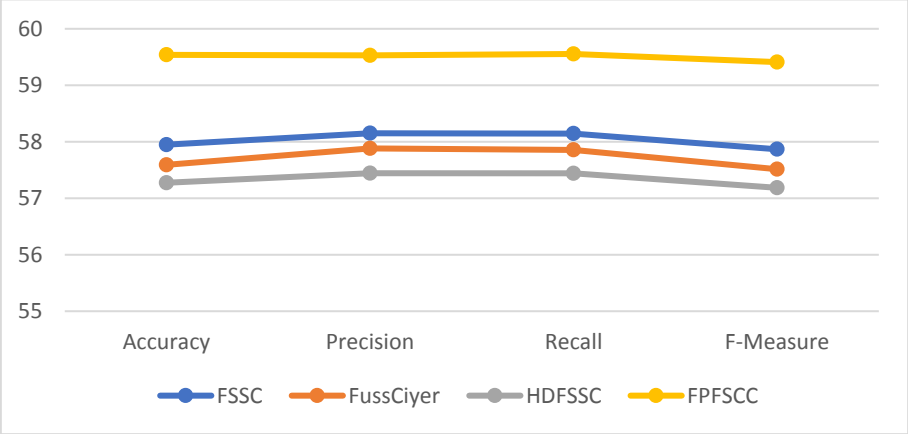

Figure 2. The Figure of the average accuracy, precision, recall, and F-measure results (%) of algorithms for "Diabetic Retinopathy" dataset in Table 2

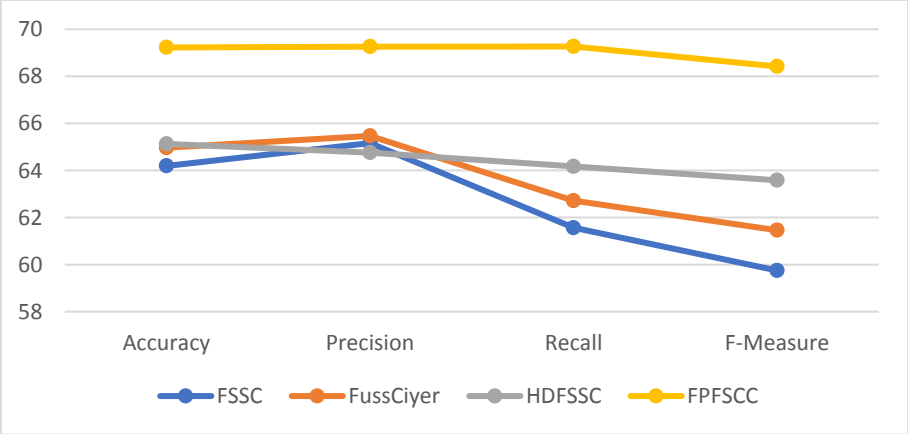

Figure 3. The Figure of the average accuracy, precision, recall, and F-measure results (%) of algorithms for "Hepatitis" dataset in Table 3

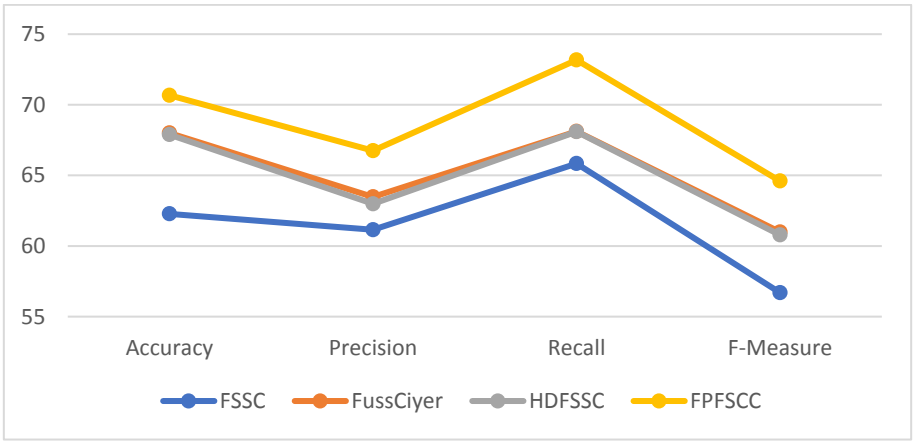

Figure 4. The Figure of the average accuracy, precision, recall, and F-measure results (%) of algorithms for "Immunotherapy" dataset in Table 3

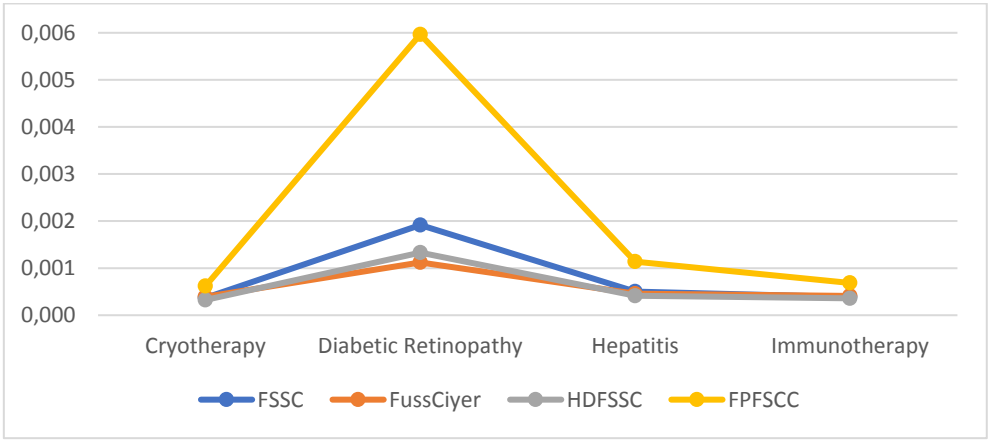

Figure 5. The Figure of the mean running times of the algorithms for the data sets in Table 4

4. Conclusion

In this paper, we have proposed the classification method FPFSCC. We then compare FPFSCC with FSSC, FussCyier, and HDFSSC in terms of the performance criterions (accuracy, precision, recall, and F-measure) and running times by using Cryotherapy, Diabetic Retinopathy, Hepatitis, and Immunotherapy medical data sets in the UCI machine learning repository. The results show that FPFSCC outperforms FSSC, FussCyier, and HDFSSC.

Since *fpfs*-matrices is a successfully mathematical tool for data classification, it is worthwhile to study this concept. Also, new classification algorithms can be developed by using soft decision-making methods constructed by *fpfs*-matrices such as (Enginoğlu and Memiş, 2018a, b, c, d; Enginoğlu et al., 2018a, b, c, d; Enginoğlu and Çağman, In Press).

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On Intuitionistic Fuzzy Parameterized Intuitionistic Fuzzy Soft Sets and Their Application in Decision-Making

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Abstract: The concept of intuitionistic fuzzy parameterized intuitionistic fuzzy soft sets (*ifpifs*-sets) is a new and useful mathematical tool propounded to model uncertainties. In this study, to improve this concept, we first present the difference and the symmetric difference between two intuitionistic fuzzy sets (*if*-sets) and investigate some properties. Secondly, on *ifpifs*-sets, we propose some new operations such as the relative union/intersection/difference and study some properties. We then suggest a new soft decision-making method and apply this method to a decision-making problem. Finally, we discuss *ifpifs*-sets and the method mentioned above for further research.

Keywords: Fuzzy sets, soft sets, intuitionistic fuzzy sets, *ifpifs*-sets, soft decision-making

1. Introduction

Standard mathematical tools are not adequate for modelling some problems containing uncertainties. To deal with this problem, many mathematical tools have propounded such as fuzzy sets (Zadeh, 1965), intuitionistic fuzzy sets (*if*-sets) (Atanassov, 1986), and soft sets (Molodtsov, 1999). Moreover, some hybrid versions of these concepts have been introduced such as fuzzy soft sets (Maji et al., 2001a), fuzzy parameterized soft sets (Çağman et al., 2011a), fuzzy parameterized fuzzy soft sets (Çağman et al., 2010), intuitionistic fuzzy soft sets (Maji et al., 2001b), intuitionistic fuzzy parameterized soft sets (Deli and Çağman, 2015), and intuitionistic fuzzy parameterized fuzzy soft sets (El-Yagubi and Salleh, 2013). So far, many theoretical and applied studies have been conducted on these concepts, from algebra to decision-making (Maji et al., 2002; Maji et al., 2003; Çağman and Enginoğlu, 2010a, b; Çağman et al., 2011b; Çağman and Deli, 2012a, b; Çağman and Enginoğlu, 2012; Çıtak and Çağman, 2015; Enginoğlu et al., 2015; Muştuoğlu et al., 2016; Şenel, 2016; Tunçay and Sezgin, 2016; Zorlutuna and Atmaca, 2016; Atmaca, 2017; Bera et al., 2017; Riaz and Hashmi, 2017; Atmaca, 2018; Çıtak, 2018; Enginoğlu and Memiş, 2018a, b; Enginoğlu et al., 2018a, b; Riaz and Hashmi, 2018; Riaz et al., 2018; Şenel, 2018a, b; Ullah et al., 2018; Karaaslan, 2019; Sezgin et al., 2019a, b; Enginoğlu and Çağman, In Press)

In recent years, Karaaslan (2016) has proposed the concept of intuitionistic fuzzy parameterized intuitionistic fuzzy soft sets (*ifpifs*-sets), to cope with some problems containing further uncertainties. Karaaslan and Karataş (2016) have defined the and-product and or-product of the *ifpifs*-sets and given a decision-making method via and-product and an aggregate-operator. Selvachandran et al. (2017) have studied on soft decision-making through the reduction and aggregation operator on *ifpifs*-sets.

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In Section 2 of the present study, we present some basic definitions and propositions required in the next sections. In Section 3, we define the concepts such as restriction, difference, and symmetric difference on *if*-sets and the concepts such as restriction, difference, symmetric difference, relative union, relative intersection, and relative difference on *ifpifs*-sets and investigate some of their basic properties. Section 3 is a part of the second author's master's thesis. In Section 4, we suggest a new soft decision-making method denoted by EA19/2. In Section 5, we apply EA19/2 to a recruitment process. Finally, we discuss the need for further research.

2. Preliminaries

In this section, we present the concepts of *if*-sets (Atanassov, 1986) and *ifpifs*-sets (Karaaslan, 2016), and some of their basic definitions by taking into account the notations used throughout this study. Throughout this paper, let E be a parameter set, $F(E)$ be the set of all fuzzy sets over E, and $\mu \in F(E)$. Here, a fuzzy set is denoted by $\left\{{}^{\mu(x)}x : x \in E\right\}$ instead of $\{(x, \mu(x)) : x \in E\}$.

Definition 2.1. (Atanassov, 1986) Let f is a function from E to $[0,1] \times [0,1]$. Then, the set $\left\{{}^{\mu(x)}_{\nu(x)}x : x \in E\right\}$ being the graphic of f is called an intuitionistic fuzzy set (*if*-set) over E such that $0 \leq \mu(x) + \nu(x) \leq 1$, for all $x \in E$.

Moreover, μ and ν are called the membership function and non-membership function, respectively, and $\pi(x) = 1 - \mu(x) - \nu(x)$ is called the degree of indeterminacy of the element $x \in E$. Obviously, each ordinary fuzzy set can be written as $\left\{{}^{\mu(x)}_{1-\mu(x)}x : x \in E\right\}$.

In the present paper, the set of all *if*-sets over E is denoted by $IF(E)$ and $f, f_1, f_2, f_3 \in IF(E)$. In $IF(E)$, since the $graph(f)$ and f generated each other uniquely, the notations are interchangeable. Therefore, as long as it does not cause any confusion, we denote an *if*-set $graph(f)$ by f.

Example 2.1. Let $\mu, \nu \in F(\mathbb{R})$. For all $x \in \mathbb{R}$, if $\mu_1(x) \coloneqq \nu(x) - \frac{\mu(x).\nu(x)}{2}$ and $\nu_1(x) \coloneqq \mu(x) - \frac{\mu(x).\nu(x)}{2}$, then $\left\{{}^{\mu_1(x)}_{\nu_1(x)}x : x \in \mathbb{R}\right\}$ is an *if*-set over $\mathbb{R}$.

Definition 2.2. (Atanassov, 2012) Let $f \in IF(E)$. For all $x \in E$, if $\mu(x) = 1$ and $\nu(x) = 0$, then f is called universal if-set and is denoted by ${}^{1}_{0}f$ or 1_E.

Definition 2.3. (Atanassov, 2012) Let $f \in IF(E)$. For all $x \in E$, if $\mu(x) = 0$ and $\nu(x) = 1$, then f is called empty *if*-set and is denoted by ${}^{0}_{1}f$ or 0_E.

Definition 2.4. (Atanassov, 1986) Let $f_1, f_2 \in IF(E)$. For all $x \in E$, if $\mu_1(x) \leq \mu_2(x)$ and $\nu_2(x) \leq \nu_1(x)$, then f_1 is called a subset of f_2 and is denoted by $f_1 \cong f_2$.

Proposition 2.1. (Arslan, 2019) Let $f, f_1, f_2, f_3 \in IF(E)$. Then,

i. $f \cong 1_E$

ii. $0_E \cong f$

iii. $f \cong f$

iv. $[f_1 \cong f_2 \wedge f_2 \cong f_3] \Rightarrow f_1 \cong f_3$

Definition 2.5. (Atanassov, 1986) Let $f_1, f_2 \in IF(E)$. For all $x \in E$, if $\mu_1(x) = \mu_2(x)$ and $\nu_1(x) = \nu_2(x)$, then f_1 and f_2 are called equal *if*-sets and is denoted by $f_1 = f_2$.

Proposition 2.2. (Arslan, 2019) Let $f, f_1, f_2, f_3 \in IF(E)$. Then,

i. $f = f$

ii. $f_1 = f_2 \Rightarrow f_2 = f_1$

iii. $[f_1 = f_2 \wedge f_2 = f_3] \Rightarrow f_1 = f_3$

iv. $[f_1 \tilde{\subseteq} f_2 \wedge f_2 \tilde{\subseteq} f_1] \Leftrightarrow f_1 = f_2$

Note 2.1. From Proposition 2.1 and 2.2, it can be seen that the equality relation is an equivalence relation, and the inclusion relation is a partial ordering relation.

Definition 2.6. (Atanassov, 1986) Let $f_1, f_2, f_3 \in IF(E)$. For all $x \in E$, if $\mu_3(x) \coloneqq \max\{\mu_1(x), \mu_2(x)\}$ and $\nu_3(x) \coloneqq \min\{\nu_1(x), \nu_2(x)\}$, then f_3 is called union of f_1 and f_2 and is denoted by $f_1 \tilde{\cup} f_2$.

Definition 2.7. (Atanassov, 1986) Let $f_1, f_2, f_3 \in IF(E)$. For all $x \in E$, if $\mu_3(x) \coloneqq \min\{\mu_1(x), \mu_2(x)\}$ and $\nu_3(x) \coloneqq \max\{\nu_1(x), \nu_2(x)\}$, then f_3 is called intersection of f_1 and f_2 and is denoted by $f_1 \tilde{\cap} f_2$.

Proposition 2.3. (Atanassov, 1986) Let $f, f_1, f_2, f_3 \in IF(E)$. Then,

i. $f \tilde{\cup} f = f$ and $f \tilde{\cap} f = f$

ii. $f_1 \tilde{\cup} f_2 = f_2 \tilde{\cup} f_1$ and $f_1 \tilde{\cap} f_2 = f_2 \tilde{\cap} f_1$

iii. $(f_1 \tilde{\cup} f_2) \tilde{\cup} f_3 = f_1 \tilde{\cup} (f_2 \tilde{\cup} f_3)$ and $(f_1 \tilde{\cap} f_2) \tilde{\cap} f_3 = f_1 \tilde{\cap} (f_2 \tilde{\cap} f_3)$

iv. $f_1 \tilde{\cup} (f_2 \tilde{\cap} f_3) = (f_1 \tilde{\cup} f_2) \tilde{\cap} (f_1 \tilde{\cup} f_3)$ and $f_1 \tilde{\cap} (f_2 \tilde{\cup} f_3) = (f_1 \tilde{\cap} f_2) \tilde{\cup} (f_1 \tilde{\cap} f_3)$

Proposition 2.4. (Arslan, 2019) Let $f_1, f_2 \in IF(E)$. Then,

i. $f_1 \tilde{\subseteq} f_2 \Rightarrow f_1 \tilde{\cup} f_2 = f_2$

ii. $f_1 \tilde{\subseteq} f_2 \Rightarrow f_1 \tilde{\cap} f_2 = f_1$

Proposition 2.5. (Atanassov, 2012) Let $f \in IF(E)$. Then,

i. $f \tilde{\cup} 0_E = f$ and $f \tilde{\cup} 1_E = 1_E$

ii. $f \tilde{\cap} 0_E = 0_E$ and $f \tilde{\cap} 1_E = f$

Definition 2.8. (Atanassov, 1986) Let $f_1, f_2 \in IF(E)$. For all $x \in E$, if $\mu_2(x) \coloneqq \nu_1(x)$ and $\nu_2(x) \coloneqq \mu_1(x)$ then f_2 is called complement of f_1 and is denoted by $f_1^{\tilde{c}}$.

Proposition 2.6. (Arslan, 2019) Let $f, f_1, f_2 \in IF(E)$. Then,

i. $(f^{\tilde{c}})^{\tilde{c}} = f$

ii. $0_E^{\tilde{c}} = 1_E$

iii. $f_1 \tilde{\subseteq} f_2 \Rightarrow f_2^{\tilde{c}} \tilde{\subseteq} f_1^{\tilde{c}}$

Proposition 2.7. (Atanassov, 1986) Let $f_1, f_2 \in IF(E)$. Then, the following De Morgan's laws are valid.

i. $(f_1 \,\tilde{\cup}\, f_2)^{\tilde{c}} = f_1^{\tilde{c}} \,\tilde{\cap}\, f_2^{\tilde{c}}$

ii. $(f_1 \,\tilde{\cap}\, f_2)^{\tilde{c}} = f_1^{\tilde{c}} \,\tilde{\cup}\, f_2^{\tilde{c}}$

Definition 2.9. (Karaaslan, 2016) Let α be a function from f to $IF(U)$. Then, the set $\left\{\left(\begin{smallmatrix}\mu(x)\\ \nu(x)\end{smallmatrix}x, \alpha\left(\begin{smallmatrix}\mu(x)\\ \nu(x)\end{smallmatrix}x\right)\right) : x \in E\right\}$ being the graphic of α is called an intuitionistic fuzzy parameterized intuitionistic fuzzy soft set (*ifpifs*-set) parameterized via E over U (or briefly over U).

Throughout this paper, the set of all *ifpifs*-sets over U is denoted by $IFPIFS_E(U)$ and let $\alpha, \alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. In $IFPIFS_E(U)$, since the $graph(\alpha)$ and α generated each other uniquely, the notations are interchangeable. Therefore, as long as it does not cause any confusion, we denote an *ifpifs*-set $graph(\alpha)$ by α.

Example 2.2. Let $E = \{x_1, x_2, x_3\}$ and $U = \{u_1, u_2, u_3, u_4\}$. Then,

$$\alpha = \{(\begin{smallmatrix}0.3\\ 0.4\end{smallmatrix}x_1, \{\begin{smallmatrix}0.9\\ 0.1\end{smallmatrix}u_1, \begin{smallmatrix}0.4\\ 0.4\end{smallmatrix}u_2, \begin{smallmatrix}0.9\\ 0.1\end{smallmatrix}u_3\}), (\begin{smallmatrix}0.8\\ 0.2\end{smallmatrix}x_2, \{\begin{smallmatrix}0.6\\ 0.4\end{smallmatrix}u_1, \begin{smallmatrix}0.8\\ 0.2\end{smallmatrix}u_3, \begin{smallmatrix}0.7\\ 0.2\end{smallmatrix}u_4\}), (\begin{smallmatrix}0.6\\ 0.2\end{smallmatrix}x_3, \{\begin{smallmatrix}0.2\\ 0.5\end{smallmatrix}u_1, \begin{smallmatrix}0.8\\ 0.1\end{smallmatrix}u_2, \begin{smallmatrix}0.2\\ 0.4\end{smallmatrix}u_4\})\}$$

is an *ifpifs*-set over U. Here, for brevity, the element such as $\begin{smallmatrix}0\\ 1\end{smallmatrix}u_4$ do not show in the *if*-sets containing them.

Definition 2.10. (Karaaslan, 2016) Let $\alpha \in IFPIFS_E(U)$. If $f = 1_E$ and for all $x \in E$, $\alpha(\begin{smallmatrix}1\\ 0\end{smallmatrix}x) = 1_U$, then α is called universal ifpifs-set and is denoted by $\begin{smallmatrix}1\\ 0\end{smallmatrix}\alpha$ or $\tilde{1}$.

Definition 2.11. (Karaaslan, 2016) Let $\alpha \in IFPIFS_E(U)$. If $f = 0_E$ and for all $x \in E$, $\alpha(\begin{smallmatrix}0\\ 1\end{smallmatrix}x) = 0_U$, then α is called empty *ifpifs*-set and is denoted by $\begin{smallmatrix}0\\ 1\end{smallmatrix}\alpha$ or $\tilde{0}$.

Definition 2.12. (Karaaslan, 2016) Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. If $f_1 \,\tilde{\subseteq}\, f_2$ and for all $x \in E$, $\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) \,\tilde{\subseteq}\, \alpha_2\left(\begin{smallmatrix}\mu_2(x)\\ \nu_2(x)\end{smallmatrix}x\right)$, then α_1 is called a subset of α_2 and is denoted by $\alpha_1 \,\tilde{\subseteq}\, \alpha_2$.

Proposition 2.8. (Karaaslan, 2016) Let $\alpha, \alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. Then,

i. $\alpha \,\tilde{\subseteq}\, \tilde{1}$

ii. $\tilde{0} \,\tilde{\subseteq}\, \alpha$

iii. $\alpha \,\tilde{\subseteq}\, \alpha$

iv. $[\alpha_1 \,\tilde{\subseteq}\, \alpha_2 \wedge \alpha_2 \,\tilde{\subseteq}\, \alpha_3] \Rightarrow \alpha_1 \,\tilde{\subseteq}\, \alpha_3$

Definition 2.13. (Karaaslan, 2016) Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. If $f_1 = f_2$ and for all $x \in E$, $\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) = \alpha_2\left(\begin{smallmatrix}\mu_2(x)\\ \nu_2(x)\end{smallmatrix}x\right)$, then $\alpha_1$and α_2 is called equal *ifpifs*-sets and is denoted by $\alpha_1 = \alpha_2$.

Proposition 2.9. (Karaaslan, 2016) Let $\alpha, \alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. Then,

i. $\alpha = \alpha$

ii. $\alpha_1 = \alpha_2 \Rightarrow \alpha_2 = \alpha_1$

iii. $[\alpha_1 = \alpha_2 \wedge \alpha_2 = \alpha_3] \Rightarrow \alpha_1 = \alpha_3$

iv. $[\alpha_1 \,\tilde{\subseteq}\, \alpha_2 \wedge \alpha_2 \,\tilde{\subseteq}\, \alpha_1] \Leftrightarrow \alpha_1 = \alpha_2$

Note 2.2. From Proposition 2.7 and 2.8, it can be seen that the equality relation is an equivalence relation, and the inclusion relation is a partial ordering relation.

Definition 2.14. (Karaaslan, 2016) Let $\alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. If $f_3 \coloneqq f_1 \tilde{\cup} f_2$ and for all $x \in E$, $\alpha_3\left(\begin{smallmatrix}\mu_3(x)\\ \nu_3(x)\end{smallmatrix}x\right) \coloneqq \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) \tilde{\cup} \alpha_2\left(\begin{smallmatrix}\mu_2(x)\\ \nu_2(x)\end{smallmatrix}x\right)$, then α_3 is called union of α_1 and α_2 and is denoted by $\alpha_1 \tilde{\cup} \alpha_2$.

Definition 2.15. (Karaaslan, 2016) Let $\alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. If $f_3 \coloneqq f_1 \tilde{\cap} f_2$ and for all $x \in E$, $\alpha_3\left(\begin{smallmatrix}\mu_3(x)\\ \nu_3(x)\end{smallmatrix}x\right) \coloneqq \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) \tilde{\cap} \alpha_2\left(\begin{smallmatrix}\mu_2(x)\\ \nu_2(x)\end{smallmatrix}x\right)$, then α_3 is called intersection of α_1 and α_2 and is denoted by $\alpha_1 \tilde{\cap} \alpha_2$.

Proposition 2.10. (Karaaslan, 2016) Let $\alpha, \alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. Then,

i. $\alpha \tilde{\cup} \alpha = \alpha$ and $\alpha \tilde{\cap} \alpha = \alpha$

ii. $\alpha \tilde{\cup} \tilde{0} = \alpha$ and $\alpha \tilde{\cap} \tilde{0} = \tilde{0}$

iii. $\alpha \tilde{\cup} \tilde{1} = \tilde{1}$ and $\alpha \tilde{\cap} \tilde{1} = \alpha$

iv. $\alpha_1 \tilde{\cup} \alpha_2 = \alpha_2 \tilde{\cup} \alpha_1$ and $\alpha_1 \tilde{\cap} \alpha_2 = \alpha_2 \tilde{\cap} \alpha_1$

v. $(\alpha_1 \tilde{\cup} \alpha_2) \tilde{\cup} \alpha_3 = \alpha_1 \tilde{\cup} (\alpha_2 \tilde{\cup} \alpha_3)$ and $(\alpha_1 \tilde{\cap} \alpha_2) \tilde{\cap} \alpha_3 = \alpha_1 \tilde{\cap} (\alpha_2 \tilde{\cap} \alpha_3)$

vi. $\alpha_1 \tilde{\cup} (\alpha_2 \tilde{\cap} \alpha_3) = (\alpha_1 \tilde{\cup} \alpha_2) \tilde{\cap} (\alpha_1 \tilde{\cup} \alpha_3)$ and $\alpha_1 \tilde{\cap} (\alpha_2 \tilde{\cup} \alpha_3) = (\alpha_1 \tilde{\cap} \alpha_2) \tilde{\cup} (\alpha_1 \tilde{\cap} \alpha_3)$

Definition 2.16. (Karaaslan, 2016) Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. If $f_2 \coloneqq f_1^{\tilde{c}}$ and for all $x \in E$, $\alpha_2\left(\begin{smallmatrix}\nu_2(x)\\ \mu_2(x)\end{smallmatrix}x\right) \coloneqq \left(\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right)\right)^{\tilde{c}}$, then α_2 is called complement of α_1 and is denoted by $\alpha_1^{\tilde{c}}$. Here, for all $x \in E$, $\left(\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right)\right)^{\tilde{c}} = \alpha_1^{\tilde{c}}\left(\begin{smallmatrix}\nu_1(x)\\ \mu_1(x)\end{smallmatrix}x\right)$.

Proposition 2.11. (Karaaslan, 2016) Let $\alpha \in IFPIFS_E(U)$. Then,

i. $(\alpha^{\tilde{c}})^{\tilde{c}} = \alpha$

ii. $\tilde{0}^{\tilde{c}} = \tilde{1}$

Proposition 2.12. (Arslan, 2019) Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then,

i. $\alpha_1 \tilde{\subseteq} \alpha_2 \Rightarrow \alpha_2^{\tilde{c}} \tilde{\subseteq} \alpha_1^{\tilde{c}}$

ii. $\alpha_1 \tilde{\subseteq} \alpha_2 \Rightarrow \alpha_1 \tilde{\cup} \alpha_2 = \alpha_2$

iii. $\alpha_1 \tilde{\subseteq} \alpha_2 \Rightarrow \alpha_1 \tilde{\cap} \alpha_2 = \alpha_1$

Proposition 2.13. (Karaaslan, 2016) Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then, the following De Morgan's laws are valid.

i. $(\alpha_1 \tilde{\cup} \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \tilde{\cap} \alpha_2^{\tilde{c}}$

ii. $(\alpha_1 \tilde{\cap} \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \tilde{\cup} \alpha_2^{\tilde{c}}$

Definition 2.17. (Karaaslan and Karataş, 2016) Let $\alpha_1 \in IFPIFS_{E_1}(U)$, $\alpha_2 \in IFPIFS_{E_2}(U)$, and $\alpha_3 \in IFPIFS_{E_1 \times E_2}(U)$. If

$$\mu_3(x, y) \coloneqq \min\{\mu_1(x), \mu_2(y)\},$$

$$\nu_3(x,y) \coloneqq \max\{\nu_1(x), \nu_2(y)\},$$

and

$$\alpha_3\left(\begin{smallmatrix}\mu_3(x,y)\\ \nu_3(x,y)\end{smallmatrix}(x,y)\right) \coloneqq \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) \widetilde{\cap}\, \alpha_2\left(\begin{smallmatrix}\mu_2(y)\\ \nu_2(y)\end{smallmatrix}y\right)$$

then α_3 is called and-product of α_1 and α_2 and is denoted by $\alpha_1 \wedge \alpha_2$.

Definition 2.18. (Karaaslan and Karataş, 2016) Let $\alpha_1 \in IFPIFS_{E_1}(U)$, $\alpha_2 \in IFPIFS_{E_2}(U)$, and $\alpha_3 \in IFPIFS_{E_1 \times E_2}(U)$. If

$$\mu_3(x,y) \coloneqq \max\{\mu_1(x), \mu_2(y)\},$$

$$\nu_3(x,y) \coloneqq \min\{\nu_1(x), \nu_2(y)\},$$

and

$$\alpha_3\left(\begin{smallmatrix}\mu_3(x,y)\\ \nu_3(x,y)\end{smallmatrix}(x,y)\right) \coloneqq \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) \widetilde{\cup}\, \alpha_2\left(\begin{smallmatrix}\mu_2(y)\\ \nu_2(y)\end{smallmatrix}y\right)$$

then α_3 is called or-product of α_1 and α_2 and is denoted by $\alpha_1 \vee \alpha_2$.

Proposition 2.14. (Karaaslan and Karataş, 2016) Let $\alpha_1, \alpha_2, \alpha_3$ be three *ifpifs*-sets over U. Then,

i. $(\alpha_1 \vee \alpha_2) \vee \alpha_3 = \alpha_1 \vee (\alpha_2 \vee \alpha_3)$

ii. $(\alpha_1 \wedge \alpha_2) \wedge \alpha_3 = \alpha_1 \wedge (\alpha_2 \wedge \alpha_3)$

Note 2.3. It must be noted that and-product and or-product of *ifpifs*-sets are not commutative and distributive.

Proposition 2.15. (Karaaslan and Karataş, 2016) Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then, the following De Morgan's laws are valid.

i. $(\alpha_1 \vee \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \wedge \alpha_2^{\tilde{c}}$

ii. $(\alpha_1 \wedge \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \vee \alpha_2^{\tilde{c}}$

3. New Operations on *if*-sets and *ifpifs*-sets

In this section, we introduce new operations on *if*-sets (Atanassov, 1986) and *ifpifs*-sets (Karaaslan, 2016) and investigate some of their basic properties. This Section is a part of the second author's master's thesis.

Definition 3.1. Let $f \in IF(E)$. For all $x \in E$, if $\mu(x) = \lambda$ and $\nu(x) = \varepsilon$, then f is called (λ, ε)-*if*-set and is denoted by $\begin{smallmatrix}\lambda\\ \varepsilon\end{smallmatrix}f$.

In some problems, ignoring some of the $f(x)$ values for an $f \in IF(E)$ may be necessary or facilitating for the solution. However, by ignoring some of $f(x)$ values with known the restriction of f, it is not always possible to obtain an *if*-set on E. In this case, some difficulties can appear in the expressions and applications of operations defined on *if*-sets. Therefore, special-restriction can be given as follows:

Definition 3.2. Let $f, f_1 \in IF(E)$ and $A \subseteq E$. Then Af_1-restriction of f, denoted by f_{Af_1}, is defined by

$$\mu_{Af_1}(x) = \begin{cases} \mu(x), & x \in A \\ \mu_1(x), & x \in E\backslash A \end{cases}$$

and

$$\nu_{Af_1}(x) = \begin{cases} \nu(x), & x \in A \\ \nu_1(x), & x \in E\backslash A \end{cases}$$

Definition 3.3. Let $f_1, f_2 \in IF(E)$. If $f_1 \,\widetilde{\subseteq}\, f_2$ and $f_1 \neq f_2$, then f_1 is called a proper subset of f_2 and is denoted by $f_1 \,\widetilde{\subsetneq}\, f_2$.

Definition 3.4. Let $f_1, f_2, f_3 \in IF(E)$. For all $x \in E$, if $\mu_3(x) \coloneqq \min\{\mu_1(x), \nu_2(x)\}$ and $\nu_3(x) \coloneqq \max\{\nu_1(x), \mu_2(x)\}$, then f_3 is called difference between f_1 and f_2 and is denoted by $f_1 \tilde{\setminus} f_2$.

Proposition 3.1. Let $f, f_1, f_2 \in IF(E)$. Then,

i. $f \tilde{\setminus} 0_E = f$

ii. $f \tilde{\setminus} 1_E = 0_E$

iii. $1_E \tilde{\setminus} f = f^{\tilde{c}}$

iv. $f_1 \tilde{\setminus} f_2 = f_1 \,\widetilde{\cap}\, f_2^{\tilde{c}}$

Note 3.1. It must be noted that on *if*-sets, the difference operation is not commutative and associative.

Definition 3.5. Let $f_1, f_2, f_3 \in IF(E)$. For all $x \in E$, if $\mu_3(x) \coloneqq \max\{\min\{\mu_1(x), \nu_2(x)\}, \min\{\nu_1(x), \mu_2(x)\}\}$ and $\nu_3(x) \coloneqq \min\{\max\{\mu_1(x), \nu_2(x)\}, \max\{\nu_1(x), \mu_2(x)\}\}$, then f_3 is called symmetric difference between f_1 and f_2 and is denoted by $f_1 \tilde{\Delta} f_2$.

Proposition 3.2. Let $f, f_1, f_2 \in IF(E)$. Then,

i. $f \tilde{\Delta} 0_E = f$

ii. $f \tilde{\Delta} 1_E = f^{\tilde{c}}$

iii. $f_1 \tilde{\Delta} f_2 = f_2 \tilde{\Delta} f_1$

iv. $f_1 \tilde{\Delta} f_2 = (f_1 \tilde{\setminus} f_2) \,\widetilde{\cup}\, (f_2 \tilde{\setminus} f_1)$

Proof. Let $f_1, f_2 \in IF(E)$. Then,

$$\begin{aligned} f_1 \tilde{\Delta} f_2 &= \left\{ \begin{matrix} \max\{\min\{\mu_1(x), \nu_2(x)\}, \min\{\nu_1(x), \mu_2(x)\}\} \\ \min\{\max\{\mu_1(x), \nu_2(x)\}, \max\{\nu_1(x), \mu_2(x)\}\} \end{matrix} x : x \in E \right\} \\ &= \left\{ \begin{matrix} \min\{\mu_1(x), \nu_2(x)\} \\ \max\{\mu_1(x), \nu_2(x)\} \end{matrix} x : x \in E \right\} \,\widetilde{\cup}\, \left\{ \begin{matrix} \min\{\nu_1(x), \mu_2(x)\} \\ \max\{\nu_1(x), \mu_2(x)\} \end{matrix} x : x \in E \right\} \\ &= \left(\left\{ \begin{matrix} \mu_1(x) \\ \nu_1(x) \end{matrix} x : x \in E \right\} \tilde{\setminus} \left\{ \begin{matrix} \mu_2(x) \\ \nu_2(x) \end{matrix} x : x \in E \right\} \right) \,\widetilde{\cup}\, \left(\left\{ \begin{matrix} \mu_2(x) \\ \nu_2(x) \end{matrix} x : x \in E \right\} \tilde{\setminus} \left\{ \begin{matrix} \mu_1(x) \\ \nu_1(x) \end{matrix} x : x \in E \right\} \right) \\ &= (f_1 \tilde{\setminus} f_2) \,\widetilde{\cup}\, (f_2 \tilde{\setminus} f_1) \end{aligned}$$

Note 3.2. It must be noted that the symmetric difference operation mentioned above is not associative. Also, the equation $(A\backslash B) \cup (B\backslash A) = (A \cup B)\backslash(A \cap B)$ provided in classical sets is not valid in *if*-sets. That is, the equation $f_1 \tilde{\Delta} f_2 = (f_1 \,\widetilde{\cup}\, f_2) \tilde{\setminus} (f_1 \,\widetilde{\cap}\, f_2)$ is not always valid.

Definition 3.6. Let $f_1, f_2 \in IF(E)$. If $f_1 \,\widetilde{\cap}\, f_2 = 0_E$, then f_1 and f_2 are called disjoint *if*-sets.

Definition 3.7. Let $\alpha \in IFPIFS_E(U)$. If $f = {}^{\lambda}_{\varepsilon}f$ and for all $x \in E$, $\alpha\left({}^{\lambda}_{\varepsilon}x\right) = {}^{\lambda}_{\varepsilon}f$, then α is called (λ, ε)-*ifpifs*-set and is denoted by ${}^{\lambda}_{\varepsilon}\alpha$.

Definition 3.8. Let $\alpha, \alpha_1 \in IFPIFS_E(U)$ and $A \subseteq E$. Then, $A\alpha_1$ restriction of α, denoted by $\alpha_{A\alpha_1}$, is defined by

$$\mu_{Af_1}(x) = \begin{cases} \mu(x), & x \in A \\ \mu_1(x), & x \in E \backslash A \end{cases}$$

$$\nu_{Af_1}(x) = \begin{cases} \nu(x), & x \in A \\ \nu_1(x), & x \in E \backslash A \end{cases}$$

and

$$\alpha_{A\alpha_1}\left({}^{\mu_{Af_1}(x)}_{\nu_{Af_1}(x)}x\right) \coloneqq \begin{cases} \alpha\left({}^{\mu(x)}_{\nu(x)}x\right), & x \in A \\ \alpha_1\left({}^{\mu_1(x)}_{\nu_1(x)}x\right), & x \in E \backslash A \end{cases}$$

Example 3.1. Let us consider the *ifpifs*-set α provided in Example 2.2, $A = \{x_2\}$, and $\alpha_1 \in IFPIFS_E(U)$ such that

$$\alpha_1 = \{({}^{0.4}_{0.2}x_1, \{{}^{0.1}_{0.6}u_1, {}^{0.6}_{0.1}u_2, {}^{1}_{0}u_3\}), ({}^{0.6}_{0}x_2, \{{}^{0.7}_{0.2}u_2, {}^{0.9}_{0}u_4\}), ({}^{0.1}_{0.1}x_3, \{{}^{0.8}_{0.2}u_1, {}^{0.3}_{0.5}u_2, {}^{0}_{0.8}u_4\})\}$$

Then,

$$\alpha_{A\alpha_1} = \{({}^{0.4}_{0.2}x_1, \{{}^{0.1}_{0.6}u_1, {}^{0.6}_{0.1}u_2, {}^{1}_{0}u_3\}), ({}^{0.8}_{0.2}x_2, \{{}^{0.6}_{0.4}u_1, {}^{0.8}_{0.2}u_3, {}^{0.7}_{0.2}u_4\}), ({}^{0.1}_{0.1}x_3, \{{}^{0.8}_{0.2}u_1, {}^{0.3}_{0.5}u_2, {}^{0}_{0.8}u_4\})\}$$

Definition 3.9. Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. If $f_1 \tilde{\subsetneq} f_2$ and for all $x \in E$, $\alpha_1\left({}^{\mu_1(x)}_{\nu_1(x)}x\right) \tilde{\subsetneq} \alpha_2\left({}^{\mu_2(x)}_{\nu_2(x)}x\right)$, then α_1 is called a proper subset of α_2 and is denoted by $\alpha_1 \tilde{\subsetneq} \alpha_2$.

Definition 3.10. Let $\alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. If $f_3 \coloneqq f_1 \tilde{\setminus} f_2$ and for all $x \in E$, $\alpha_3\left({}^{\mu_3(x)}_{\nu_3(x)}x\right) \coloneqq \alpha_1\left({}^{\mu_1(x)}_{\nu_1(x)}x\right) \tilde{\setminus} \alpha_2\left({}^{\mu_2(x)}_{\nu_2(x)}x\right)$, then α_3 is called difference between α_1 and α_2 and is denoted by $\alpha_1 \tilde{\setminus} \alpha_2$.

Proposition 3.3. Let $\alpha, \alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then,

i. $\alpha \tilde{\setminus} \tilde{0} = \alpha$

ii. $\alpha \tilde{\setminus} \tilde{1} = \tilde{0}$

iii. $\tilde{1} \tilde{\setminus} \alpha = \alpha^{\tilde{c}}$

iv. $\alpha_1 \tilde{\setminus} \alpha_2 = \alpha_1 \tilde{\cap} \alpha_2^{\tilde{c}}$

Note 3.3. It must be noted that on *ifpifs*-sets, the difference operation is not commutative and associative.

Definition 3.11. Let $\alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. If $f_3 \coloneqq f_1 \tilde{\Delta} f_2$ and for all $x \in E$, $\alpha_3\left({}^{\mu_3(x)}_{\nu_3(x)}x\right) \coloneqq \alpha_1\left({}^{\mu_1(x)}_{\nu_1(x)}x\right) \tilde{\Delta}\, \alpha_2\left({}^{\mu_2(x)}_{\nu_2(x)}x\right)$, then α_3 is called symmetric difference between α_1 and α_2 and is denoted by $\alpha_1 \tilde{\Delta}\, \alpha_2$.

Proposition 3.4. Let $\alpha, \alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then,

i. $\alpha \tilde{\Delta} \tilde{0} = \alpha$

ii. $\alpha\widetilde{\Delta}\tilde{1} = \alpha^{\tilde{c}}$

iii. $\alpha_1\widetilde{\Delta}\alpha_2 = \alpha_2\widetilde{\Delta}\alpha_1$

iv. $\alpha_1\widetilde{\Delta}\alpha_2 = (\alpha_1\tilde{\setminus}\alpha_2)\ \widetilde{\cup}\ (\alpha_2\tilde{\setminus}\alpha_1)$

Proof. Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then, from Proposition 3.2, because $f_1, f_2 \in IF(E)$, $f_1\widetilde{\Delta}f_2 = (f_1\tilde{\setminus}f_2)\ \widetilde{\cup}\ (f_2\tilde{\setminus}f_1)$ and for all $x \in E$,

$$\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right)\widetilde{\Delta}\alpha_2\left(\begin{smallmatrix}\mu_2(x)\\ \nu_2(x)\end{smallmatrix}x\right) = \left(\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right)\tilde{\setminus}\alpha_2\left(\begin{smallmatrix}\mu_2(x)\\ \nu_2(x)\end{smallmatrix}x\right)\right)\widetilde{\cup}\left(\alpha_2\left(\begin{smallmatrix}\mu_2(x)\\ \nu_2(x)\end{smallmatrix}x\right)\tilde{\setminus}\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right)\right),$$

$\alpha_1\widetilde{\Delta}\alpha_2 = (\alpha_1\tilde{\setminus}\alpha_2)\ \widetilde{\cup}\ (\alpha_2\tilde{\setminus}\alpha_1)$ is obtained.

Note 3.4. It must be noted that on *ifpifs*-sets, the symmetric difference operation is not associative. In addition, the equation $(A\setminus B) \cup (B\setminus A) = (A \cup B)\setminus(A \cap B)$ provided in classical sets is not valid in *ifpifs*-sets. That is, the equation $\alpha_1\widetilde{\Delta}\alpha_2 = (\alpha_1\ \widetilde{\cup}\ \alpha_2)\tilde{\setminus}(\alpha_1\ \widetilde{\cap}\ \alpha_2)$ is not always valid.

Example 3.2. Let $U = \{u_1, u_2, u_3\}$ and $E = \{x_1, x_2\}$,

$$\alpha_1 = \{(\tbinom{0.5}{0.2}x_1, \{\tbinom{0.2}{0.4}u_1, \tbinom{0.3}{0.3}u_2, \tbinom{0.8}{0.2}u_3\}), (\tbinom{0.2}{0.1}x_2, \{\tbinom{0.2}{0.7}u_1, \tbinom{0.4}{0.6}u_2, \tbinom{1}{0}u_3\})\},$$

and

$$\alpha_2 = \left\{\left(\tbinom{0.5}{0.5}x_1, \{\tbinom{0.5}{0.3}u_1, \tbinom{0.4}{0.1}u_2, \tbinom{1}{0}u_3\}\right), (\tbinom{0.9}{0}x_2, \{\tbinom{0.2}{0.5}u_1, \tbinom{0.8}{0.1}u_2, \tbinom{0.5}{0.2}u_3\})\right\}$$

Then,

$$\alpha_1\tilde{\setminus}\alpha_2 = \left\{\left(\tbinom{0.5}{0.5}x_1, \{\tbinom{0.2}{0.5}u_1, \tbinom{0.1}{0.4}u_2\}\right), (\tbinom{0}{0.9}x_2, \{\tbinom{0.2}{0.7}u_1, \tbinom{0.1}{0.8}u_2, \tbinom{0.2}{0.5}u_3\})\right\}$$

and

$$\alpha_1\widetilde{\Delta}\alpha_2 = \left\{\left(\tbinom{0.5}{0.5}x_1, \{\tbinom{0.4}{0.3}u_1, \tbinom{0.3}{0.3}u_2, \tbinom{0.2}{0.8}u_3\}\right), (\tbinom{0.1}{0.2}x_2, \{\tbinom{0.2}{0.5}u_1, \tbinom{0.6}{0.4}u_2, \tbinom{0.2}{0.5}u_3\})\right\}$$

Definition 3.12. Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. If $\alpha_1\ \widetilde{\cap}\ \alpha_2 = \tilde{0}$, then α_1 and α_2 are called disjoint *ifpifs*-sets.

Definition 3.13. Let $\alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$ and $A \subseteq E$. If

$$\mu_3(x) \coloneqq \begin{cases}\max\left\{\mu_1(x), \min\limits_{y\in A}\{\mu_2(y)\}\right\}, & x \in A\\ \mu_1(x), & x \in E\setminus A\end{cases}$$

$$\nu_3(x) \coloneqq \begin{cases}\min\left\{\nu_1(x), \max\limits_{y\in A}\{\nu_2(y)\}\right\}, & x \in A\\ \nu_1(x), & x \in E\setminus A\end{cases}$$

and

$$\alpha_3\left(\begin{smallmatrix}\mu_3(x)\\ \nu_3(x)\end{smallmatrix}x\right) \coloneqq \begin{cases}\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right)\widetilde{\cup}\left(\widetilde{\cap}_{y\in A}\ \alpha_2\left(\begin{smallmatrix}\mu_2(y)\\ \nu_2(y)\end{smallmatrix}y\right)\right), & x \in A\\ \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right), & x \in E\setminus A\end{cases}$$

then α_3 is called A-relative union of α_1 and α_2 and is denoted by $\alpha_1\ \widetilde{\cup}_A^r\ \alpha_2$. Here, for brevity, "relative union" can be used instead of "E-relative union" and denoted $\alpha_1\ \widetilde{\cup}^r\ \alpha_2$.

Definition 3.14. Let $\alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$ and $A \subseteq E$. If

$$\mu_3(x) \coloneqq \begin{cases} \min\left\{\mu_1(x), \max\limits_{y\in A}\{\mu_2(y)\}\right\}, & x \in A \\ \mu_1(x), & x \in E\backslash A \end{cases}$$

$$\nu_3(x) \coloneqq \begin{cases} \max\left\{\nu_1(x), \min\limits_{y\in A}\{\nu_2(y)\}\right\}, & x \in A \\ \nu_1(x), & x \in E\backslash A \end{cases}$$

and

$$\alpha_3\left(\begin{smallmatrix}\mu_3(x)\\ \nu_3(x)\end{smallmatrix}x\right) \coloneqq \begin{cases} \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) \widetilde{\cap} \left(\widetilde{\cup}_{y\in A}\, \alpha_2\left(\begin{smallmatrix}\mu_2(y)\\ \nu_2(y)\end{smallmatrix}y\right)\right), & x \in A \\ \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right), & x \in E\backslash A \end{cases}$$

then α_3 is called A-relative intersection of α_1 and α_2 and is denoted by $\alpha_1 \,\widetilde{\cap}_A^r\, \alpha_2$. Here, for brevity, "relative intersection" can be used instead of "E-relative intersection" and denoted $\alpha_1 \,\widetilde{\cap}^r\, \alpha_2$.

Definition 3.15. Let $\alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$ and $A \subseteq E$. If

$$\mu_3(x) \coloneqq \begin{cases} \min\left\{\mu_1(x), \min\limits_{y\in A}\{\nu_2(y)\}\right\}, & x \in A \\ \mu_1(x), & x \in E\backslash A \end{cases}$$

$$\nu_3(x) \coloneqq \begin{cases} \max\left\{\nu_1(x), \max\limits_{y\in A}\{\mu_2(y)\}\right\}, & x \in A \\ \nu_1(x), & x \in E\backslash A \end{cases}$$

and

$$\alpha_3\left(\begin{smallmatrix}\mu_3(x)\\ \nu_3(x)\end{smallmatrix}x\right) \coloneqq \begin{cases} \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right) \widetilde{\setminus} \left(\widetilde{\cap}_{y\in A}\, \alpha_2\left(\begin{smallmatrix}\mu_2(y)\\ \nu_2(y)\end{smallmatrix}y\right)\right), & x \in A \\ \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\ \nu_1(x)\end{smallmatrix}x\right), & x \in E\backslash A \end{cases}$$

then α_3 is called A-relative difference between α_1 and α_2 and is denoted by $\alpha_1 \widetilde{\setminus}_A^r \alpha_2$. Here, for brevity, "relative difference" can be used instead of "E-relative difference" and denoted $\alpha_1 \widetilde{\setminus}^r \alpha_2$.

Proposition 3.5. Let $\alpha, \alpha_1, \alpha_2, \alpha_3 \in IFPIFS_E(U)$. Then,

i. $\alpha \,\widetilde{\cup}_A^r\, \alpha = \alpha$ and $\alpha \,\widetilde{\cap}_A^r\, \alpha = \alpha$

ii. $\alpha \,\widetilde{\cup}_A^r\, \tilde{0} = \alpha$ and $\tilde{0} \,\widetilde{\cap}_A^r\, \alpha = \tilde{0}$

iii. $\tilde{1} \,\widetilde{\cup}_A^r\, \alpha = \tilde{1}$ and $\alpha \,\widetilde{\cap}_A^r\, \tilde{1} = \alpha$

iv. $(\alpha_1 \,\widetilde{\cup}_A^r\, \alpha_2) \,\widetilde{\cup}_A^r\, \alpha_3 = \alpha_1 \,\widetilde{\cup}_A^r\, (\alpha_2 \,\widetilde{\cup}_A^r\, \alpha_3)$ and $(\alpha_1 \,\widetilde{\cap}_A^r\, \alpha_2) \,\widetilde{\cap}_A^r\, \alpha_3 = \alpha_1 \,\widetilde{\cap}_A^r\, (\alpha_2 \,\widetilde{\cap}_A^r\, \alpha_3)$

Note 3.5. It must be noted that the relative union and relative intersection of *ifpifs*-sets are not commutative and distributive.

Example 3.3. Let us consider the *ifpifs*-sets α_1 and α_2 provided in Example 3.2 and $A = \{x_1\}$. Then,

$$\alpha_1 \,\widetilde{\cup}_A^r\, \alpha_2 = \{(\begin{smallmatrix}0.5\\ 0.2\end{smallmatrix}x_1, \{\begin{smallmatrix}0.5\\ 0.3\end{smallmatrix}u_1, \begin{smallmatrix}0.4\\ 0.1\end{smallmatrix}u_2, \begin{smallmatrix}1\\ 0\end{smallmatrix}u_3\}), (\begin{smallmatrix}0.2\\ 0.1\end{smallmatrix}x_2, \{\begin{smallmatrix}0.2\\ 0.7\end{smallmatrix}u_1, \begin{smallmatrix}0.4\\ 0.6\end{smallmatrix}u_2, \begin{smallmatrix}1\\ 0\end{smallmatrix}u_3\})\}$$

and

$$\alpha_1 \,\widetilde{\cap}^r\, \alpha_2 = \{\left(\begin{smallmatrix}0.5\\0.2\end{smallmatrix}\right)x_1, \{\left(\begin{smallmatrix}0.2\\0.4\end{smallmatrix}\right)u_1, \left(\begin{smallmatrix}0.3\\0.3\end{smallmatrix}\right)u_2, \left(\begin{smallmatrix}0.8\\0.2\end{smallmatrix}\right)u_3\}), (\left(\begin{smallmatrix}0.2\\0.1\end{smallmatrix}\right)x_2, \{\left(\begin{smallmatrix}0.2\\0.7\end{smallmatrix}\right)u_1, \left(\begin{smallmatrix}0.4\\0.6\end{smallmatrix}\right)u_2, \left(\begin{smallmatrix}1\\0\end{smallmatrix}\right)u_3\})\}$$

Proposition 3.6. Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then, the following De Morgan's laws are valid.

i. $(\alpha_1 \,\widetilde{\cup}_A^r\, \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \,\widetilde{\cap}_A^r\, \alpha_2^{\tilde{c}}$

ii. $(\alpha_1 \,\widetilde{\cap}_A^r\, \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \,\widetilde{\cup}_A^r\, \alpha_2^{\tilde{c}}$

Proof. Let $\alpha_1, \alpha_2 \in IFPIFS_E(U)$. Then,

$$\begin{aligned}
(\alpha_1 \,\widetilde{\cup}_A^r\, \alpha_2)^{\tilde{c}} &= \left\{\left\langle\begin{pmatrix}\max\{\mu_1(x), \min\limits_{y\in A}\{\mu_2(y)\}\}\\ \min\{\nu_1(x), \max\limits_{y\in A}\{\nu_2(y)\}\}\end{pmatrix}x, \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\\nu_1(x)\end{smallmatrix}\right)x\right) \,\widetilde{\cup}\, \left(\widetilde{\cap}_{y\in A}\ \alpha_2\left(\begin{smallmatrix}\mu_2(y)\\\nu_2(y)\end{smallmatrix}\right)y\right)\right\rangle, \quad x \in E\right\}^{\tilde{c}}\\
&= \left\{\left\langle\begin{pmatrix}\min\{\nu_1(x), \max\limits_{y\in A}\{\nu_2(y)\}\}\\ \max\{\mu_1(x), \min\limits_{y\in A}\{\mu_2(y)\}\}\end{pmatrix}x, \left(\alpha_1\left(\begin{smallmatrix}\mu_1(x)\\\nu_1(x)\end{smallmatrix}\right)x\right) \,\widetilde{\cup}\, \left(\widetilde{\cap}_{y\in A}\ \alpha_2\left(\begin{smallmatrix}\mu_2(y)\\\nu_2(y)\end{smallmatrix}\right)y\right)\right)^{\tilde{c}}\right\rangle, \quad x \in E\right\}\\
&= \left\{\left\langle\begin{pmatrix}\min\{\nu_1(x), \max\limits_{y\in A}\{\nu_2(y)\}\}\\ \max\{\mu_1(x), \min\limits_{y\in A}\{\mu_2(y)\}\}\end{pmatrix}x, \alpha_1^{\tilde{c}}\left(\begin{smallmatrix}\nu_1(x)\\\mu_1(x)\end{smallmatrix}\right)x\right) \,\widetilde{\cap}\, \left(\widetilde{\cup}_{y\in A}\ \alpha_2^{\tilde{c}}\left(\begin{smallmatrix}\nu_2(y)\\\mu_2(y)\end{smallmatrix}\right)y\right)\right\rangle, \quad x \in E\right\}\\
&= \alpha_1^{\tilde{c}} \,\widetilde{\cap}_A^r\, \alpha_2^{\tilde{c}}
\end{aligned}$$

Definition 3.16. Let $\alpha_1 \in IFPIFS_{E_1}(U)$, $\alpha_2 \in IFPIFS_{E_2}(U)$, and $\alpha_3 \in IFPIFS_{E_1\times E_2}(U)$. If

$$\mu_3(x,y) \coloneqq \min\{\mu_1(x), \nu_2(y)\}$$

$$\nu_3(x,y) \coloneqq \max\{\nu_1(x), \mu_2(y)\}$$

and

$$\alpha_3\left(\begin{smallmatrix}\mu_3(x,y)\\\nu_3(x,y)\end{smallmatrix}\right)(x,y)\Big) \coloneqq \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\\nu_1(x)\end{smallmatrix}\right)x \,\widetilde{\cap}\, \alpha_2^{\tilde{c}}\left(\begin{smallmatrix}\nu_2(y)\\\mu_2(y)\end{smallmatrix}\right)y\Big)$$

then α_3 is called andnot-product of α_1 and α_2 and is denoted by $\alpha_1 \,\overline{\wedge}\, \alpha_2$.

Definition 3.17. Let $\alpha_1 \in IFPIFS_{E_1}(U)$, $\alpha_2 \in IFPIFS_{E_2}(U)$, and $\alpha_3 \in IFPIFS_{E_1\times E_2}(U)$. If

$$\mu_3(x,y) \coloneqq \max\{\mu_1(x), \nu_2(y)\}$$

$$\nu_3(x,y) \coloneqq \min\{\nu_1(x), \mu_2(y)\}$$

and

$$\alpha_3\left(\begin{smallmatrix}\mu_3(x,y)\\\nu_3(x,y)\end{smallmatrix}\right)(x,y)\Big) \coloneqq \alpha_1\left(\begin{smallmatrix}\mu_1(x)\\\nu_1(x)\end{smallmatrix}\right)x \,\widetilde{\cup}\, \alpha_2^{\tilde{c}}\left(\begin{smallmatrix}\nu_2(y)\\\mu_2(y)\end{smallmatrix}\right)y\Big)$$

then α_3 is called ornot-product of α_1 and α_2 and is denoted by $\alpha_1 \,\underline{\vee}\, \alpha_2$.

Example 3.4. Let us consider the *ifpifs*-sets α_1 and α_2 provided in Example 3.2. Then,

$$\alpha_1 \,\overline{\wedge}\, \alpha_2 = \{\left(\begin{smallmatrix}0.5\\0.5\end{smallmatrix}\right)(x_1,x_1), \{\left(\begin{smallmatrix}0.2\\0.5\end{smallmatrix}\right)u_1, \left(\begin{smallmatrix}0.1\\0.4\end{smallmatrix}\right)u_2\}), (\left(\begin{smallmatrix}0\\0.9\end{smallmatrix}\right)(x_1,x_2), \{\left(\begin{smallmatrix}0.2\\0.4\end{smallmatrix}\right)u_1, \left(\begin{smallmatrix}0.1\\0.8\end{smallmatrix}\right)u_2, \left(\begin{smallmatrix}0.2\\0.5\end{smallmatrix}\right)u_3\}),$$

$$(\left(\begin{smallmatrix}0.2\\0.5\end{smallmatrix}\right)(x_2,x_1), \{\left(\begin{smallmatrix}0.2\\0.7\end{smallmatrix}\right)u_1, \left(\begin{smallmatrix}0.1\\0.6\end{smallmatrix}\right)u_2\}), (\left(\begin{smallmatrix}0\\0.9\end{smallmatrix}\right)(x_2,x_2), \{\left(\begin{smallmatrix}0.2\\0.7\end{smallmatrix}\right)u_1, \left(\begin{smallmatrix}0.1\\0.8\end{smallmatrix}\right)u_2, \left(\begin{smallmatrix}0.2\\0.5\end{smallmatrix}\right)u_3\})\}$$

Proposition 3.7. Let $\alpha_1 \in IFPIFS_{E_1}(U)$ and $\alpha_2 \in IFPIFS_{E_2}(U)$. Then, the following De Morgan's laws are valid.

i. $(\alpha_1 \underline{\vee} \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \,\overline{\wedge}\, \alpha_2^{\tilde{c}}$

ii. $(\alpha_1 \,\overline{\wedge}\, \alpha_2)^{\tilde{c}} = \alpha_1^{\tilde{c}} \,\underline{\vee}\, \alpha_2^{\tilde{c}}$

Proof. Let $\alpha_1 \in IFPIFS_{E_1}(U)$ and $\alpha_2 \in IFPIFS_{E_2}(U)$.Then,

$$\begin{aligned}
\left(\alpha_1 \underline{\vee} \alpha_2\right)^{\tilde{c}} &= \left\{\binom{\max\{\mu_1(x),\nu_2(y)\}}{\min\{\nu_1(x),\mu_2(y)\}}(x,y), \alpha_1\binom{\mu_1(x)}{\nu_1(x)}x\right) \tilde{\cup}\, \alpha_2\binom{\mu_2(y)}{\nu_2(y)}y\right) : (x,y) \in E_1 \times E_2\Bigg\}^{\tilde{c}} \\
&= \left\{\left(\binom{\min\{\nu_1(x),\mu_2(y)\}}{\max\{\mu_1(x),\nu_2(y)\}}(x,y), \left(\alpha_1\binom{\mu_1(x)}{\nu_1(x)}x\right) \tilde{\cup}\, \alpha_2\binom{\mu_2(y)}{\nu_2(y)}y\right)\right)^{\tilde{c}} : (x,y) \in E_1 \times E_2\right\} \\
&= \left\{\left(\binom{\min\{\nu_1(x),\mu_2(y)\}}{\max\{\mu_1(x),\nu_2(y)\}}(x,y), \alpha_1^{\tilde{c}}\binom{\nu_1(x)}{\mu_1(x)}x\right) \tilde{\cap}\, \alpha_2^{\tilde{c}}\binom{\nu_2(y)}{\mu_2(y)}y\right) : (x,y) \in E_1 \times E_2\right\} \\
&= \alpha_1^{\tilde{c}} \,\overline{\wedge}\, \alpha_2^{\tilde{c}}
\end{aligned}$$

Note 3.6. It must be noted that andnot-product and ornot-product of *ifpifs*-sets are not associative, commutative, and distributive.

4. A Soft Decision-Making Method: EA19/2

In this section, via *ifpifs*-sets, we propose a soft decision-making method denoted by EA19/2.

Step 1. Construct $\alpha_1, \alpha_2 \in IFPIFS_E(U)$

Step 2. For $A \subseteq E$, find the A-relative union/intersection/difference *ifpifs*-set α_3 of α_1 and α_2

Step 3. For $A \subseteq E$, find the A-relative union/intersection/difference *ifpifs*-set α_4 of α_2 and α_1

Step 4. Obtain sets $f^*: = \left\{\binom{\mu_f^*(u_j)}{\nu_f^*(u_j)}u_j : u_j \in U\right\}$ and $g^*: = \left\{\binom{\mu_g^*(u_j)}{\nu_g^*(u_j)}u_j : u_j \in U\right\}$.

Here, $\mu_f^*(u_j) \coloneqq \min\limits_{i \in I_{\alpha_3}}\{(\mu_3(x_i))\alpha_3(\mu_3(x_i))(u_j)\}$, $\nu_f^*(u_j): = \max\limits_{i \in I_{\alpha_3}}\{(\nu_3(x_i))\alpha_3(\nu_3(x_i))(u_j)\}$, $\mu_g^*(u_j) \coloneqq \min\limits_{i \in I_{\alpha_4}}\{(\mu_4(x_i))\alpha_4(\mu_4(x_i))(u_j)\}$, and $\nu_g^*(u_j): = \max\limits_{i \in I_{\alpha_4}}\{(\nu_4(x_i))\alpha_4(\nu_4(x_i))(u_j)\}$ such that $I_{\alpha_3} \coloneqq \{j : \mu_3(x_j) \neq 0 \wedge \nu_3(x_j) \neq 1\}$ and $I_{\alpha_4} \coloneqq \{j : \mu_4(x_j) \neq 0 \wedge \nu_4(x_j) \neq 1\}$.

Step 5. Obtain the decision set $\left\{\mu(u_k)u_k | u_k \in U\right\}$ such that $\mu(u_k) = \frac{\mu^*(u_k) + |\min\limits_i \mu^*(u_i)|}{\max\limits_i \mu^*(u_i) + |\min\limits_i \mu^*(u_i)|}$. Here, $\mu^*(u_k) = \max\{\mu_f^*(u_k), \mu_g^*(u_k)\} - \min\{\nu_f^*(u_k), \nu_g^*(u_k)\}$.

In Step 4, $\mu_3(x_i)$ and $\alpha_3(\mu_3(x_i))(u_j)$ indicate the membership value of the parameter x_i in α_3 and the membership value of alternative u_j in $\alpha_3\binom{\mu_3(x_i)}{\nu_3(x_i)}x_i\right)$, respectively. Similarly, $\nu_3(x_i)$ and $\alpha_3(\nu_3(x_i))(u_j)$ indicate the nonmembership value of the parameter x_i in α_3 and the nonmembership value of alternative u_j in $\alpha_3\binom{\mu_3(x_i)}{\nu_3(x_i)}x_i\right)$, respectively.

5. An Illustrative Example for EA19/2 in Recruitment Process

Assume that five candidates, denoted by $U = \{u_1, u_2, u_3, u_4, u_5\}$, have applied to two vacant positions announced by a company. Let the parameter set determined by the human resources unit of the company and a member of the board of directors appointed for this recruitment be $E = \{x_1, x_2, x_3\}$ such that $x_1 =$ "*experience*", $x_2 =$ "*technological competence*", and $x_3 =$ "*work ethic*". Also, let the *if*-sets over E determined by these two decision-makers be $\{{}^{0.8}_{0.1}x_1, {}^{0.4}_{0.6}x_2, {}^{0.7}_{0.2}x_3\}$ and $\{{}^{0.5}_{0.5}x_1, {}^{0.9}_{0}x_2, {}^{0.6}_{0.2}x_3\}$, respectively.

Step 1. Let two *ifpifs*-sets α_1 and α_2 constructed by the decision-makers are as follows:

$$\begin{aligned}\alpha_1 = \; & \{({}^{0.8}_{0.1}x_1, \{{}^{0.9}_{0}u_1, {}^{0.3}_{0.5}u_2, {}^{0}_{0.7}u_3, {}^{0.4}_{0.3}u_4, {}^{0.3}_{0.6}u_5\}),\\ & ({}^{0.4}_{0.6}x_2, \{{}^{0.3}_{0.3}u_1, {}^{0.7}_{0.1}u_2, {}^{0.5}_{0.2}u_3, {}^{0.8}_{0.1}u_4, {}^{0.6}_{0.1}u_5\}),\\ & ({}^{0.7}_{0.2}x_3, \{{}^{0.2}_{0.6}u_1, {}^{0.7}_{0.3}u_2, {}^{0.6}_{0.3}u_3, {}^{0.3}_{0.7}u_4, {}^{0.4}_{0.5}u_5\})\}\end{aligned}$$

and

$$\begin{aligned}\alpha_2 = \; & \{\left({}^{0.5}_{0.5}x_1, \{{}^{0.1}_{0.7}u_1, {}^{0.2}_{0.6}u_2, {}^{0.6}_{0.2}u_4, {}^{0.7}_{0.2}u_5\}\right),\\ & ({}^{0.9}_{0}x_2, \{{}^{0.6}_{0.1}u_1, {}^{0.9}_{0}u_2, {}^{0.5}_{0.3}u_3, {}^{1}_{0}u_4, {}^{0.2}_{0.1}u_5\}),\\ & \left({}^{0.6}_{0.2}x_3, \{{}^{0.8}_{0}u_1, {}^{0.5}_{0.5}u_2, {}^{0.4}_{0.6}u_3, {}^{0}_{0.7}u_4, {}^{0.6}_{0.2}u_5\}\right)\}\end{aligned}$$

Step 2. Relative union of α_1 and α_2 is obtained as follows:

$$\begin{aligned}\alpha_1 \,\tilde{\cup}^r\, \alpha_2 = \; & \{({}^{0.8}_{0.1}x_1, \{{}^{0.9}_{0}u_1, {}^{0.3}_{0.5}u_2, {}^{0}_{0.7}u_3, {}^{0.4}_{0.3}u_4, {}^{0.3}_{0.2}u_5\}),\\ & \left({}^{0.5}_{0.5}x_2, \{{}^{0.3}_{0.3}u_1, {}^{0.7}_{0.1}u_2, {}^{0.5}_{0.2}u_3, {}^{0.8}_{0.1}u_4, {}^{0.6}_{0.1}u_5\}\right),\\ & ({}^{0.7}_{0.2}x_3, \{{}^{0.2}_{0.6}u_1, {}^{0.7}_{0.3}u_2, {}^{0.6}_{0.3}u_3, {}^{0.3}_{0.7}u_4, {}^{0.4}_{0.2}u_5\})\}\end{aligned}$$

Step 3. Relative union of α_2 and α_1 is obtained as follows:

$$\begin{aligned}\alpha_2 \,\tilde{\cup}^r\, \alpha_1 = \; & \{\left({}^{0.5}_{0.5}x_1, \{{}^{0.2}_{0.6}u_1, {}^{0.3}_{0.5}u_2, {}^{0}_{0.7}u_3, {}^{0.6}_{0.2}u_4, {}^{0.7}_{0.2}u_5\}\right),\\ & ({}^{0.9}_{0}x_2, \{{}^{0.6}_{0.1}u_1, {}^{0.9}_{0}u_2, {}^{0.5}_{0.3}u_3, {}^{1}_{0}u_4, {}^{0.3}_{0.1}u_5\}),\\ & \left({}^{0.6}_{0.2}x_3, \{{}^{0.8}_{0}u_1, {}^{0.5}_{0.5}u_2, {}^{0.4}_{0.6}u_3, {}^{0.3}_{0.7}u_4, {}^{0.6}_{0.2}u_5\}\right)\}\end{aligned}$$

Step 4. f^* and g^* is obtained as follows:

$$f^* = \{{}^{0.14}_{0.15}u_1, {}^{0.24}_{0.06}u_2, {}^{0}_{0.1}u_3, {}^{0.21}_{0.14}u_4, {}^{0.24}_{0.05}u_5\}$$

and

$$g^* = \{{}^{0.1}_{0.3}u_1, {}^{0.15}_{0.25}u_2, {}^{0}_{0.35}u_3, {}^{0.18}_{0.14}u_4, {}^{0.27}_{0.1}u_5\}$$

Step 5. The decision set is obtained as follows:

$$\{{}^{0.28}u_1, {}^{0.88}u_2, {}^{0}u_3, {}^{0.53}u_4, {}^{1}u_5\}$$

The optimal ranking order of the five candidates is $u_3 \preccurlyeq u_1 \preccurlyeq u_4 \preccurlyeq u_2 \preccurlyeq u_5$. The results show that u_5 and u_2 are more suitable than the others for the two vacant positions. Thus, candidates u_5 and u_2 are selected for the positions announced by the company.

6. Conclusion

In this paper, we have proposed the concepts of restriction, difference, and the symmetric difference on *if*-sets. Moreover, on *ifpifs*-sets, we have suggested the concepts of restriction, difference, symmetric, relative union, relative intersection, and the relative difference. We then have constructed a new soft decision-making method, denoted by EA19/2, and given an application of EA19/2 to a recruitment process of a company. This application has shown that *ifpifs*-sets can be successfully applied to the problems associated with uncertainty in the real world. Moreover, to model certain further uncertainties, *ifpifs*-sets can be expanded to interval-valued intuitionistic fuzzy parameterized interval-valued intuitionistic fuzzy soft sets through the closed subintervals of $[0,1]$, and effective decision-making methods can be developed. In addition, in the future, theoretical and applied studies about various fields such as algebra and topology on the *ifpifs*-sets are necessary and worthwhile.

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The Use of Filamentous Algae In Biological Monitoring

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Abstract: Water pollution, along with freshwater scarcity, is a global environmental problem. In water bodies, the content of substances of anthropogenic origin increases, the toxicity of which for most aquatic organisms is already manifested in small concentrations. The greatest environmental danger is represented by heavy metals (HM). It is established that even essential metals such as copper, Nickel, zinc, cobalt in the accumulation in the aqueous medium are a potential threat to living systems. It is known that they are able to violate the integrity of physiological and biochemical processes, cause serious changes in metabolic reactions in hydrobionts. This is the basis for the use of many parameters of the state of the community of filamentous algae for biological monitoring. The ability of algae to accumulate HM indicates the possibility of their use for biotesting, monitoring, forecasting the level of pollution, as well as determining their role in the processes of self-purification.
Limited liability partnership (LLP) KAZZINC - one of the largest industrial enterprises of East Kazakhstan region. From Kazzinc to the Irtysh water flow should be in the following order: river Filippovka, Quiet, Ulba and the Irtysh. Semey (former Semipalatinsk) is a large city on the Irtysh, the water of which is taken by "SemeyVodokanal". In the laboratory we investigated the possibility of using filamentous algae (of ulothrix, Spirogyra, cladophora) as biological monitoring in the waters of the Semipalatinsk region. Since the main products of "Kazzinc" LLP are metals such as zinc, cadmium, lead and copper, in the laboratory of elemental analysis of the branch of "Institute of Radiation safety and ecology" of National nuclear center of the Republic of Kazakhstan the absorption capacity of filamentous algae in relation to zinc, copper, cadmium, iron and lead, as well as the residual concentration of heavy metals in the test water is determined. In idle test identifies such elements as Be, Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, Cd, Cs, Pb, and U. The concentrations of these elements were determined by inductively coupled plasma mass spectrometry (ICP - MS) on the Agilent 7700x instrument and atomic emission spectrometry (NPP – ISP) on the iCAP 6300.

Keywords: Filamentous algae, toxicity, heavy metals, Inductively Coupled Plasma Mass Spectrometry (ICP – MS), Atomic Emission Spectrometry (AES – ICP)

1. Introdiction

Currently, more and more attention is paid to the appearance in water bodies of substances of anthropogenic origin, toxic to most aquatic organisms in low concentrations. In terms of pollution, potential biological and environmental hazards, HMS are the most important. HM compounds entering the aquatic environment are immediately involved in a chain of various displacements and transformations under the influence of numerous factors. At the same time

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there are physical processes (mechanical mixing, deposition, adsorption and desorption), chemical (dissociation, hydrolysis, complexation, redox reactions), biological (absorption by living organisms, destruction and transformation involving enzymes and metabolites), geological (burial in bottom sediments and rock formation) (Rice and Gulyaeva 2003).
In the aquatic ecosystems of Semey region filamentous algae are not only the main primary producers of organic matter, but also can serve as biological indicators of the functioning of the phytoplankton community in water pollution. The advantage of using filamentous algae in their prevalence, they have a short life cycle, it allows you to assess the environmental consequences of anthropogenic factors.
The aim of the work was to study the possibility of using filamentous multicellular algae in biomonitoring pollution of Semey reservoirs with heavy metals. The objectives of the study included: to determine the absorption capacity of filamentous algae with respect to zinc, copper, cadmium, iron and lead, as well as to determine the residual concentration of heavy metals in the water under study, to calculate the mass fraction of HM salts, which was adsorbed by algae. To determine in a single sample of such elements as Be, Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, Cd, Cs, Pb, and U.

2. Material and Method

The concentrations of these elements were determined by inductively coupled plasma mass spectrometry (ICP – MS) on the Agilent 7700x instrument and by atomic emission spectrometry (AES – ICP) on the iCAP 6300 Duo instrument. All tests were carried out on the 3rd day of the test.

3. Results

Cultures of multicellular river algae of Semey reservoirs were used in the work. The sampling point was the village of Bobrovka, as this area is one of the polluted parts of the city. The experiments were carried out in Teflon, sealed glasses with a capacity of 250 ml with 100 ml of algae culture, in an autoclave at a temperature of 24 °C, humidity not exceeding 80%, pressure – (90-101) kPa. 3 samples of filamentous algae were taken, nitrates of heavy metals (Fe, Cu, Zn, Cd, Pb) were forcibly added. In the case of *Spirogyra* algae, the MPC of heavy metals in water exceeds 10 times. The concentration of forcibly added HMS in the case of *Spirogyra* is: T (Pb^{2+}) = 0.16 mg/l, T (Cd^{2+}) = 0.021 mg/l, T (Cu^{2+}) = 0.01 mg/l, T (Zn^{2+}) = 0.02 mg/l, T (Fe^{2+}) = 0.16 mg/l. in the case of *Ulotrix* algae, the MPC of heavy metals in water exceeds 10 to 50 times. The concentration of forcibly added HMS in the case of Ulotrix is: T (Pb^{2+}) = 1.28 mg/l, T (Cd^{2+}) = 0.06 mg/l, T (Cu^{2+}) = 0.02 mg/l, T (Zn^{2+}) = 0.1 mg/l, T (Fe^{2+}) = 1.6 mg/l. in the case of *Cladophora* algae, the MPC of heavy metals in water exceeds 50 to 100 times. The concentration of forcibly added HMS in the case of *Cladophora* is: T (Pb^{2+}) = 6.4 mg/l, T (Cd^{2+}) = 0.42 mg/l, T (Cu^{2+}) = 0.05 mg/l, T (Zn^{2+}) = 0.6 mg/ l, T (Fe^{2+}) = 6.43 mg/l.

The elemental analysis laboratory of the branch "Institute of Radiation safety and ecology" of the National nuclear center of the Republic of Kazakhstan determined the content of elements in filamentous algae, where Fe, Cu, Zn, Cd, Pb salts were forcibly added (Table 1), as well as the residual concentration of heavy metals in the test water (Table 2).

Table 1. The content of elements in filamentous algae (Fe, Cu, Zn, Cd, Pb salts were forcibly added)

The algae	Content of elements, mcg/l				
	Fe	Cu	Zn	Cd	Pb
Spirogyra	750000±120000	1200±170	8700±1300	280±30	1400±200
Ulotrix	870000±140000	1300±200	8000±1300	140±20	2300±300
Cladophora	630000±100000	1100±170	10000±1600	160±23	11000±1700

Table 2. Residual concentration of elements in water with algae (Fe, Cu, Zn, Cd, Pb salts were forcibly added)

The algae	Content of elements, mcg/l				
	Fe	Cu	Zn	Cd	Pb
Spirogyra	84260±11000	200±10	2107±100	144±21	366±21
Ulotrix	115277±10000	220±20	2526±23	42±12	742±42
Cladophora	90000±10000	846±20	1363±80	187±21	5700±300

Note: the extended measurement uncertainty shown in the table is calculated with a coverage factor of two, giving a confidence level of approximately 95%.
Experiments with heavy metals revealed different adsorption capacity of algae to a particular metal belonging to the species of the same taxonomic group.
According to the results (Table 3), that in different samples of algae can be seen, *Spirogyra* most accumulates Fe, Zn and Cd, *Ulotrix* most accumulates iron and copper, which is not physiologically necessary in large quantities, by adsorption on the mucous membranes of the colonies. *Cladophora* predominantly accumulates Fe, Zn and Pb. Data on the accumulation of heavy metals by macroalgae confirm their active participation in HM sedimentation.

Table 3. Adsorption of heavy metal ions by algae

The algae	Adsorbed mass fraction of heavy metal salts, %				
	Fe	Cu	Zn	Cd	Pb
Spirogyra	89.9	85.7	80.5	66.0	79.3
Ulotrix	88.3	85.5	76.0	77.0	75.6
Cladophora	87.5	56.5	88.0	46.0	66.0

Table 4 and 5 shows the results of quantitative analysis of algae in a blank sample and the convergence of measurements obtained by inductively coupled plasma mass spectrometry (ICP-MS) on the device Agilent 7700x and atomic emission spectrometry (AES – ICP) on the device iCAP 6300 Duo. Elements such as Be, Cr, Mn, Fe, Co, Ni, Cu, Zn, Sr, Cd, Cs, Pb, U. are defined.

Table 4. Elemental composition of filamentous algae in a blank sample

The algae	Content of elements, mcg/l					
	Be	Cr	Mn	Fe	Co	Ni
Spirogyra	0.04±0.01	0.03±0.01	1.33±0.02	2.02±0.02	0.20±0.01	2.33±0.02
Ulotrix	0.06±0.02	0.05±0.02	1.20±0.01	1.53±0.01	0.13±0.01	2.01±0.01
Cladophora	0.07±0.01	0.07±0.01	1.30±0.01	1.66±0.01	0.15±0.01	2.66±0.03

Table 5. Elemental composition of filamentous algae in a blank sample

The algae	Content of elements, mcg/l						
	Cu	Zn	Sr	Cd	Cs	Pb	U
Spirogyra	3.33±0.02	170.1± 9.1	1.20±0.02	0.06±0.01	0.03±0.01	1.43±0.01	0.03±0.01
Ulotrix	3.33±0.02	200.0±10.0	0.66±0.01	0.06±0.01	0.05±0.02	1.39+0.01	0.05±0.02
Cladophora	1.33±0.01	143.3±5.6	0.88±0.01	0.10±0.01	0.08±0.01	0.98±0.01	0.07±0.01

4. Conclusions

We found that algae have the ability to adsorb heavy metals and other toxic substances in high concentrations for only 3 days of the experiment (Table 3), which mainly proves that algae should not be in water contaminated with HM for more than 3 days. A high content of elements such as iron, manganese and zinc, a significant content of lead, copper and strontium were found in the blank sample. The remaining elements are contained in small quantities. It was revealed that the level of concentration of toxic metals in the blank sample of algae corresponds to the normalized indicators. According to the content of toxic elements in the studied samples, the conclusion was made about the favorable situation of fresh water bodies in the Semey region.

References

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