# Study of the Quality Indicators for the Indoor Swimming Pool Water Samples in Romania

**DANIELA DIRTU[1,2], MANUELA PANCU[2], MANUELA LUMINITA MINEA[2], MARIN CHIRAZI[3], ION SANDU[4], ALIN CONSTANTIN DIRTU[1]***

[1] Alexandru Ioan Cuza University of Iasi, Department of Chemistry, 11 Carol I Blvd., 700506, Iasi, Romania

[2] Public Health Institute, Regional Center of Public Health Iasi, 14 V. Babes Str., 700465, Iasi, Romania

[3]Alexandru Ioan Cuza University of Iasi, Faculty of Physical Education and Sport, 3 Toma Cozma Str., 700053, Iasi, Romania

[4]Alexandru Ioan Cuza University of Iasi, ARHEOINVEST Interdisciplinary Platform, 11 Carol I Blvd., 700506, Iasi, Romania

*This study aimed on assessing the water quality for randomly selected indoor swimming pools located in Iasi city in order to determine its compliance with the Romanian regulation (order no. 119/2014). Physical and chemical parameters, including free and combined chloride, $KMnO_4$ consumption, total hardness, pH, temperature and turbidity together with microbiological characterization (Escherichia coli, Coliforms, Pseudomonas aeruginosa, Enterococci, Staphylococcus aureus) was carried out for a total of 30 samples, using standard analytical protocols. The obtained results of the present study showed significant correlations ($p<0.05$) between the investigated parameters. However, in order to determine the compliance with the Romanian regulation, after evaluating the obtained results it could be concluded that only 20% of the total analyzed samples correspond within the regulatory limits. The results of the present study suggest the need of continuously monitoring of the indoor swimming pool water quality in order to increase bather hygienic practices and awareness of the risks.*

*Keywords: water quality, swimming pool, quality parameters, monitoring*

Swimming facilities are used by most of the people for rehabilitative treatment, sport or recreational activities. Proper water quality is essential to maintaining safety for the users of swimming pools as there is a direct contact between the users and the swimming pool waters. There are many factors playing an important role in the water quality of swimming pools such a quality water sources, treatment and disinfection processes as well as the number and behaviour of swimmers which may affect the water quality [1-10].

Bathers might contaminate the water with large amounts of microorganisms as a result of theirs' secretions which are shed from skin, mouth, nose and throat, urine or by contaminated objects and clothes, making water a possible vehicle for the dissemination of diseases among swimmers. From the skin alone hundreds of millions of bacteria are rinsed during swimming. If left untreated, these microorganisms will build up in water, increasing the risk of infection to the swimmers [11].

Microorganisms that are usually connected to swimming pools include *Pseudomonas aeruginosa, Escherichia coli, Coliforms, Enterococci, Staphylococcus aureus* and others [12-14]. Previous literature in the field suggests that microbiological quality of the swimming pools might be affected through several pathways including microorganisms derived from the skin, mouth, and upper respiratory tract of bathers as well as from fecal contamination. Some studies show that the microbiological quality of swimming pools is best measured by using fecal coliform which indicates fecal contamination together with total coliform and heterotrophic bacteria [15], while others consider that the risk of infection is more associated with microorganisms derived from the skin, mouth, and upper respiratory tract of bathers rather than fecal contamination [16]. Given the multitude of microbiologically contamination pathways of these sites, generally the swimming pool waters are pretreated with several chemical formulations, while the most used water treatment method is chlorination [17]. In order to control the microbiological loadings of the swimming pools during use, the monitoring of the chemical agents used for water pretreatment is extremely important: there is a possibility that chemical agents are excessively used while leading to human exposure to rather high levels of such compounds, while if they are applied at too low levels, they became inefficient for the microbiological control of the water. As a consequence, for quality indicators monitoring of such waters, beside microbiological control, monitoring of physical and chemical parameters characterizing these samples became important. Physical and chemical parameters, including free and combined chloride, $KMnO_4$ consumption, total hardness, pH, temperature and turbidity could also predict the quality of the pool water [17, 18].

This study aimed on assessing the water quality for randomly selected indoor swimming pools located in Iasi city in order to determine its compliance with the Romanian regulation (Order no. 119/2014). Also, the study provides baseline data concerning the water quality of indoor swimming pools in Romania and identifies the risk factors associated with using these pools. It will suggest corrective measures to protect all swimmers from health hazards associated with swimming in unsanitary pools.

## Experimental part

*Sample collection*

In this study a total of 30 samples from the water of two indoor swimming pools in Iasi, Romania were collected in

* email: alin.dirtu@chem.uaic.ro

| Parameters | Analytical methods | Method determination |
|---|---|---|
| **Free Chlorine** | SR EN ISO 7393 | Water quality-Determination of free and total chlorine. Part 2: Colorimetric method using N,N-diethyl-1,4-phenylenediaine |
| **Combined Chlorine** | | |
| **pH** | SR ISO 10523 | Water quality-Determination of pH |
| **Turbidity** | SR EN ISO 7027 | Water quality-Determination of turbidity |
| **$KMnO_4$ Consumption** | SR EN ISO 8467 | Water quality-Determination of permanganate index |
| **Total Hardness** | SR ISO 6059 | Water quality-Determination of the sum of calcium and magnesium. EDTA titrimetric method |
| ***Escherichia coli*** | SR ISO 9308 – 1 : 2009 | Water filtration method |
| **Coliforms** | SR ISO 9308 – 1 : 2009 | Water filtration method |
| **Enterococci** | SR ISO 7899 – 2 : 2002 | Water filtration method |
| ***Pseudomonas aeruginosa*** | SR ISO 16266 : 2008 | Water filtration method |
| ***Staphylococcus aureus*** | - | VITEK Compact identification |

SR – reference standard; ISO - International Organization for Standardization

**Table 1**
ANALYZED PARAMETERS AND METHODS USED FOR DETERMINATION

different seasons during 2013 – 2014. The standard procedure followed for collecting samples involved the use of a manual plastic pump, in a 500 mL sterilized bottle. Samples were collected from 20 cm beneath the surface during 9 – 10 P.M. The temperature was examined on site and then the samples were transferred to the laboratory in a cool box.

*Material and methods*

Water samples were collected, preserved, and analyzed physically, chemically, and biologically according to the Standard Methods for the Examination of Water and Wastewater. Therefore, physical and chemical parameters characterizing the collected samples included: free and combined chloride, $KMnO_4$ consumption, total hardness, *p*H, temperature and turbidity. The microbiological characterization including: *Escherichia coli, Coliforms, Pseudomonas aeruginosa, Enterococci* and *Staphylococcus aureus* were carried out using standard analytical protocols which are mentioned in table 1.

*Statistical analysis*

All statistical analyses were performed using XLStat-Pro version 2013.5.01 (Addinsoft, 1995-2013). For data which did not follow a normal distribution (Shapiro-Wilk test, $p > 0.05$) they were *log*-transformed ($y = log(x+1)$) and further tested for normality. For data which did not show a normal distribution after *log*-transformation, non-parametric statistics was applied. For data which followed a normal distribution after *log*-transforming, parametric statistics was used on the new set of data. Correlations were carried out using parametric Pearson correlations (for normally distributed parameters or *log*-transformed data). The significance level was set at $\alpha = 0.05$ throughout the study.

## Results and discussions

*Physical-chemical quality evaluation*

Results concerning the physical and chemical parameters investigated from each of the 30 swimming pool water samples included in this study are presented in table 2. Therefore, the *p*H values showed a large fluctuation in all of the investigated swimming pool water samples, (6.03 – 7.70) and 30% of the analyzed samples (table 2 - grey highlighted boxes with data presented in bold) presented lower *p*H values when compared with the Romanian regulation (order no. 119/2014), which provides a range between 7.2 – 7.8 *p*H units.

Only 20% of the samples showed that free residual chlorine met the Romanian standards (0.5 – 1.0 mg/L) for indoor swimming pool, while a number of 20 of the analyzed samples (table 2-highlighted boxes, bold values) presented levels for the free chlorine outside of the regulatory standards.

The mean values of turbidity ranged between 0.066 and 1.222 while the temperature (measured on site) had values between 27 and 31°C. Water temperature monitoring is important since higher temperatures may promote the growth of some microorganisms (WHO, 2006). According to the previous literature in the field, the surveyed indoor pools with water temperature values higher than 27°C were more likely to be contaminated when compared to pools with a temperature between 22 – 27°C [19, 20].

The $KMnO_4$ consumption represents a chemical parameter indicating the existence of the polluting organic compounds in the water and thus reflecting quality of water preparation. In this study, the mean values of $KMnO_4$ consumption ranged between 0.860 and 7.360 mg/L, data being in agreement with previous literature in the field of water monitoring quality [1].

The mean values of the Total Hardness ranged between 6.95 – 18.62°DH, presenting a normal fluctuation, comparable to drinking water [21].

*Microbiological quality evaluation*

According to the Romanian standards (order no. 119/ 2014), which provides 0 UFC/100 mL (UFC – colony forming units) 17% of the samples included in our study were declared unacceptable after the microbiological investigation. The obtained results for the microbiological quality evaluation were correlated with *p*H and free chlorine values below the maximum allowable concentrations CMA (table 3).

| Sampling periode | pH unitPH | $Cl_2$ Free mg/L | $Cl_2$ Comb. mg/L | Turb. UNT | Total Hard. $^0$DH | Temp. $^0$C | $KMnO_4$ mg/L |
|---|---|---|---|---|---|---|---|
| III/2014 | **6.60** | **0.04** | 1.38 | 0.15 | 17.50 | 27 | 4.35 |
| III/2014 | 7.40 | **2.38** | 3.54 | 0.26 | 12.57 | 28.00 | 4.24 |
| IV/2014 | **6.48** | **2.14** | 3.61 | 0.45 | 18.62 | 29.00 | 7.36 |
| IV/2014 | 7.20 | **2.80** | 4.75 | 1.22 | 11.89 | 31.00 | 6.93 |
| V/2014 | **6.82** | **1.51** | 3.37 | 0.14 | 17.95 | 27.00 | 3.54 |
| V/2014 | 7.70 | **2.42** | 3.61 | 0.31 | 10.10 | 30.00 | 4.48 |
| V/2014 | **6.03** | **2.79** | 4.20 | 0.15 | 17.50 | 28.00 | 3.69 |
| V/2014 | 7.24 | **3.01** | 4.14 | 0.32 | 8.30 | 29.00 | 4.07 |
| VI/2014 | **7.02** | **2.17** | 3.12 | 0.22 | 15.48 | 30.00 | 3.91 |
| VI/2014 | 7.33 | **1.82** | 3.68 | 0.21 | 8.07 | 29.00 | 4.40 |
| VI/2014 | 7.30 | **3.62** | 4.42 | 0.25 | 13.91 | 29.00 | 3.28 |
| VI/2014 | 7.25 | **4.19** | 5.68 | 0.55 | 11.22 | 28.00 | 4.90 |
| VII/2014 | **6.32** | **0.40** | 2.82 | 0.35 | 9.20 | 29.00 | 4.86 |
| VII/2014 | **6.60** | **0.06** | 0.68 | 0.28 | 14.81 | 29.00 | 2.95 |
| VII/2014 | **7.11** | **9.57** | 9.72 | 0.08 | 11.22 | 28.00 | 0.86 |
| VII/2014 | 7.44 | 1.00 | 2.06 | 0.31 | 7.18 | 28.00 | 4.19 |
| VIII/2014 | 7.34 | **2.59** | 3.16 | 0.20 | 12.11 | 28.00 | 3.08 |
| VIII/2014 | 7.43 | **2.01** | 2.83 | 0.95 | 6.95 | 28.00 | 3.48 |
| IX/2013 | **6.74** | **2.49** | 3.32 | 0.06 | 11.89 | 28.00 | 2.88 |
| IX/2013 | 7.53 | **1.88** | 2.77 | 0.28 | 6.95 | 28.00 | 2.64 |
| X/2013 | 7.26 | 0.86 | 0.73 | 0.18 | 15.26 | 28.00 | 5.33 |
| X/2013 | 7.39 | 0.57 | 0.90 | 0.69 | 10.10 | 30.00 | 3.66 |
| X/2013 | 7.20 | 0.50 | 1.57 | 0.20 | 14.95 | 28.00 | 4.40 |
| X/2013 | 7.30 | 0.71 | 0.85 | 0.62 | 10.55 | 29.00 | 3.84 |
| XI/2013 | **6.81** | **0.04** | 0.40 | 0.33 | 14.36 | 28.00 | 4.16 |
| XI/2013 | 7.36 | 0.64 | 0.77 | 0.70 | 10.77 | 29.00 | 3.81 |

$^0$DH - German degrees, UNT - nephelometric turbidity units

**Table 2**
MEASURED PHYSICAL AND CHEMICAL PARAMETERS

| pH Unit pH | E. Coli UFC/100 mL | Coliforms UFC/100 mL | P. Aeruginosa UFC/100 mL | Enterococci UFC/100 mL | Staphylococcus aureus UFC/100 mL |
|---|---|---|---|---|---|
| < CMA | 0% | 13% Present | 10% Present | 0.3% | 6.66% |
| 7.2 – 8.2 | 0% | 0% | 0% | 0% | 0% |
| >CMA | 0% | 0% | 0% | 0% | 0% |
| | | | Free Chlorine, mg/L | | |
| < CMA | 0% | 13% Present | 10% Present | 0.3% | 6.66% |
| 0.5 – 1.0 | 0% | 0% | 0% | 0% | 0% |
| >CMA | 0% | 0% | 0% | 0% | 0% |

CMA - maximum allowable concentrations, UFC - colony forming units

**Table 3**
INFLUENCE OF THE *p*H AND FREE CHLORINE LEVELS ON THE MICROBIOLOGICAL PARAMETERS OF THE ANALYZED WATER SAMPLES

As shown in the results included in table 3, water samples which presented pH and free chlorine values below the regulatory allowable concentrations (CMA) encountered microbiological contamination. Between 0.3 and 13% of these analyzed samples presented measurable units for the following microbiological parameters: *Coliforms, P. Aeruginosa, Enterococci* and *Staphylococcus aureus*. Free residual chlorine and lower pH values have a significant negative effect on the microbiological contamination. Free residual chlorine of less than 0.5 mg/L was associated with increased odds of contamination. This indicates that chlorine concentration between 0.5 – 1.0 mg/L is a good operational index to control the quality of indoor swimming pool (order no. 119/2014). Also, for *p*H values lower than 7.2 a total of 17% of the analyzed samples presented a positive microbiological contamination.

| Statistic | pH | $Cl_2$ Free | $Cl_2$ Comb. | Turbidity | Total Hardness | Temp. | $KMnO_4$ Cons. |
|---|---|---|---|---|---|---|---|
| No. of observations | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Minimum | 6.030 | 0.040 | 0.400 | 0.060 | 6.950 | 27.000 | 0.860 |
| Maximum | 7.700 | 9.570 | 9.720 | 1.220 | 18.620 | 31.000 | 7.360 |
| 1st Quartile | 6.759 | 0.503 | 1.480 | 0.185 | 10.213 | 28.000 | 3.570 |
| Median | 7.220 | 1.665 | 3.140 | 0.270 | 11.890 | 29.000 | 4.115 |
| 3rd Quartile | 7.353 | 2.473 | 3.663 | 0.425 | 14.755 | 29.000 | 4.400 |
| Mean | 7.065 | 1.798 | 2.999 | 0.355 | 12.375 | 28.700 | 4.071 |
| Variance (n-1) | 0.184 | 3.494 | 3.795 | 0.073 | 11.014 | 0.907 | 1.397 |

**Table 4**
DESCRIPTIVE STATISTICS PAREMETERS OBTAINED FOR THE INVESTIGATED WATER SAMPLES

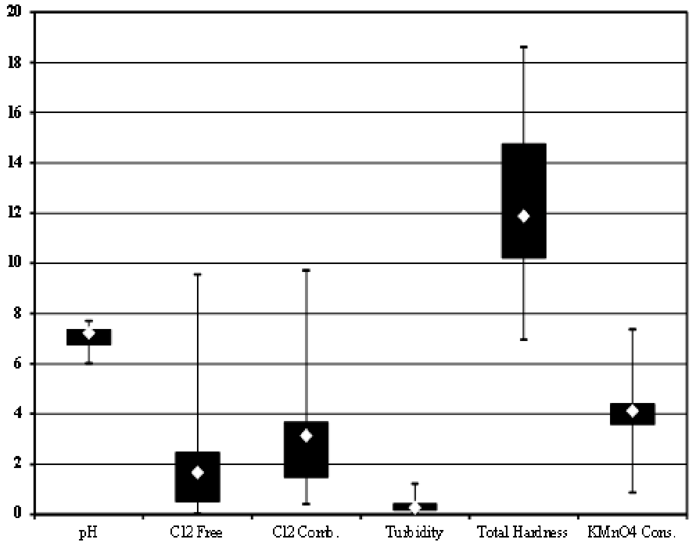


Fig. 1. Overview of physical and chemical parameters charactersing the swimming pool water samples (minimum and maximum concentrations are presented as limit intervals. Boxplots represent the 1st and the 3rd quartile concentrations while median concentrations are given as rectangles)

| Variables | pH | $Cl_2$ Free | $Cl_2$ Comb. | Turbidity | Total Hardness | Temp. | $KMnO_4$ Cons. |
|---|---|---|---|---|---|---|---|
| pH | **1** | 0.241 | -0.060 | 0.200 | **-0.560** | 0.030 | -0.040 |
| $Cl_2$ Free | 0.241 | **1** | **0.730** | -0.033 | -0.158 | -0.063 | -0.156 |
| $Cl_2$ Comb. | -0.060 | **0.730** | **1** | -0.239 | -0.013 | 0.029 | 0.112 |
| Turbidity | 0.200 | -0.033 | -0.239 | **1** | **-0.474** | **0.440** | 0.169 |
| Total Hardness | **-0.560** | -0.158 | -0.013 | **-0.474** | **1** | -0.203 | 0.160 |
| Temp. | 0.030 | -0.063 | 0.029 | **0.440** | -0.203 | **1** | 0.221 |
| $KMnO_4$ Cons. | -0.040 | -0.156 | 0.112 | 0.169 | 0.160 | 0.221 | **1** |

Statistically significant correlations $p < 0.01$

**Table 5**
CORRELATION MATRIX (PEARSON) OBTAINED BETWEEN MEASURED PHYSICAL AND CHEMICAL PARAMETERS OF THE INVESTIGATED WATER SAMPLES

For a better view of the distribution obtained for the results of the physical and chemical analyses of the investigated samples, table 4 includes results concerning the following descriptive statistical parameters: minimum, maximum, mean, median, 1st quartile and 3rd quartile concentrations.

The highest variability of the results was obtained for the following parameters: free and combined chlorine, total hardness and $KMnO_4$ consumption (fig. 1). Given the seasonal variation of the results, it was expected that especially the chemical parameters free and combined chlorine would present such a high variability especially for the water samples collected in the summer season. Indeed, as can also be seen from table 1, the highest number of highlighted boxes (representing data which were below or exceeded the regulatory CMA) is represented for the samples collected in the warm season. However, while generally the swimming pool waters are excessively pretreated with chemical agents (chlorination) in order to control for the microbiological loadings of the swimming pools, the results obtained for such a high number of samples which exceeds the CMA will lead to human exposure to rather high levels of such compounds. Surprisingly, during warm season, a significant number of samples presented values for the free chlorine which were below the CMA limits.

Testing for correlations (Pearson correlations) between the physical and chemical parameters investigated in the collected samples for this study (table 5) would bring important information concerning the dependent variables which eventually would explain the positive microbiological characterization of the analyzed samples. Few parameters were significant positively correlated ($p < 0.5$) like free and combined chlorine (r = 0.730) as well as turbidity and water temperature (r = 0.440) while other parameters were significant negatively correlated ($p < 0.5$) like pH and total hardness (r = -0.560) as well as turbidity and total hardness (r = -0.474). Given that the available legislation provides limits only for few parameters among the investigated indicators through the following of this study, these parameters seems to be influenced (through the following of the correlation tests) by other variables tested in the collected samples. Therefore, even if targeting for analysis only the indicators included in the official legislation (*p*H, free chlorine and microbiological parameters), due to their direct dependence on other chemical characteristics, it should be stated that only after following a complete chemical analysis of such samples a good indication of the water quality can be assessed.

## Conclusions

According to the Romanian legislation (Order no. 119/ 2014), which specifies maximum allowable concentrations (CMA) only to *p*H, free chlorine and microbiological parameters, 20% of the total analyzed samples correspond within the regulatory limits. The results showed that the hygienic quality of the swimming pools was dependent on the efficacy of disinfection. Thus, the free chlorine an *p*H were good operational indices for the quality control of indoor swimming pools and must be maintained in the recommended range to ensure optimal disinfection [22].

The results of the present study suggest the need of continuously monitoring of the indoor swimming pool water quality in order to increase bather hygienic practices and awareness of the risks.

*Acknowledgments: This work was supported by the strategic grant POSDRU/159/1.5/S/133652, co-financed by the European Social Fund within the Sectorial Operational Program Human Resources Development 2007 – 2013.*

## References

1.SAQUARAT, B., HARAHSHED, S., JIRIES, A., Research Journal of Environment and Earth Science, **4**, no 10, 2012, p. 890.

2.ROMANESCU, G., ZAHARIA, C., SANDU, A.V., JURAVLE, D.T., International Journal of Conservation Science, **6,** no. 1, 2015, p. 92.

3.BILAJAC, L., VUKIC, D., DOKO J., RUKAVINA, T., J. Water Health, **10**, no 1, 2012, p. 108.

4.VASILACHE, V., CRETU, M.A., PASCU, L..F., RISCA, M., CIORNEA, E., MAXIM, C., SANDU, I.G., CIOBANU, C.I., International Journal of Conservation Science, **6,** no. 4, 2015, p. 729.

5.ROMANESCU, G., COJOC, G.M., SANDU, I.G., TIRNOVAN, A., DASCALITA, D., SANDU, I., Rev. Chim. (Bucharest), **66**, no. 6, 2015, p.855.

6.DRAGOI, G., FUNAR, S., SOLEA, M., COTET, C.E., Mat. Plast., **44**, No. 1, 2007, p. 81.

7.CIRTINA, D., PASARE, M., Rev. Chim. (Bucharest), **65**, no. 6, 2014, p. 737.

8.ROMANESCU, G., PAUN, E., SANDU, I., JORA, I., PANAITESCU, E., MACHIDON, O., STOLERIU, C., Rev. Chim. (Bucharest), **65**, no. 4, 2014, p. 401.

9.MARUSIC, G., SANDU, I., VASILACHE, V., FILOTE, C., SEVCENCO, N., CRETU, M.A., Rev. Chim. (Bucharest), **66**, no. 4, 2015, p. 503.

10.NANDI, D., KANT, J., SAHU, K.C., International Journal of Conservation Science, **6,** no. 3, 2015, p. 383.

11.RABI, A., KHADER, Y., ALKAFAJEI, A., AQOULAH, A., Int. J. Environ. Res. Public Health, **5**, no 3, 2008, p. 152.

12.SATO, M.I.Z., ALVES, M.N., STOPPE N.C., MARTINYS, M.T., Pergamon, **29**, no 10, 1995, p. 2412.

13.TATE, D., MAWER, S., NEWTON, A., Epidemiology and Infection, **130**, 2003, p. 187.

14.FIORILLO, L., ZUCKER, M., SAWYER, D., LIN, A., The New England J. of Med., **345**, 2001, p. 335.

15.RASTI, S., ASSADI, M.A., IRANSHAHI, L., SAFFARI, M., GILASI, H.R., POURBABAEE, M., Jundishapur J. Microbiol., **5**, no 3, 2012, p. 450.

16.MAGDY, M. and EL-SALAM, A., Environ. Monit. Assess. **184**, 2012, p. 7395.

17.PERJU, S., STANESCU, I., Rev. Chim. (Bucharest), **66**, no. 6, 2015, p. 886.

18.TELEMBICI, T., RETEZAN, A., FLORESCU, C., Rev. Chim. (Bucharest), **66**, no. 1, 2015, p. 74.

19.ESTERMAN, A., RODER, D.M., CAMERON, A.S., ROBENSON, B.S., WALTER, R.P., LAKE, J.A., CHRISTY, P.E., Applied and Environ. Microbiology, **47**, no 2, p. 325.

20.MOSSEL, D.A., American J. of Pub. Health, **76**, no.3, 1986, p. 297.

21.CARABET, A., FLORESCU, C., STANILOIU, C., PODOLEANU, C., VISESCU, M., BELU, M., ILIE, C., Rev. Chim. (Bucharest), **64**, no. 5, 2013, p.559.

22.NIKAEEN, M., HATAMZADEH, M., DASTJERDI, M., HASSANZADEH, A., Water Sci. Technol., **60**, no.12, 2009, p. 3101

Manuscript received: 8.01.2016