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Ecological status of Varna Bay through the state of phytoplankton, macrozoobenthos and macrophytes during the autumn of 2011

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Abstract. *The paper assessed the ecological status of Varna Bay during the autumn of 2011, according to the assessment of biotic components phytoplankton, macrozoobenthos and macrophytes in accordance with the requirements of the European Water Framework Directive WFD EU (2000). The state of Varna Bay is assessed as "good".*

Keywords: phytoplankton, macrozoobenthos, macrophytes, Varna bay, Black Sea, ecological status

Introduction

Phytoplankton communities dominate in the pelagic ecosystems, which cover 70% of the area of the globe. At sea and in the largest lakes (over 500 km^2) phytoplankton is the only photo-autotrophic primary producer (Reynolds, 2006). Phytoplankton plays a key role as an important element in the environmental assessment of the quality of coastal waters (WFD EU 2000).

Macrophytes are a major part of coastal biocenoses, creating new substrates and habitats for other organisms, involved as well in the primary production in water basins. Their sensitivity to changes in hydroclimate and their ability to concentrate on their thallus lots of elements makes them indicators of organic and technical pollution of the environment (Dimitrova-Konaklieva, 2000). Their role as bioindicators characterized them as reliable indicators for determining the ecological status of aquatic ecosystems. Long-term changes in the status of water bodies can be traced through the state of macrophyte communities.

The large catchment area of the Black Sea (it gathers the waters of Danube, Dnieper, Dniester and Buck Rivers) and its slow outflow (Kerch Strait and the Bosphorus) led to accumulation of large quantities of pollutants which made it one of the most polluted seas on Earth (Golemanski, 1998). The results are expressed in the frequent and massive blooms of phytoplankton, leading to hypooxide processes and disastrously affecting its biodiversity. Most vulnerable are the benthic organisms, particularly their attached forms. For this reason, some members of macro-zoobenthos are used as indicators of pollution.

Applying an ecosystem approach to the management of human activities allows for sustainable use of marine resources. This requires obtaining a good status of the marine ecosystems, continuous effective protection and conservation, and prevention of deterioration of the Black Sea biodiversity in times of global climate change. To achieve this goal we applied an environmental assessment (by biotic components: phytoplankton, benthic macroalgae and macrozoobenthos) of the status of Varna Bay during the autumn of 2011.

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Material and methods

Hydrobiological samples were collected for phytoplankton, macrophytes and macrozoobenthos in September, October and November 2011 from 5 stations located in Varna Bay and the adjacent marine areas (Galata–1mile) (Figure 1). Samples for phytoplankton and macrozoobenthos were collected on board R/V *Prof. Valkanov* and those for macrophytes – by scuba diving technique. Galata marine area (1mile) is often subjected to eutrophying impact of the water flowing out of Varna Lake (Report IFR, 2002).

Hydrographic parameters were measured using CTD-60 sensors for pressure, temperature, salinity and oxygen, fluorimetar (Mini back Scat I, Model: 1010P) for chlorophyll-a. Water body transparency was measured by Secchi disk at daylight from the sun-lit side of the vessel (Schloss, 2002).

For processing of phytoplankton, the sedimention method was used for concentration of samples (Morozova-Vodyanitskaya, 1954). Sampling was done with Nansen Bottles – 5 l, fixation with formalin (2%). A geometric method was applied to determine the biomass of microalgae. Cell volume was calculated using geometric formulas (Edler, 1979) and software Phytomar 2.0 (IFR-Varna).

To determine the ecological status according to the Biological Quality Element (BQE) phytoplankton, the indices of Shannon,

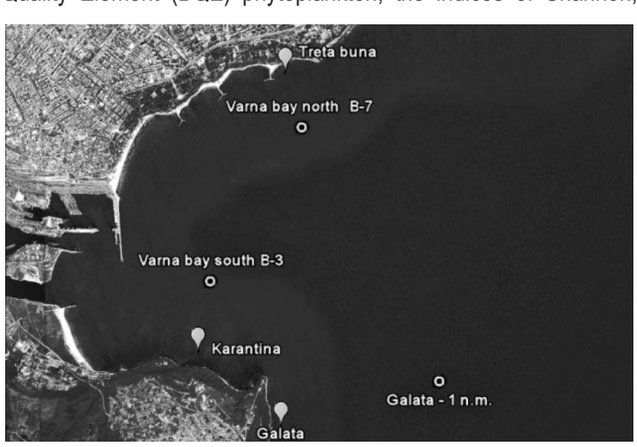

Figure1. Map of the sampling stations (Google Earth).

Sheldon, Menhinick, TRIX, DE % were accepted (Basin Directorate Report, 2005; Approaches to the assessment of eutrophication in Mediterranean coastal waters, 2007; Moncheva and Boicenco, 2010; Petrova et al., 2012).

Zoobenthos research methodology employed 0.1 m^2 (bite size) Van Veen Grab Sampler. Laboratory tests included: additional washing of samples, taxonomic identification of species composition, determination of quantitative characteristics (number and biomass) and statistical analyzes to assess the ecological status according to macrozoobenthos element – The Shannon-Weaver Diversity Index – H' (Shannon and Weaver, 1963); Marine Biotic Index (AMBI) (Borja et al., 2000, 2003; Muxika et al., 2005); Multivariate AMBI (M-AMBI) for assessment of the ecological status and EQR (Borja et al., 2006). A key to Black Sea and Azov Sea fauna (Morduhay–Boltovskoy, 1968, 1969, 1972) and Fauna of Bulgaria, 6 (Marinov, 1977) have been used as taxonomic basis.

The sampling for qualitative and quantitative analysis of macrophytes was carried out using the method of squares (Kalugina – Gutnik, 1975). The wet weight was recalculated in relation to a square meter and thus provided estimates of species in g/m^2. Temporary microscopic preparations were made to identify the morphological characteristics. Classification was performed by the determinants of Zinova (1967) and Dimitrova – Konaklieva (2000).

The Ecological Evaluation Index (EEI), (Orfanidis et al., 2001) was calculated in compliance with the European Water Framework Directive (WFD EU, 2000).

Results and discussion

The assessment of the biological quality elements is based on two groups of quantitative and qualitative characteristics, giving information about the trophic state, biodiversity and primary productivity of the marine ecosystems.

Index values and ecological status on the stations in the nearby coastal area:

Station Varna Bay – North

According to the Biological Quality Element (BQE) phytoplankton, the status of the coastal water body at Station Varna Bay–North, in the transitional period between hydrobiological summer and autumn (September – November), was assessed as "moderate" (Table 1). Macrozoobenthos samples were taken on mixed substrate at 15 m depth. Low species diversity was observed. The ecological status was "moderate" (Table 2).

Station Varna Bay – South

According to BQE phytoplankton, the status of the coastal water body at Station Varna Bay–South was assessed as "moderate" (Table 3). A current passes through the south part of Varna Bay which brings water from the polluted lake system. This reflects on the established macrozoobenthos species that were in the range from 7 to 9 ind. between replicates. The ecological status was defined as "moderate" (Table 4).

Table 1. Values of phytoplankton indices (A) and parameters (B) at Varna Bay Station - North, 2011.

Date (year, month, day)	Depth (m)	Index Shannon	Number of species in a sample	Index Menhinick	Index Sheldon	%MEC	DE%	IBI	Code of coastal water body	Type coastal waters
2011_09_18	Surface layer (0 m)	2.27	21	0.03	0.46	78.8	92.17	3.17	BG2BS000C005	CW602330
2011_09_18	Middle layer (7 m)	2.79	15	0.02	1.09	59.4	49.85	4.33	BG2BS000C005	CW602330
2011_09_18	Bottom layer (13 m)	2.85	23	0.03	0.75	57.7	89.78	3.57	BG2BS000C005	CW602330
2011_11_03	Surface layer (0 m)	2.47	43	0.03	0.27	27.1	75.64	2.89	BG2BS000C005	CW602330
2011_11_03	Bottom layer (10 m)	2.74	31	0.03	0.50	34.4	81.35	3.65	BG2BS000C005	CW602330

(A)

Date (year, month, day)	Depth (m)	Abundance (mln. cells/l)	Biomass (mg/m3)	Chl-a (µg/l)	TRIX	Transparency (m)
2011_09_18	Surface layer (0 m)	664.29	489.81	0.18	4.82	7.4
2011_09_18	Middle layer (7 m)	432.11	418.77	0.21		
2011_09_18	Bottom layer (13 m)	562.88	784.18	0.47		
2011_11_03	Surface layer (0 m)	1831.61	2422.12	0.23	5.10	3.6
2011_11_03	Bottom layer (10 m)	1394.81	1521.87	0.88		

(B)

Table 2. Values of macrozoobenthos parameters and indexes at Varna Bay Station–North

Stations macrozoobenthos	H'	Status	AMBI	Status	M-AMBI	Status
Varna Bay–North	2.74	moderate	3.876	moderate	0.54	moderate

Table 3. Values of phytoplankton indices (A) and parametrs (B) at Station Varna Bay - South, 2011.

Date (year, month, day)	Depth (m)	Index Shannon	Number of species in a sample	Index Menhinick	Index Sheldon	%MEC	DE%	IBI	Code of coastal water body	Type coastal waters
2011_09_18	Surface layer (0 m)	2.44	22	0.02	0.52	29.2	82.51	3.65	BG2BS000C005	CW602330
2011_09_18	Bottom layer (12 m)	2.65	21	0.03	0.67	60.3	83.70	3.71	BG2BS000C005	CW602330
2011_11_03	Surface layer (0 m)	2.95	33	0.03	0.58	39.1	69.01	3.82	BG2BS000C005	CW602330
2011_11_03	Bottom layer (7 m)	2.32	15	0.02	0.68	65.9	80.03	3.71	BG2BS000C005	CW602330

(A)

Date (year, month, day)	Depth (m)	Abundance (mln. cells/l)	Biomass (mg/m^3)	Chl-a (µg/l)	TRIX	Transparency (m)
2011_09_18	Surface layer (0 m)	994.14	1076.69	0.74	5.32	4
2011_09_18	Bottom layer (12 m)	407.31	661.13	0.47		
2011_11_03	Surface layer (0 m)	971.18	2254.82	0.8	5.47	2.6
2011_11_03	Bottom layer (7 m)	446.58	700.35	1.28		

(B)

Table 4. Values of macrozoobenthos parameters and indexes at Station Varna Bay – South

Stations macrozoobenthos	H'	Status	AMBI	Status	M-AMBI	Status
Varna Bay – South	3.36	good	3.713	moderate	0.60	good

Station Galata – 1 mile

According to BQE phytoplankton, the status of the coastal water body at Station Galata – 1 mile was assessed as “moderate” (Table 5). Macrozoobenthos samples were taken at 24 m depth on slimy sediments. The remoteness of the station from the coast reflected on species composition and hence the status was defined as "good" (Table 6).

Phytoplankton studies established high species diversity, amounting to 43 ind. in a sample from Varna Bay Station – North in November. In the waters of Varna Bay and up to one nautical mile from Galata also in November were found 63 species of phytoplankton microalgae among which dominated peridiniales (51%), followed by diatoms (30%) and others (19%). The tendency in the development of phytoplankton after 1995 was toward reduction of the quantitative indicators of species in multiannual aspect. Low levels of chlorophyll–a were registered in the coastal waters. For the period 1992–1997 the average phytoplankton biomass was 5.75 g/m^3, and for 1998 – 2006 the established phytobiomass averaged was 1.60 g/m^3 (Petrova and Gerdzhikov, 2011). Together with the reduction of the average phytoplankton biomass, the number of blooming species, prevalence, duration and intensity of "blooms" phenomena in the Bulgarian coastal waters also decreased.

The number of phytoplankton in Varna Bay from late summer to autumn rose twice from 0.61x10^6 cells/l (September) to 1.16x10^6 cells/l (November), on average. At Station Galata – 1 mile, adjacent to the bay, the number was less than 0.57x10^6 cells/l (September) to 0.72x10^6 cells/l (November) and changed with smaller amplitude. Phytoplankton biomass in Varna Bay was 0.70 g/m^3 in September and 1.72 g/m^3 in November. At Station Galata – 1 mile the change was from 0.35 g/m^3 in September to 0.95 g/m^3 in November. Phytoplankton biomass increased 2.5 times from September to November.

During the autumn of 2011 the status of the studied aquatory according to BQE phytoplankton was assessed as "moderate." At Varna Bay Station – North in November was registered a "bloom" of the diatom *Leptocylindrus minimus* Gran. 1.0x10^6 cells/l. According to multiannual data of different indices, in recent years phytoplankton number and biomass are generally characterized as "very good" and "good" and the displacement of the valuation on the rating scale toward worse is due to the prevailing estimates of “moderate”, “bad” and "very bad" structural characteristics of the community (Index Menhinick, Index Sheldon, % MEC, DE%).

During macrozoobenthos studies in Varna Bay were found 33 species. The percentage breakdown by groups is as follows: with equal percentage are the groups of polychaetes and molluscs (33%), followed by crustaceans (18%) and the aggregate group "Diversa" (15%). At Station Galata – 1 mile the number of species is 31 for the period of study, with the highest percentage of the group of molluscs (42%), followed by group of polychaetes (32%). An analysis of quantitative parameters (number and biomass) shows that in Varna Bay prevails the group of polychaetes which are tolerant to the environmental conditions while at the Station Galata – 1 mile dominant in number are the molluscs species. Data of biomass show a similar trend (Figures 2 and 3).

The average number of macrozoobenthos in the studied area is calculated on 516 ind/m^2, and the average biomass – on 234.3 g/m^2. The stations Varna Bay–North and Varna Bay–South have a status of moderately polluted. The most likely reason is the influx of pollutants from rivers or infusion of contaminated water from Varna Lake System. The remoteness of Station Galata – 1 mile from the

Table 5. Values of phytoplankton indices (A) and parametrs (B) at Station Galata - 1 mile, 2011.

Date (year, month, day)	Depth (m)	Index Shannon	Number of species in a sample	Index Menhinick	Index Sheldon	%MEC	DE%	IBI	Code of coastal water body	Type coastal waters
2011_09_17	Surface layer (0 m)	2.47	17	0.03	0.70	71.3	91.91	3.71	BG2BS000C013	CW602330
2011_09_17	Middle layer (17 m)	2.16	17	0.02	0.51	70.4	74.74	3.81	BG2BS000C013	CW602330
2011_09_17	Bottom layer (22 m)	1.25	7	0.02	0.50	91.5	66.47	3.71	BG2BS000C013	CW602330
2011_11_03	Surface layer (0 m)	2.41	17	0.02	0.65	35.4	88.09	3.72	BG2BS000C013	CW602330
2011_11_03	Middle layer (10 m)	2.69	23	0.03	0.64	34.7	78.49	3.65	BG2BS000C013	CW602330
2011_11_03	Bottom layer (20 m)	1.97	9	0.01	0.80	54	74.42	3.88	BG2BS000C013	CW602330

(A)

Date (year, month, day)	Depth (m)	Abundance (mln. cells/l)	Biomass (mg/m^3)	Chl-a (µg/l)	TRIX	Transparency (m)
2011_09_17	Surface layer (0 m)	327.26	466.09	0.29	4.98	5.6
2011_09_17	Middle layer (17 m)	841.14	340.77	0.86		
2011_09_17	Bottom layer (22 m)	198.66	23.91	0.29		
2011_11_03	Surface layer (0 m)	704.75	599.16	0.33	5.00	4
2011_11_03	Middle layer (10 m)	742.23	1354.13	0.42		
2011_11_03	Bottom layer (20 m)	679.17	484.01	0.46		

(B)

Table 6. Values of macrozoobenthos parameters and indexes at Station Galata-1mile

Stations macrozoobenthos	H'	Status	AMBI	Status	M-AMBI	Status
Galata	3.31	Very good	0.702	Very good	0.83	good

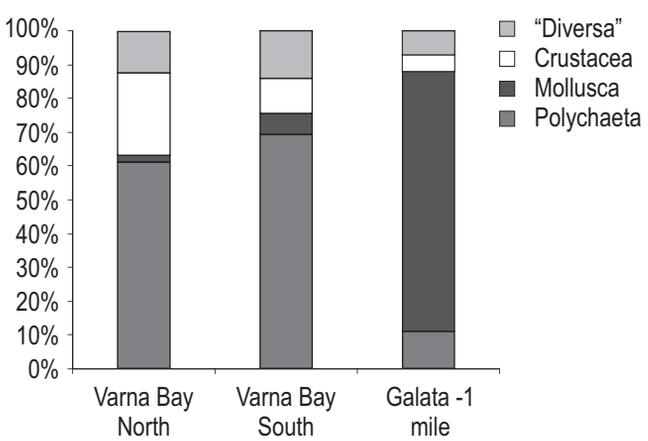

Figure 2. Average density (ind/m2) of the macrozoobenthos during 2011.

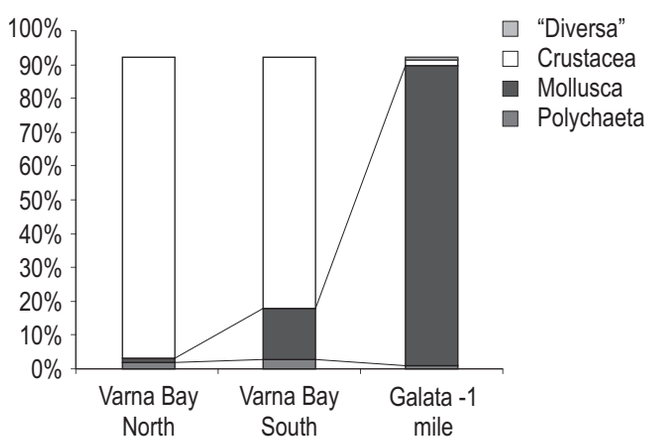

Figure 3. Average biomass (g/m2) of the macrozoobenthos during 2011.

coast reflects on species composition and hence the status is "good."

In October, seven species of macrophytes were identified as distributed at the stations Treta Buna, Karantinata and Galata (Table 7). They are referred to the environmental groups ESG I and ESG II. By EEI index values and macrophyte biomass we defined the ecological status of each station. The environmental index was calculated on the basis of the percentage ratio of coverage between the two environmental groups ESG I and ESG II, (Figure 4). At Station Karantinata there were no macrophytes of ESGI. A transect with macrophytes referred only to ESG II – tolerant, without the presence of species from ESGI-sensitive, automatically fell in a very bad environmental state (Orfanidis et al., 2001). At the stations Treta Buna and Galata the lower rates of sensitive species and high rates of opportunists defined a bad status, with EEI index for Galata–4 and for Treta buna – 3.6 (Figure 4). Dencheva (2008) registered for station Treta buna EEI index –1, witch defined "very bad" ecological status.

All three stations are characterized by low biomass of

Table 7. Species distribution at the stations.

№	Species	Station*			ESG
		1	2	3	
	Chlorophyta				
1	*Ulva rigida* C. Agardh, 1823	+	+	+	II
2	*Enteromorpha intestinalis* (L.) Link, 1820		+		II
3	Enteromorpha flexuosa (Wulfen) J. Agardh, 1883		+		II
	Rhodophyta				
4	*Ceramium elegans* (Roth) Ducluzean,1806	+			II
5	*Ceramium rubrum* (Huds.) Agardh,1811	+			II
6	*Callithamnion corymbosum* (Smith) Lyngbue,1819	+			II
	Phaeophyta				
7	*Cystoseira barbata* (Stackhouse) C. Agardh,1820	+		+	I

* - Stations: 1.Treta Buna, 2.Karantina, 3.Galata

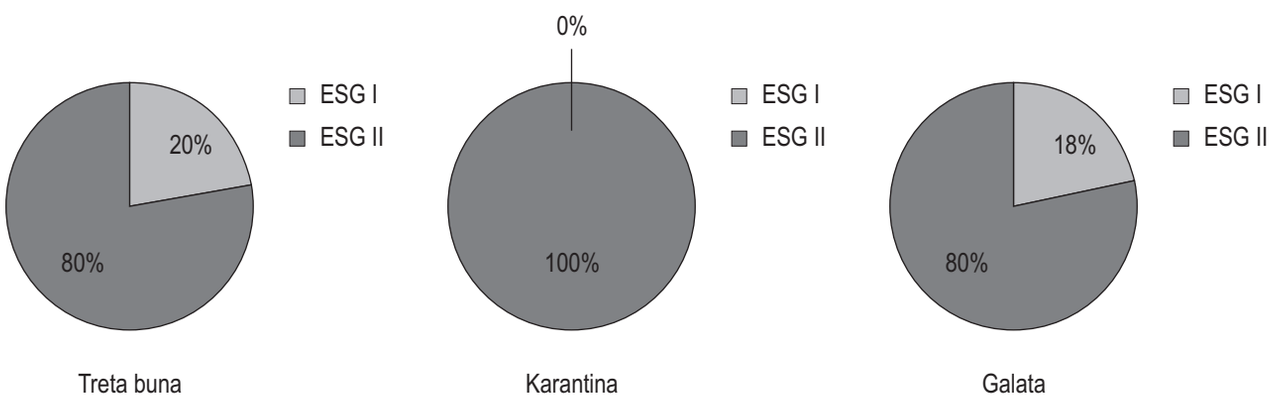

Figure 4. Percentage ratio between ESGI and ESGII at stations Treta buna, Karantinata and Galata.

macrophytes (Figure 5). At Karantinata the extremely low biomass is determined by the fact that at this transect there was a very weak development of macrophyte communities. The low values at the stations in Varna Bay are determined by the prvalence of species with high specific surface area and low biomass, which is typical for the species of ESG II. Long-term experience in the region of Varna Bay shows a tenedency of decrease of the sensitive macrophyte species and the macrophyte communities as a whole. Dencheva (2008) reported that in Burgas and Varna Bay Chlorophyta species increase at the expense of Rhodophyta and Phaeophyta species. This marks the negative changes of macrophyte communities in the Bay.

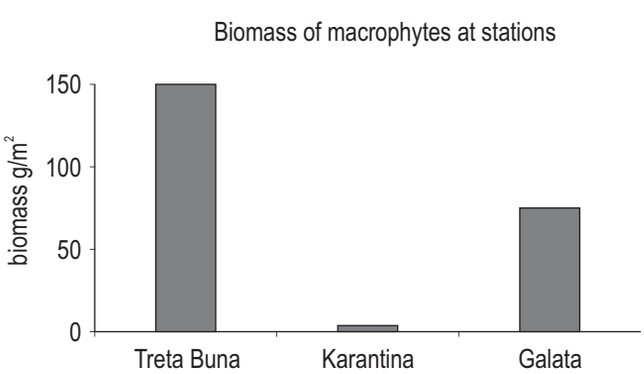

Figure 5. Distribution of the Biomass (g/m2) of the macrophytes, autumn, 2011

The main change in recent years in Varna Bay has been the reduction of biomass of *Cystoseira* species, which are indication of high water quality. These macrophytes are replaced by other species such as *Enteromorpha intestinalis* (L.) Link, 1820; *Cladophora vagabunda* (L.) Hoek, 1963; *Ceramium rubrum* C. Agardh, which have higher specific surface area, especially in more eutrophic (Dencheva, 2008). The biomass of species with long life cycle and low specific surface area decreases, and the biomass of species with short life cycles and higher specific surface area increases.

Conclusions

During the autumn period of 2011 the status of the studied aquatory according to BQE phytoplankton was assessed as "moderate". Phytoplankton studies established high species diversity, amounting max 63 ind. in one sample .

At the surveyed stations, in October, were established a total of 7 species of macrophytes. The very bad ecological status was determined by the predominance of macrophytes of ESG II. By raising the level of nutrients (anthropogenic impact) the share of opportunistic green algae species increases and the number, size and quantity of brown macrophyte species decrease. During the studies on macrozoobenthos in Varna Bay were found 33 species.

The stations in Varna Bay–North and Varna Bay–South have a status of moderately polluted. The most likely reason is the influx of pollutants from rivers or infusion of contaminated water from Varna Lake System. The remoteness of station Galata – 1 mile from the coast reflects on species composition and hence the status is assessed as "good."

Finally, the status of the Varna Bay in autumn 2011 is determined by bad to good depending on environmental parameter analyzed.

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Product Quality and Safety

Instruction for authors

Preparation of papers

Papers shall be submitted at the editorial office typed on standard typing pages (A4, 30 lines per page, 62 characters per line). The editors recommend up to 15 pages for full research paper (including abstract references, tables, figures and other appendices)

The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods,Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

The title needs to be as concise and informative about the nature of research. It should be written with small letter /bold, 14/ without any abbreviations.

Names and affiliation of authors

The names of the authors should be presented from the initials of first names followed by the family names. The complete address and name of the institution should be stated next. The affiliation of authors are designated by different signs. For the author who is going to be corresponding by the editorial board and readers, an E-mail address and telephone number should be presented as footnote on the first page. Corresponding author is indicated with *.

Abstract should be not more than 350 words. It should be clearly stated what new findings have been made in the course of research. Abbreviations and references to authors are inadmissible in the summary. It should be understandable without having read the paper and should be in one paragraph.

Keywords: Up to maximum of 5 keywords should be selected not repeating the title but giving the essence of study.

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Discussion: The objective of this section is to indicate the scientific significance of the study. By comparing the results and conclusions of other scientists the contribution of the study for expanding or modifying existing knowledge is pointed out clearly and convincingly to the reader.

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