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WATER FOOTPRINT OF DOMESTIC WATER CONSUMPTION. IS IT SUSTAINABLE?

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Abstract:

Water consumption and, in particular, the rational use of water, is one of the main objectives of sustainable development. Research over the last decades has highlighted both the uneven distribution of this vital resource and significant differences between the world's states in its effective use. Taking into account these aspects, the paper analyzes the water footprint of domestic consumption in 27 European countries, taking into account the results of previous studies. The results obtained show a relatively low concentration of both blue water and the gray water footprint of domestic consumption as well as the grouping of countries of consumption intervals.

Key words: water footprint, water footprint of domestic consumption, concentration, sustainable development

JEL classification:Q25, Q53, C10

INTRODUCTION

Water is undoubtedly the most important resource of humanity, an essential component of the environment, with a complex use (Gallopin and Rijsberman, 2000; Galli et al., 2012) and its irrational use can irreversibly affect not only sustainable development but even the future of humanity.

It is estimated that by 2025 about one-third of the world's population will live in water-stressing countries (Pryor, 2007). Under these circumstances, a careful and consistent study of its use as well as the transfer from one country to another is a necessity. In this respect, one of the most elaborate and complete studies belongs to Mekonnen and Hoekstra which analyzed in the National water footprint accounts (Mekonnen and Hoekstra, 2011) the direct and indirect water consumption by categories registered in the period 1996-2005, in most states in the world.

Considering the essential nature of water in the development of human society, in order to ensure sustainable development, water resource management requires a series of actions aimed at both besides water and waste water (Andrei et al., 2019)

Although water footprint of domestic water consumption represents only a few percent of the total water footprint consumption, we consider that attention should be paid to this area, especially with regard to the amount of fresh water needed to absorb pollutants resulting from household consumption in order to meet the standards of water quality. If we are to refer to Romania, it is all the more necessary to increase the share of inhabitants who have access to water supply services (Ciomos et al., 2013), but under conditions of efficiency and non-discrimination (Froone and Frone, 2012), as water consumption increases will also be recorded in other sectors which may lead to a lack of water in one area or another (Mitrica et al., 2017).

Based on these aspects and the results of the Value of Water Research Report No. 50, UNESCO-IHE (Mekonnen and Hoekstra, 2011), the paper analyzes the distribution of water footprint of domestic water consumption per capita in 27 EU states, both in in terms of water from groundwater or surface area, and the amount of fresh water needed to absorb pollutants to meet water quality standards. There is also a grouping of 27 countries according to the per capita consumption of the two water categories.

RESARCH METHOLOGY

The water footprint of national consumption (WFS) is calculated as the sum of the direct water footprint of consumers and two indirect components of the water footprint (Mekonnen et al., 2011) which includes consumption of water needed by other countries for the production of agricultural products (WFA) and / or industrial (WFI) imported and consumed by citizens of the analyzed country:

$$WF = WF_{cons.dir} + WFA_{cons.indir} + WFI_{cons.indir} \quad (1)$$

Taking into account their place of provenance in industrial or agricultural products consumed by citizens of one country, two quantities of water are included: domestic water from the country's resources and external water coming from the water resources of the producing country of those products.

On the other hand, depending on the type of water source and water quality, three water categories are distinguished: green water (precipitation water), blue water (groundwater or surface water), and gray water (the amount of fresh water needed to assimilate pollutants to meet water quality standards).

Given that the subject of this paper is water footprint of domestic water consumption, a component of the total internal water footprint of national consumption, only some of the indicators, which characterize the water footprint of national consumption per capita, were included in the analysis. The variables corresponding to the indicators included in this analysis are shown in Table 1.

Table no. 1. The main indicators used in the water footprint analysis of domestic water consumption per year (yr) and per capita (cap)

Variables	Significance	Unit
TIWFN	Total internal water footprint of national consumption	m^3/yr/cap
TIWFA	Total internal water footprint of agricultural products	m^3/yr/cap
TIWFI	Total internal water footprint of industrial products	m^3/yr/cap
WFD	Total water footprint of domestic water consumption	m^3/yr/cap
BWFD	Blue water footprint of domestic water consumption	m^3/yr/cap
GWFD	Gray water footprint of domestic water consumption	m^3/yr/cap
TBWFD	Total blue water footprint of domestic water consumption	thousands m^3/yr
TGWFD	Total gray water footprint of domestic water consumption	thousands m^3/yr
TINH	Total inhabitants	thousands

The main relationships between the variables presented in Table 1 are:

$$\begin{aligned} TIWFN &= TIWFA + TIWFI + WFD \\ WFD &= BWFD + GWFD \\ TBWFD &= \sum_{i=1}^{n} BWFD_i \cdot NRINH_i \\ TGWFD &= \sum_{i=1}^{n} GWFD_i \cdot NRINH_i \\ TINH &= \sum_{i=1}^{n} NRINH_i \end{aligned} \quad (2)$$

In relation (2), $BWFD_i$ and $GWFD_i$ represent consumption of BWFD and GWFD (m^3/yr/cap) from contry *i*, and $NRINH_i$ is the number of inhabitants (thousands) of that country.

The basis of the study is the series of data published by UNESCO-IHE Institute for Water Education, in 2011, in “Value of Water Research Report Series No. 50” (Mekonnen and Hoekstra,

2011) "Appendix VIII. The water footprint of national consumption per capita, shown by major consumption category and by internal and external component (m3/yr/cap)".

Of the 28 EU Member States in 2018, only 27 were included in the analysis, since both BWFD and GWFD in Croatia have null values (real and practical impossible), comparisons with other countries being inconclusive.

A first method used to analyze WFD distribution in the 27 countries included in the analysis was the graphical method (Concentration Curve). This consists in the graphical determination and representation for each variable of a polygonal curve obtained from its data series indexed in increasing order $(w_i \le w_{i+1})$, by connecting the points $(x_i, y_i)_{i=\overline{0,28}}$ where:

$$(x_i, y_i) = \begin{cases} (x = 0, y = 0), i = 0 \\ \left(x_i = \frac{i}{27}, y_i = \frac{S_i}{S_n} \right), S_i = \sum_{j=1}^{i} w_j, i = \overline{1,27} \end{cases} \tag{3}$$

In addition to the graphical method, the assessment of concentration grades was also carried out using the following indicators: Gini Coefficient (G), Entropy (S), Normalized Entropy (S_0), Hirschman-Herfindahl (H) and Normalized Herfindahl (H^*) (Jaba, 2002):

$$G = \sqrt{\sum_{i=1}^{n} g_i^2}, \quad g_i = \frac{x_i}{\sum_{i=1}^{n} x_i}, \quad G \in \left[\sqrt{\frac{1}{n}}, 1 \right]$$

$$S = \sum_{i=1}^{n} g_i \cdot \ln \frac{1}{g_i}, \quad S \in [1, \ln n]; \quad S_0 = \frac{S}{\ln n}, \quad S_0 \in [0,1] \tag{4}$$

$$H = \sum_{i=1}^{n} g_i^2, \quad H \in \left[\frac{1}{n}, 1 \right]; \quad H^* = \frac{H - \frac{1}{n}}{1 - \frac{1}{n}}, \quad H^* \in [0,1]$$

Taking into account that the 27 EU Member States were included in the analysis in 2018, then n = 27, and under these conditions, $GC \in [0.192, 1]$ and $SE \in [1, 3.296]$.

RESULTS AND DISCUSSIONS

Starting from the data series corresponding to BWFD variables, using the graphical method (3), the blue water footprint curve of the domestic water consumption per capita of the 27 states included in the analysis was obtained, shown in figure no. 1. This highlights a very weak concentration, basically pointing to a lack of concentration.

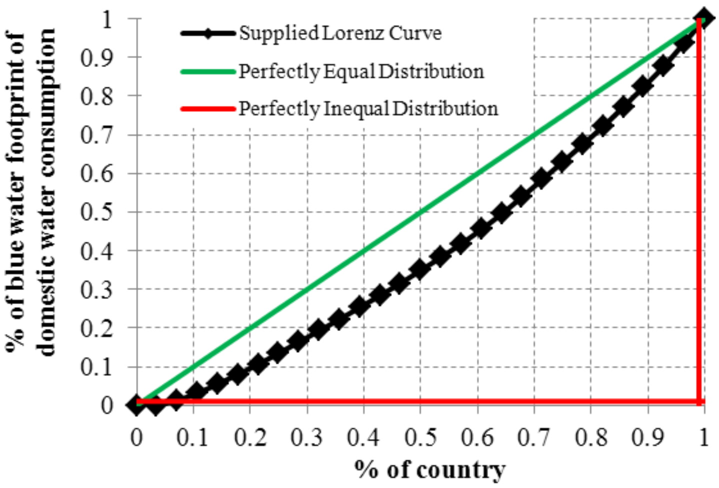

Figure no. 1. Concentration curve of BWFD in 27 EU countries

It should be emphasized, however, that there are significant differences in absolute values. Thus, while in Netherlands and UK, the BWFD values are the lowest (3.07 m^3/yr/cap in the Netherlands and 4.14 m^3/yr/cap, in the UK), in Bulgaria and Italy they reach 13.84 m^3/yr/cap, and 14.33 m^3/yr/cap), about 3.5 times more. As far as Romania is concerned, it ranks 15th (relatively close to the EU average), with a BWFD of 7.65 m^3/yr/cap.

The graphical representation of the concentration curve for GWFB (Figure no. 2) highlights in this case also a low degree of concentration, but higher than in the case of BWFD.

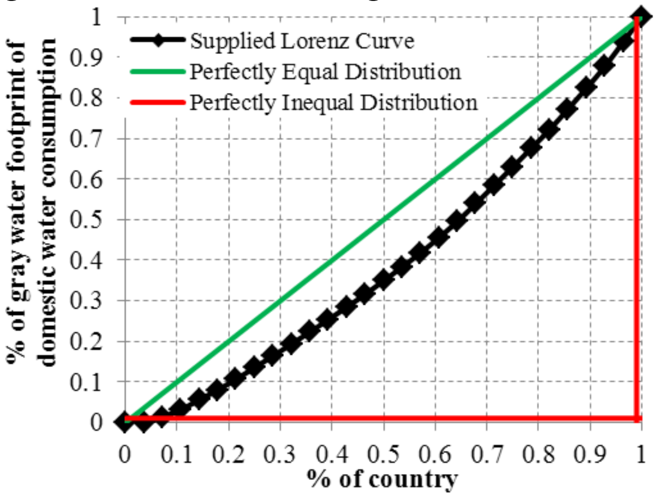

Figure no. 2. Concentration curve of GWFD in 27 EU countries

For GWFD, the countries with the smallest consumption are also UK (4.1 m^3/yr/cap) and Netherlands (6.5 m^3/yr/cap). At the other end, with the highest consumption, there are also Bulgaria (88.5 m^3/yr/cap) and Italy (67.7 m^3/yr/cap), among them Malta (81.0 m^3/yr/cap), from the tenth place in terms of the BWFD, is now ranked second. In this ranking on GWFD, Romania ranks 7th, between Portugal and Greece, with 58.5 m^3/yr/cap.

The comparative analysis of the two concentration curves highlights the lack of significant concentration on both GWFD and GWFD. This statement is reinforced by the values of the numerical indicators that characterize the level of concentration (Table no. 2).

Table no. 2. Concentration indicator values for BWFD and GWFD in 27 EU countries

	Gini Coefficient	Entropy	Normalized Entropy	Hirschman-Herfindahl	Normalized Herfindahl
	G	**S**	**S_0**	**H**	**H^***
BWFD	0.2145	3.24	0.97	0.0055	0.2145
GWFD	0.3315	3.14	0.94	0.0131	0.3315

Analyzing the concentration indicator values shows that GWFD in the 27 analyzed countries has a higher degree of concentration than the BWFD, the values of the G, H, H* coefficients being higher for the GWFD than for the BWFD, respectively lower values in the case indicators S and S_0.

On the other hand, since both the BWFD and the GWFD, the values of the G, H, H* coefficients are close to the lower limit (0.192 for G, 0.037 for H and 0 for H*), respectively of the upper limit of the coefficients S and S_0 (3.296 for S and 1 for S_0) it results that their concentration levels are very low.

For a clearer image of the distribution of WFD and its BWFD and GWFD components in the 27 analyzed states, the orderly increasing values of BWFD and GWFD (m^3/yr/cap) were grouped into six equal amplitudes ranges.

Starting from these groups, for each of the two water categories, taking into account the population number of the respective countries (thousands) and the per capita consumption, TBWFD and TGWFD were determined at group level (thousand m^3/yr), as well as their weight in total domestic water consumption in the 27 countries.

Also, for comparability, weights of the population of each of the six groups were determined in the total population of the 27 countries at the level of the survey year [2]. The results are shown in Table no. 3.

Table no. 3. The characteristics of the WFD concentration in the 27 countries per intervals of consumption per capita, water types, weights in TBWFD and TGWFD and the weights of the number of inhabitants in the countries of each group in TINH

Groups of countries	BWFD				GWFD			
	Variation ranges (m^3/yr/cap)	No. of countries	Weight in total (%)		Variation ranges (m^3/yr/cap)	No. of countries	Weight in total (%)	
			TINH	TBWFD			TINH	TGWFD
1	3.07-4.89	2	15.56	7.06	4.09-18.15	4	16.77	2.75
2	4.89-6.72	6	10.92	7.25	18.15-32.21	9	40.27	29.69
3	6.72-8.55	8	28.70	24.03	32.21-46.27	5	18.68	20.75
4	8.55-10.37	4	4.28	4.87	46.27-60.33	5	10.24	17.23
5	10.37-12.20	4	25.14	32.18	60.33-74.39	2	12.31	25.00
6	12.20-14.03	3	15.40	24.61	74.38-88.45	2	1.73	4.58

The variation ranges, shown in Table 3, show a significantly higher GWFD than the BWFD in the 27 countries.

For blue water, Group 1 includes two countries, Neatherlands and UK (Table no. 4), which accounted for 15.56% of the EU population at the time of the study, and consumed 7.06% of the TBWFD. In the case of gray water, Group 1 has four countries: Netherlands, UK, Luxembourg and Denmark with 16.77% of the total population and with a GWFD consumption of 2.75% of the TGWFD.

Table no. 4. The distribution of the 27 countries by groups and by type of water footprint of domestic water onsumption per capita

Groups	Structure of groups	
	BWFD	GWFD
1	Netherlands, UK	UK, Netherlands, Luxembourg, Denmark
2	Poland, Luxembourg, Lithuania, Estonia, Finland, Ireland	Germany, Spain, Belgium, Estonia, Lithuania, Finland, Ireland, Poland, Sweden
3	Latvia, Hungary, Germany, Belgium, Romania, Denmark, Slovakia, Cyprus	Austria, Latvia, Hungary, France, Czech Republic
4	Austria, Slovenia, Malta, Czech Republic	Slovakia, Greece, Romania, Portugal, Cyprus
5	Portugal, France, Greece, Spain	Slovenia, Italy
6	Sweden, Bulgaria, Italy	Malta, Bulgaria

At the opposite pole, in Group 6, there is the largest water footprint of domestic consumption. Thus Sweden, Bulgaria, Italy, with a share of 15.40% of the total population of the 27 countries, have a BWFD share of 24.61%. Compared with the first group (with a similar weight in TINH), the BWFD consumption is 3.49 times higher. Noteworthy that these three countries, together with Portugal, France, Greece, Spain, which form Group 5, from the BWFD point of view, consume 56.79% of the TBWFD, which means that 7 out of the 27 countries consume more half of the TBWFD.

As regards GWFD, Malta and Bulgaria (Group 6) with a share of 1.73% of TINH consume 4.58% of TGWFD. These together with Slovenia and Italy (Group 5) consume 29.58% of TGWFD, which means that in 4 of the 27 countries with 14.04% of TINH consumed almost one third of TGWFD, while in the four countries of Gropu 1 (UK, Netherlands, Luxembourg, Denmark) with a share of 16.77% of TINH consumes only 2.75% of TGWFD. The differences are enormous.

The differences between BWFD and GWFD consumption are evident also by analyzing the evolution of their cumulative values against the cumulative evolution of TINH. Thus, in the blue water category (Figure no. 3), the cumulative BWFD (TBWFD) and TIHN cumulative values are almost parallel. These evolutions point to a very low degree of concentration (as the population increases, the consumption of BWFD increases).

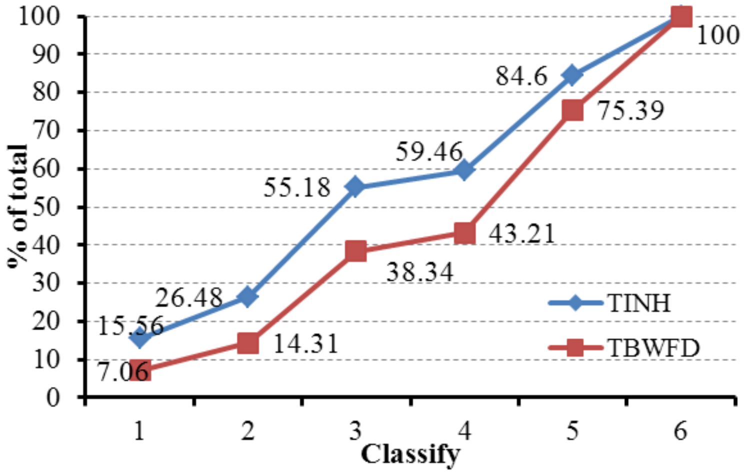

Figure no. 3. Cumulative evolutions of TIHN and TBWFD

Regarding GWFD, its cumulative evolution, represented by TGWFD (Figure 4), differs from that of TINH. The differences are evident for the first two groups, for which TGWFD weights increase much more slowly than for TINH, which means that GWFD consumption is relatively small in relation to population growth. On the other hand, in the case of the latter two groups, increases in cumulative weights of TINH are lower than the increases in TGWFD weights. In this case, we are seeing a significantly higher consumption of GBWD than in previous groups.

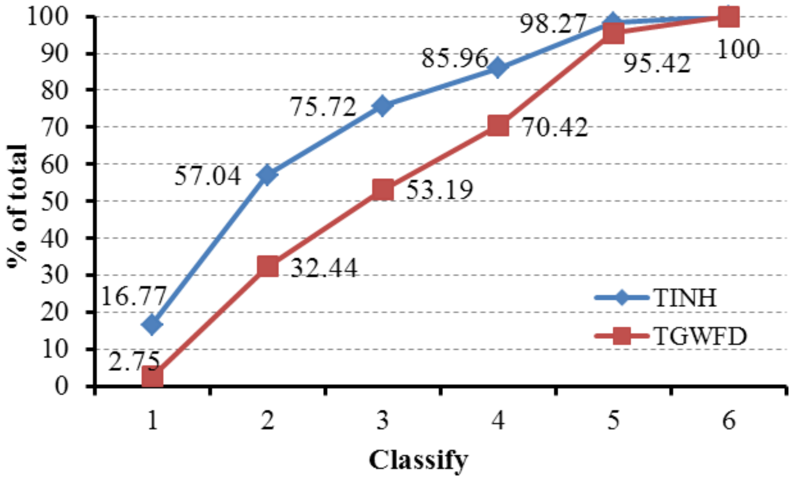

Figure no. 4. Evolution of the cumulative values of TIHN and TGWFD

Different characteristics of BWFD and GWFD consumption are found in other groups. In the case of BWFD in Group 3 and Group 4, with consumption between 6.72-8.55 m^3/yr/cap and 8.35-10.37 m^3/yr/cap, the weights of the populations of the countries in these groups in TINH are approximately equal to the BWFD weights in the TBWFD. Thus, in these two groups, one third of the population of the 27 countries consumed about 30% of the TBWFD.

In terms of GWFD, the 14 countries, from Group 2 and Group 3, accounted for 58.95% of TINH and consumed 50.44% of TGWFD. It should be noted, however, that in Group 2, the share of the population of the 9 countries in TINH is 10.58 percentage points higher, in the case of the 5 countries of Group 3, the share of their population in TINH is lower by 2.07 percentage points, hilights a significant difference between GWFD consumption in the two groups, the difference being accentuated by the fact that, per capita, the consumption in Group 3 is higher than in Group 2.

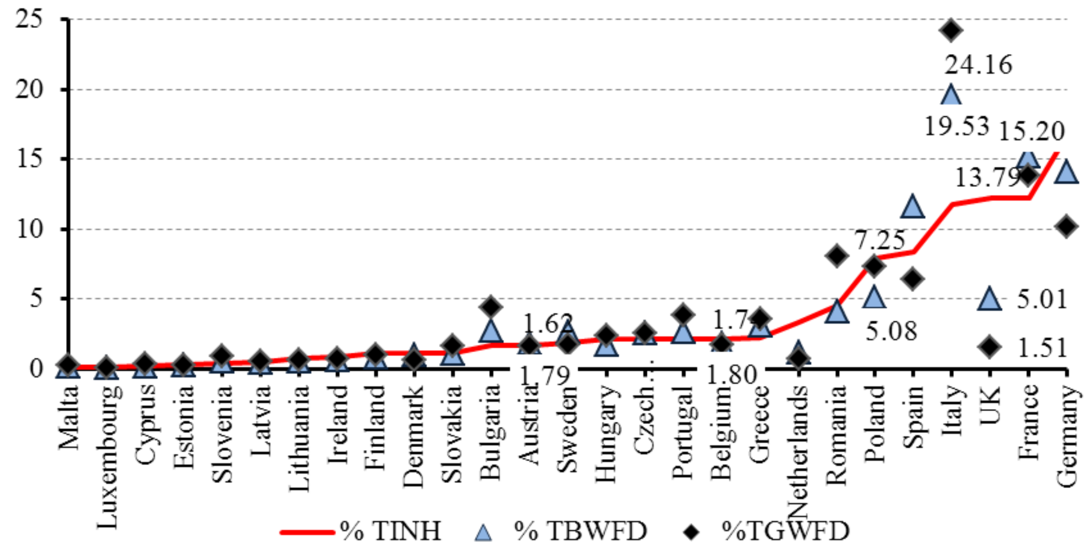

Figure no. 5. The weights of the populations of the analyzed countries in TINH and the weights of BWFD and GWFD in TBWFD and TGWFD

Although the main focus of the work was to analyze the consumption of BWFD and GWFD per capita, we also consider it useful to have a 27-country comparative presentation of their TINH population share along with the BWFD and GWFD consumption weights in TBWFD and TGWFD (Figure no, 5).

In much of the 27 countries, there are significant differences between the weights of their population in TINH (represented in Figure no. 5 through the continuous red line) and the weights of consumption in the two types of water. The largest consumer is Italy. With a population of 11.79 in TINH, it consumes nearly a quarter (24.16%) of TGWFD and one fifth (19.53%) of TBEFD.

On the opposite side lies the UK, whose population represented 12.16% of TINH, consumed only 5.01% of TBWFD and 1.51% of TGWFD. Weights of BWFD and GWFD, significantly lower than those of TINH were registered in Denmark, Poland and Germany.

CONCLUSIONS

The water footprint analyzes of domestic consumption per capita in the 27 countries included in the analysis revealed a relatively low degree of concentration for both BWFD and GWFD, which has some particularities in the sense that variation ranges have much larger amplitudes . Thus, while the BWFD ranged from 3.07 to 14.04 m^3/yr/cap, the GWFD ranged between 4.09 and 88.45 m^3/yr/cap.

Also, as a result of the grouping of countries on consumption intervals, the relatively low concentration of both water footprint of domestic categories is analyzed and highlighted, both by graphical representations and by the population of the respective countries, and by consumption per capita.

The comparative analysis of the population share of each of the six groups in the total population of the 27 countries and the weights of consumption in the two water categories revealed that there are differences between BWFD and GWFD consumption. Analyzing the evolution of the cumulative values of BWFD and TIHN, it can be concluded that, as they are almost parallel, population growth has led to an increase in BWFD. At the same time, consumption of GWFD is relatively small in relation to population growth, especially for the first two groups of countries, while for the countries of the latter two groups we are witnessing a reverse situation.

The analysis highlights that both for the BWFD component and for the GWFB, Netherlands and UK are the countries with the lowest water footprint of domestic consumption, while for Bulgaria and Italy, the records show that they are the largest consumers.

Starting from the results presented in this paper, those highlighted by the research team in other papers, as well as from the studies and reports existing or to be published in the near future, we propose that in future works we disseminate the results of the research in particular in terms of Romania and Balkan and Central European countries.

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