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AN OVERVIEW ON THE DEVELOPMENT AND PROGRESS OF WATER SUPPLY AND WASTEWATER TREATMENT IN ROMANIA

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Abstract

The water supply system is very important for the development of the country. Furthermore, a wastewater treatment with more than two levels of treatment decreases the risk of environmental pollution with heavy metals and better cleans the water that will be reused. According to Eurostat, in 2011 more than 40% of the Romanian population was not connected to the public water supply and even more to the wastewater system. In the present study raw data were analyzed and plotted to show the evolution of the drinking water supply and wastewater treatment, sludge production and disposal, precipitation and evaporation, freshwater abstraction, water consumption for different activities, and renewable freshwater resources during the period 2001 to 2011, before and after joining the European Union, integrated in the context of the future challenges. Since the Romania joined to the EU the projects co-financed by the EU for water supply development and rehabilitation were executed very fast. New modern water treatment plants were constructed and many villages were connected to the safe water supply system and wastewater treatment plants. As a result, a large number of RRomanian inhabitants have access to a safe water resource monitored permanently.

Keywords: renewable freshwater resource, sludge production, wastewater treatment, water supply

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1. Introduction

The challenges of the 21st Century are multiple and variable. The demand for resources is increasing parallel to the human population on Earth. Humans cannot live without air, water and food, therefore the exploitation of these resources requires the best strategies and plans which do not harm the environment and the other life forms sharing the resources of the planet.

The man needs water for his biological and physiological functions. Since the beginning, water resource played an important role. The interest for water resource control and treatment with the purpose to protect the inhabitants of the cities started at the beginning of the 19st Century (Molinos-Senante et al., 2014). The concentration of the human populations in the urban areas is positively correlated to the economic activities and water demand (Istrate et al., 2017; Jiang and Xiao, 2017; Talalaj 2017).

Clean water is converted to wastewater by anthropogenic activities. This can easily contaminate the soil, groundwater and surface water with toxic metals, organic compounds and pathogenic microorganisms (Hidri et al., 2014). The economic prosperity and life quality of the inhabitants depend on cities' infrastructure like highways, roads, water supply, wastewater treatment system (Harchaoui et al., 2004; Rehan et al., 2014) and the decision support system for wastewater solutions (Chamberlain et al.,

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2014). The water supply and sewerage of a city can be compared with the biological “circulatory system”. This comparison makes the cities same as “biological forms” with “organs” that have different functions, in this case to provide clean and safe drinking water for inhabitants, different business and to collect the contaminated water that will be stored, treated, reused and returned to environment (Rehan et al., 2014).

According to the theory of Kauwenbergh (2010) about phosphorus depletion, the experts agreed and claimed that reserve of phosphate rock will last 300-400 years for exploitation at current rate with countries like Morocco and Western Sahara that holding almost 70% of the known resource. European Commission proposed for 2014 a directive (Directive of the European Parliament and of the Council amending EC Directive 98, (2008); EC Directive 62 (1994); EC Directive 31, (1999); EC Directive 53, (2000); EC Directive 66, (2006) and EC Directive 19 (2012) in the general context of Union’s economy that loses a significant amount of potential secondary raw materials which are found in waste streams. Furthermore, the Union misses out significant opportunities to improve resource efficiency and create a circular economy based on economic growth, jobs and reduction of dependency on imported raw materials. The investments in the public water supply, sewerage and wastewater treatment are not visible all the time because the pipes are buried underground and they are hard to be seen by the citizen (Brubaker, 2011). Each wastewater treatment plant and pumping station must be optimized and controlled to have a better efficiency and quality at the lowest price possible (Molinos-Senante et al., 2014).

Almost 70% of the freshwater pumped all around the world is used for agricultural irrigation; some countries use more than 95% of the quantity pumped. The competition for the water resource is between agriculture, industry and urban areas (Sato et al., 2013). The result of the increased use of water for non-agricultural activities will be the production of a higher wastewater quantity that is expected to be even larger because of the growing population. The complete information for wastewater treatment and freshwater usage is available for ten European countries only. Romania is one of the countries with partial data available and it was classified by Sato et al. (2013) as having a ratio of treated wastewater to total wastewater generated below 20%, based on data from Eurostat (2012).

Since the Romania joined to the EU the projects co-financed by the EU for water supply development and rehabilitation were executed very fast. New modern water treatment plants were constructed and many villages were connected to the safe water supply system and wastewater treatment plants. As a result, a large number of RRomanian inhabitants have access to a safe water resource monitored permanently. In the present overview were used raw data that were analyzed and plotted to present the evolution of the drinking water supply and wastewater treatment, sludge production and disposal, precipitation and evaporation, freshwater abstraction, water consumption for different activities, and renewable freshwater resources in Romania from 2001 to 2011, before and after joining the European Union. These were integrated in the context of future world challenges and sustainability the safe water drinking resources.

2. Methods

We used published data and web-based online data provided by European Commission (Eurostat, (2011),) supporting Eurostat available for Romania. The data were extracted on 05.04.2014 with the last update made on 20.03.2014. We extracted data sets necessary for this study (Table 1). Data were analyzed and plotted in OriginPro8.Ink. The results for freshwater resource were estimated for an average population of 21.5 million inhabitants. The statistical analysis with the comparison tests were not applied to the extracted data because these data were not continuous. The missing data did not allow the correct testing of the hypothesis in the comparison tests; nevertheless, a simple comparison test was applied to the available data in case of water consumption for different activities, sludge production and disposal. First these data sets were separated in two groups: water consumption for different activities (Group 1: 2002 to 2006; Group 2: 2007 to 2011), sludge production and disposal (Group 1: 2005 to 2007; Group 2: 2008 to 2011).

The normality of the data was first tested by applying Shapiro-Wilk test, and afterwards T-test was applied for the comparison between the groups in case of each data set. The data were separated in two groups with same size in order to proceed a correct test. The rest of the data were presented in simple graphs and tables.

3. Results and discussion

3.1. Freshwater resource estimated for abstraction

The estimated available groundwater resource (Fig. 1) that can be extracted was estimated 9,000-9,600 million cubic meters per year during the years 2003 to 2011, a stable amount that can be considered the water reserve of the country.

According to The International Benchmarking Network for Water and Sanitation Utilities (IBNET, 2017) the total water consumption estimated per capita per day in Romania was between 206 liters in 2006 and 153 liters in 2010. The main water resource that has the highest potential for abstraction is represented by the internal flow which was estimated to be between 28,500 and 63,300 millions of cubic meters per year during the years 2003 to 2011 (Fig. 1). This resource depended on the total precipitation (Fig. 2).

Table 1. Data set extracted from Eurostat with the measurement units used in the study

Data set	Measurement Unit
Renewable freshwater resource	
Precipitation	10^6 m³
Total actual outflow	10^6 m³
Groundwater available for annual abstraction	10^6 m³
Actual external inflow from neighboring territories	10^6 m³
Actual evapotranspiration	10^6 m³
Generation and discharge of wastewater in volume	
Total generation of wastewater at point sources	10^6 m³
Urban wastewater treatment – total inflow	10^6 m³
Total discharges to inland waters	10^6 m³
Total discharge of wastewater treatment plants	10^6 m³
Total discharge to the sea	10^6 m³
Sewage sludge production and disposal	
Total sludge production	10^3 tones
Total sludge disposal	10^3 tones
Annual freshwater abstraction by source and sector	
Water abstraction for agriculture	10^6 m³
Water abstraction for public water supply	10^6 m³
Water abstraction for manufacturing industry	10^6 m³
Population connected to public water supply	%
Population connected to wastewater treatment plants	%
Total connected to wastewater treatment	%
Urban wastewater collecting system	%
Total urban wastewater treatment plants	%
Urban wastewater treatment plants with secondary treatment	%
Urban wastewater treatment plants with tertiary treatment	%
Wastewater treatment plants by treatment level	
Number of urban wastewater treatment plants with secondary treatment	numeric value
Number of urban wastewater treatment plants with tertiary treatment	numeric value
Number of urban wastewater treatment plants with tertiary treatment-nitrogen removal	numeric value
Number of urban wastewater treatment plants with tertiary treatment-phosphorus removal	numeric value

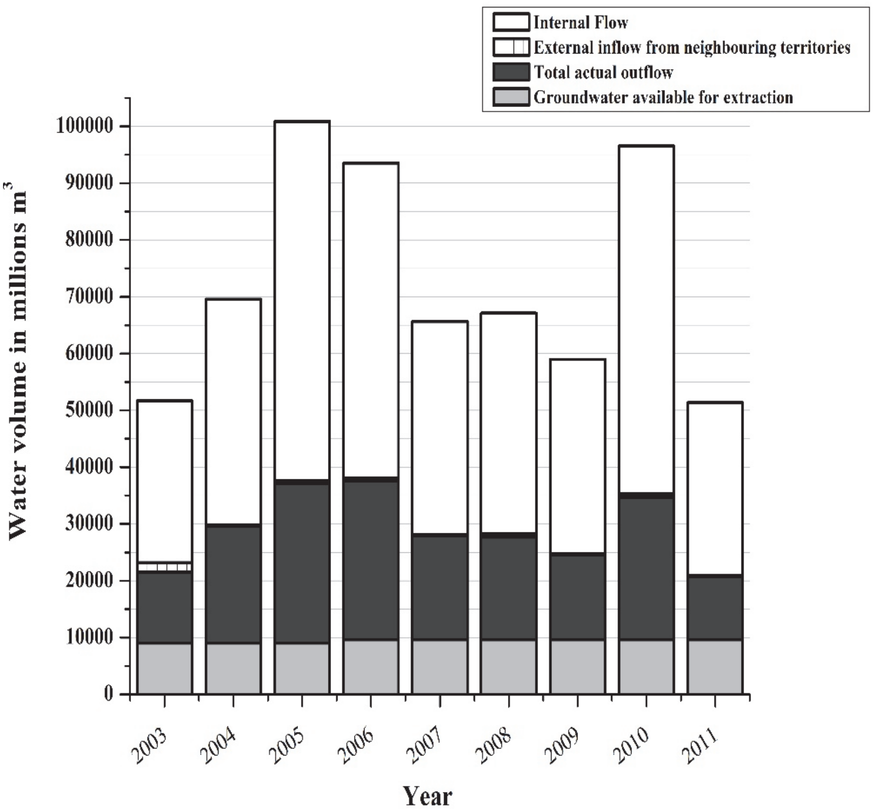


Fig. 1. Freshwater volume estimated for abstraction in Romania during 2003-2011

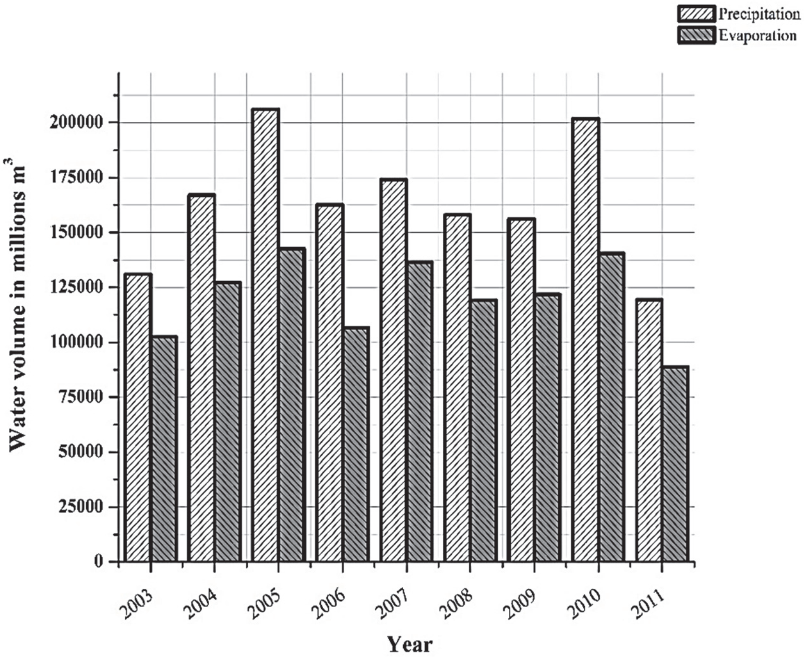


Fig. 2. Precipitation and evaporation volume estimated in Romania during 2003-2011

For instance, during the year 2005 it had the highest level - around 206,000 million cubic meters. Evaporation plays an important role in the abstraction of the water resource. In Romania, according to the estimations, it was lower than the volume of the precipitation. This provided an extra volume of water that could be used for the country's' activities.

Supposing that all population of the country was connected to the national water supply, we estimated the volume of water that was available for each Romanian inhabitant during the years 2003-2011. In the case of an average population of 21.5 million inhabitants, the groundwater available resource is between 428.57 and 457.14 m³ per capita. The volume of internal flow is between 1357.14 and 3014.28 m³ per capita and external inflow from neighboring territories is between 11.9 and 78.76 m³ per capita. These are theoretical estimations. This amount cannot be entirely used because there are protected areas like natural reserves, private properties and areas contaminated with different compounds (Pavel et al., 2009; 2010).

3.2. Population connected to public water supply and wastewater collecting system

Romania became a member state of the European Union on 1st of January 2007. It was a long way of negotiations before the membership affiliation. In Chapter 12 of the Negotiations is written that the implementation of the decisions requires statistical data base. The country must be capable to provide real and continuous data.

The quality of the data and statistics depends pretty much on the general administration of the country, the services' quality, the capacity to recruit and keep the high qualified staff (Romania's accession to EU: Negotiation Chapters, 2007). The future challenge for Romania is to develop even more the public water supply, the wastewater collecting system and the technology for water cleaning and reuse. The data are available starting with the year 2002 (Fig. 3) but are not complete. According to these data, 54% of the population was connected to the public water supply in 2002. This estimation is questionable because in the year 2007 only 49% of the population was connected (Fig. 3). It has been observed an increasing between the years 2007 and 2011 of the percentage of the connected population, more than 16 % to public water supply. The data available for population connected to wastewater collecting system are available starting with the year 2006. Connection to wastewater collection system increased from 31.4% in 2006 to 41.6% in 2011. According to these estimations, in 2011 more than 14% of the population was connected to the public water supply, without a properly connection to wastewater system. The percentage of the population connected in this year to the treatment plants was 27.2% and increased to 40% in 2011. In 2004 it was estimated that only 16.9% of the population was connected to the treatment plants with secondary treatment, but this percentage increased to 30.2% in 2011.

The data for treatment plants with tertiary treatment are available for the year 2010 and 2011, but the percentage of the population connected to these plants was around 0.7% in 2010 and 0.8 to1 % in 2011. These values are very low compared to other EU countries where more than 80% of the population is connected to treatment plants with secondary and tertiary treatment (e.g.: population connected – tertiary treatment: Germany 91-92%, Austria 93%, Sweden 81-83%, Denmark 87%, Greece 82%, Lithuania 62%, Belgium 63%, Poland 52%, Ireland 43%, Hungary 37%, Bulgaria 34%), data source Eurostat.

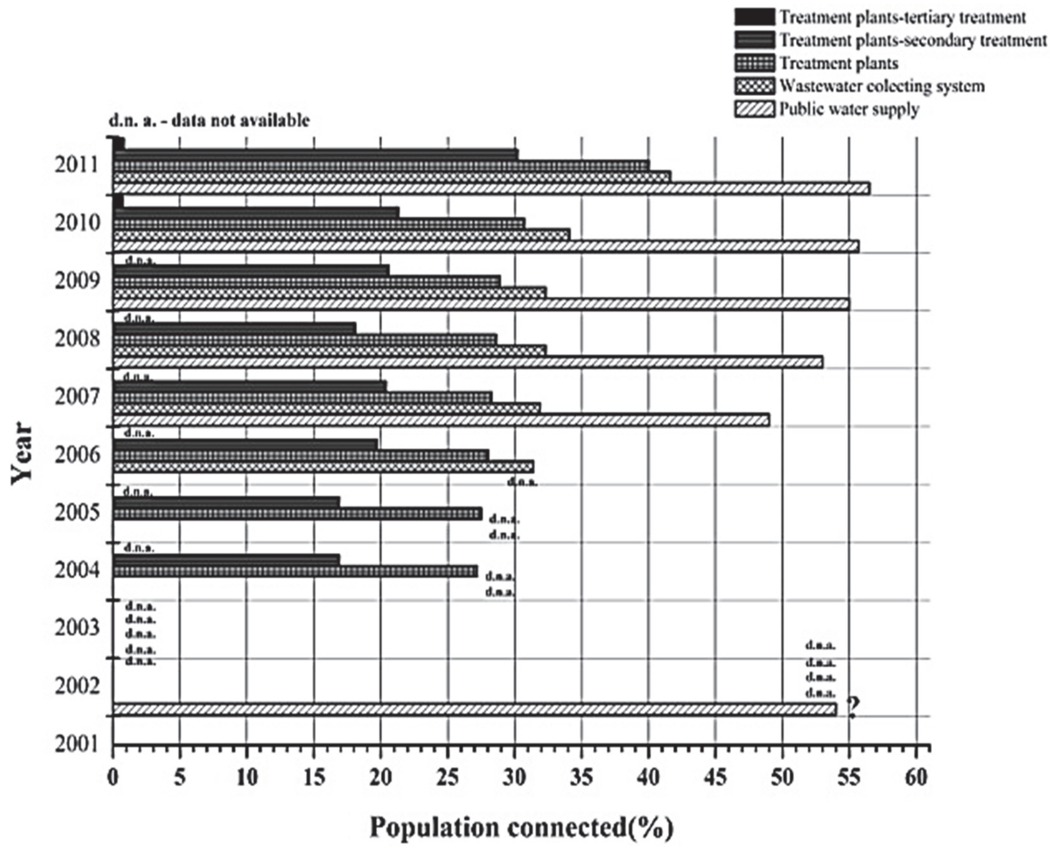


Fig. 3. Percentage of the Romanian population connected to the public water supply and wastewater collecting system during 2001-2011

The quality of the data and statistics depends pretty much on the general administration of the country, the services' quality, the capacity to recruit and keep the high qualified staff (Romania's accession to EU: Negotiation Chapters, 2007). The future challenge for Romania is to develop even more the public water supply, the wastewater collecting system and the technology for water cleaning and reuse. The data are available starting with the year 2002 (Fig. 3) but are not complete. According to these data, 54% of the population was connected to the public water supply in 2002. This estimation is questionable because in the year 2007 only 49% of the population was connected (Fig. 3). It has been observed an increasing between the years 2007 and 2011 of the percentage of the connected population, more than 16 % to public water supply. The data available for population connected to wastewater collecting system are available starting with the year 2006. Connection to wastewater collection system increased from 31.4% in 2006 to 41.6% in 2011. According to these estimations, in 2011 more than 14% of the population was connected to the public water supply, without a properly connection to wastewater system. The percentage of the population connected in this year to the treatment plants was 27.2% and increased to 40% in 2011. In 2004 it was estimated that only 16.9% of the population was connected to the treatment plants with secondary treatment, but this percentage increased to 30.2% in 2011. The data for treatment plants with tertiary treatment are available for the year 2010 and 2011, but the percentage of the population connected to these plants was around 0.7% in 2010 and 0.8 to1 % in 2011. These values are very low compared to other EU countries where more than 80% of the population is connected to treatment plants with secondary and tertiary treatment (e.g.: population connected – tertiary treatment: Germany 91-92%, Austria 93%, Sweden 81-83%, Denmark 87%, Greece 82%, Lithuania 62%, Belgium 63%, Poland 52%, Ireland 43%, Hungary 37%, Bulgaria 34%), data source Eurostat.

3.3. Water consumption for the main activities

Three main activities for water consumption in Romania were identified. These are: agriculture, domestic consumption and manufacturing industry.

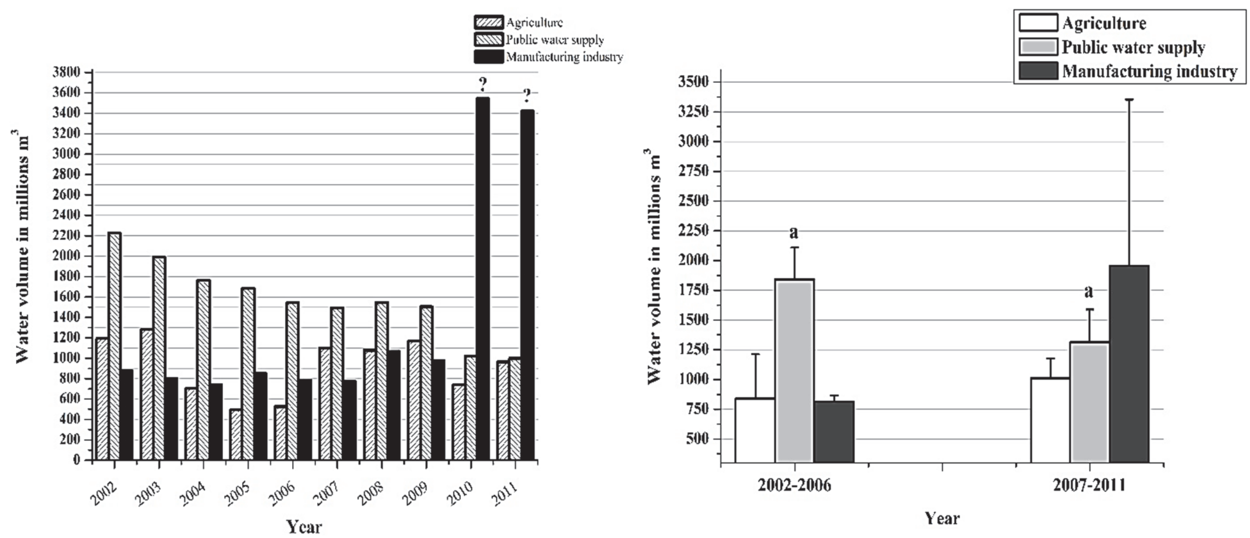
Data are available starting with the year 2002 when the highest water consumption was estimated in the public sector and it was around 2,225 million of cubic meters year^{-1}, followed by agriculture (Fig. 4) with 1.192 million of cubic meters year^{-1} and manufacturing industry with 877 million of cubic meters year^{-1}. It is obvious that the highest amount of water is pumped for the public sector and not for agriculture. The years 2005 and 2006 had the lowest water demand for agriculture. This can be correlated with the precipitations which were in the highest amount. This means that agriculture sector has the main water resource from precipitations and it used more pumped water in the years with lower amount of rainfalls. Another problem that was noticed is the estimated water consumption in the public sector which was lower in 2010 and 2011 than the rest of the years though the percentage of the population connected to the water supply increased. The data values suddenly increased for manufacturing industry in the years 2010-2011. This problem raises some doubts about it. The results of the comparison T-test conducted between two equal size groups 2002-2006 and 2007-2011 for each component were significant for the public water supply only. According to the results it was significantly decrease of public water supply volume in 2007-2011 (T-value was 3.065659, P-Value was 0.007725 and the result was significant). This result interpretation is based on the numerical estimation provided by Eurostat. In the case of agriculture (T-value was 0.929699, P-Value was 0.189863 and the result was not significant) and of manufacturing industry (T-value was 1.828231, P-Value was 0.052461 and the result was not significant), it was not observed any improvement. Anyway, it is hard to prove improvement based on the estimation data. The data provided from monitoring of these water consumers are important. Each water distribution company has all the data for each consumer. These data well interpreted may provide important information about the needs and evolution of water supply (Fig. 4).

3.4. Wastewater production, sludge production and discharges

The population rapidly growth from the last fifty years demanded rapidly the development of the water supply system. With water consumption higher demand, the wastewater production increased very fast. The human population growth increased the environmental pollution and the resources demand. An important question appeared from this – How to control this phenomenon? (supplying the population with clean water and other resources, reduction the pollution and to sustain the future Earth inhabitants). It is known that untreated wastewater represents an environmental pollution source with industrial chemicals, pesticides, pharmaceutical compounds, personal care products (Gavrilescu et al., 2014) and pathogens (Hidri et al., 2014; Singh & Agrawal, 2008; Yoshida et al., 2013). Toxic heavy metals as Pb(II), Cd(II), Hg(II), Cu(II), Ni(II), Zn(II), Cr(III) and Cr(VI) will cause major problems to the life forms, if they are not removed from the wastewater (Hlihor and Gavrilescu, 2009; Hlihor et al., 2013; Jitar et al., 2013; Pintilie et al., 2007).

It is important the constant monitoring of wastewater production and discharges in environment in order to do strategies planning to avoid the water resources pollution and to preserve these resources for the future generation. In table 2 are presented the estimations for the discharges in Romania during the years 2002 – 2011. It is very important that the missing data to be presented in order to estimate the trend line of these in environment.

The application of household wastewater rich in nutrients as fertilizer was a good idea for soils irrigation because this has the potential to gradually eliminate the chemical base fertilizers from chemical industry (Hidri et al., 2014). In the end, this idea proved to be a contamination source of soils with heavy metals, organic chemicals and pathogens in many studies all around the world (Hidri et al., 2014). Metals as copper, zinc and nickel are coming in household wastewaters from pharmaceutical and house cleaning products (Lain et al., 2001). On the average, a man can contaminate the wastewater from his house with trace elements more than 20% by fecal and urine (Minale and Worku, 2014).



(a) (b)

Fig. 4. Estimated water consumption for the main activities in Romania during 2002-2011
(a- p<0.05 in the comparison of public water supply between (a) 2002-2006 and (b)2007-2011)

Table 2. Total estimated discharges in Romania during 2002-2011 (millions of cubic meters)

Year	*Urban wastewater treatment - total inflow*	*Total discharges to inland waters*	*Total discharges of wastewater treatment plants (urban and other)*	*Total discharges to the sea*
2002	d.n.a.	d.n.a.	d.n.a.	d.n.a.
2003	d.n.a.	d.n.a.	d.n.a.	d.n.a.
2004	d.n.a	d.n.a.	d.n.a.	d.n.a
2005	d.n.a.	4480	d.n.a.	578
2006	d.n.a.	3937.4	d.n.a.	272.5
2007	d.n.a.	4848.7	d.n.a	80.1
2008	642.2	5716.4	1121.4	294.4
2009	606.1	5088.5	970	d.n.a.
2010	755	4834.9	1226.8	d.n.a.
2011	752.5	5210.9	937.3	d.n.a.

d.n.a. – data not available

Untreated wastewater discharge to inland waters may create several problems to aquatic biodiversity. Data are available for total discharges to inland waters starting from the year 2005. These data show wastewater discharges per year ranging from 3,937.4 to 5,210.9 millions of cubic meters per year from 2005 - 2011 (Table 2). The data available for the total discharges to the Black Sea are estimated for the 2005-2008 (Table 2). These, combined with the discharges to the Danube, increased in the last decades the concentrations of the coastline waters, sediments and marine organisms in the Romanian Black Sea area with cadmium, cobalt, copper, nickel and lead (Jitar et al., 2013).

Wastewater treatment plants equipped with secondary and tertiary treatment levels are better for the environmental pollution prevention, and more efficient nitrogen and phosphorus removal. The plants equipped with secondary treatment increased from 206 in 2005 to 217 in 2011 (Table 3). There are no available data for 2012. Properly treated wastewaters can be reused for a lot of applications such as aquaculture, industry, irrigations, reusing in the residential areas, for recreation and swimming and regeneration of the water resources (Huertas et al., 2008).

The sludge that results from wastewater treatment has many possible applications. Many studies revealed that it can be used as land fertilizer and raw material for different construction products. Yoshida et al. (2013) explained the importance of phosphorus recovery from sludge, because it is a non-renewable and non-substitutable resource. The agriculture also requires phosphate fertilizers to increase its productivity and quality of the nutrients from the products.

Recovery of the phosphate from wastewater and sludge is very important for the future. The development and implementation of such technologies will be positive to environment, soils regeneration and agriculture. Romania produced more than 60 thousand tons of sludge in the year 2005 and this quantity increased to more than 100 thousand tons in 2011 (Fig. 5). The value for 2006 is questionable because it looks like an error, how is possible such a suddenly estimation of increasing the total sludge production. There is no confidence of this estimation followed by a decreasing of the value. The results of the comparison T-test conducted between groups 2005-2007 and 2008-2011 (Fig. 5) sludge total production were not significant (T-value was 0.758408, P-Value was 0.241202, the result was not significant at $p < 0.05$). Same situation for sludge total disposal (T-value was 0.903244, P-Value was 0.203902, the result was not significant at $p < 0.05$). An additional test between sludge total production and disposal was applied for each studied year group. In case of the group 2005 -2007 is was not observed any significant difference between the sludge production quantity and disposal (T-value was 1.445717, P-Value was 0.110892, the result was not significant at $p < 0.05$) on the other hand the results for the group 2008-2011 showed significant different between sludge production quantity and disposal (T-value was 3.780526, P-Value is 0.004587, the result was significant at $p < 0.05$).

Toxic metals in high levels of concentration in the sludge represent another problem that can be solved using the low-cost methods of extraction (Hlihor and Gavrilescu, 2009). This depends on how efficient these methods are on a large scale and on how they can be properly applied.

3.5. New challenges for the future

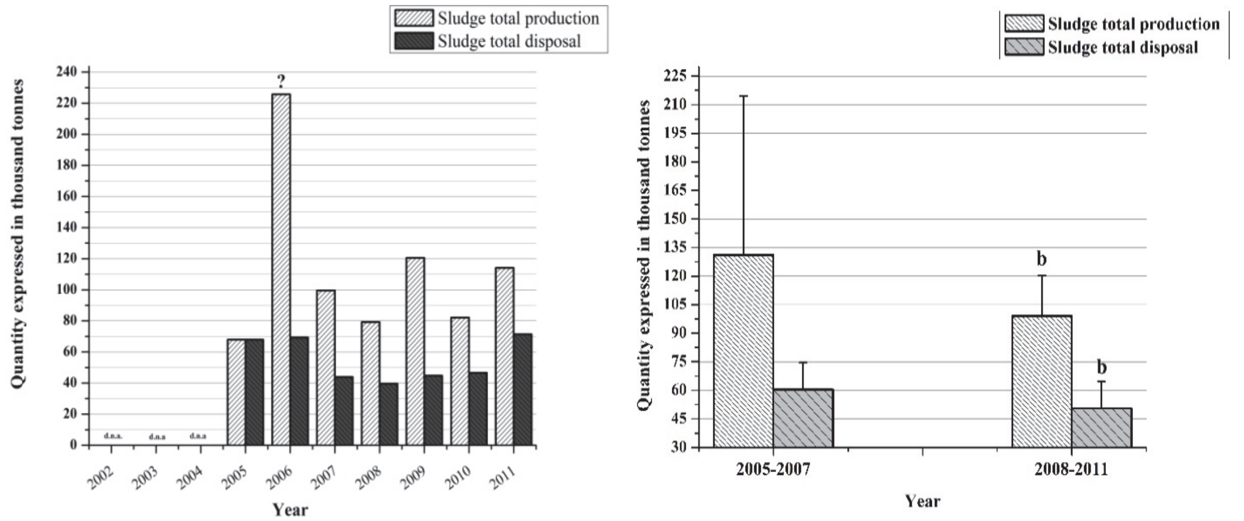
An important problem is represented by customers' requirements and expectations. Younis and Knight (2014) integrated these with the economy of the cities and social-political overviews. The authors identified in their study the main strategic targets of the water supply and wastewater system: the public health and safety, environmental protection through reduction of the damage to underground and surface waters, meetings with the customers to debate the future requirements, problems and expectations that will ensure the growing of the performances in water resource and wastewater treatment area, education of the population regarding the water consumption and wastewater production.

Molinos-Senante et al. (2014) identified other challenges in wastewater treatment, like environmental sustainability through the processes that involve the reduction of the resources consumption and wastes recycling.

Table 3. Number of treatment plants with secondary and tertiary treatment in Romania during 2002-2011

Year	*Secondary treatment*	*Tertiary treatment*	*Tertiary treatment with nitrogen removal*	*Tertiary treatment with phosphorus removal*
2003	d.n.a	d.n.a	d.n.a	d.n.a
2004	d.n.a	d.n.a	d.n.a	d.n.a
2005	206	d.n.a	d.n.a	d.n.a
2006	210	d.n.a	d.n.a	d.n.a
2007	235	d.n.a	d.n.a	d.n.a
2008	160	7	5	2
2009	160	7	5	2
2010	192	d.n.a	d.n.a	d.n.a
2011	217	4	2	2
2012	d.n.a	d.n.a	d.n.a	d.n.a

d.n.a. – data not available



(a) (b)

Fig. 5. Estimated sludge production and disposal in Romania (a) during 2002-2011
(b - p<0.05 in the comparison of sludge total production and (b) disposal in 2008-2011

Another challenge is the reduction of the costs at minimum necessary for improving these systems (water supply, treatment and reuse) and to search low costs methods but highly efficient in order to cover them. There are hundreds of studies in literature focused on the finding of new low-cost methods to treat and reuse the water but only few of them represent a high application potential. The problem with the prices was well explained by Rehan et al. (2014) in their study. According to their study, the price unit of wastewater treatment increases with the treatment costs and methods but It decreases when a higher water volume is treated. The costumers can answer to taxes increasing by reduction of water consumption, but this measure will provide a lower profit which will reduce the future investments. The investments in water/sewerage for development decrease the investments in rehabilitation activities because there are many factors involve: the water demand, price elasticity for water demand, current population and growing rate, the salaries, education level and socio-economic development.

One of the future challenges in the water supply development is the pipes inspection using the latest technology like high definition cameras with zoom to analyze the pipes surface, ultrasounds scanners, and laser analysis for pipes profiles and other nondestructive technology with sensors (Rehan et al., 2014). This is useful in the reduction of some costs. The collected data must be integrated in municipality data base, using GIS to faster identify the major problems that require major investments (Rehan et al., 2014). All of these innovations may increase the water supply price. For instance, according to IBNET (2017), the operational cost for a cubic meter water sold in Romania was 0.94 US $ in 2010.

The database is very important future investments. An international database with open access will give valuable information about water supply and sewage for different areas in a country, knowing that the entire system is an indicator for the quality of life and country development. The data management should be integrated with resources in activities planning and strategy. This combined with health and care system, education and water resource should minimize the anthropogenic pressures upon the environment. Thus, will sustain the resources and will increase the quality of life.

4. Conclusions

Romania is on the right track in terms of development of water supply system and wastewater treatment, but the progress was slow between 2001-2011, though some of the provided data show a different picture, where the development tendency is falling (if we can trust the available data). There are many challenges for the future, but the main problems must be firstly identified.

The European membership increased investments in development of the water supply and technology of wastewater treatment; this should be continued in the future. A strong and well analyzed national database with open access is necessary in order to avoid errors. This will be very important for the future investments and strategic development plans. Education, public health, environment management, recycling the resources, high quality data and strategies play the most important role and these should work together in order to confront the future challenges that create more visible pressure to the environment. The profit from water business should be calculated for a long time period, based on the analysis of customer resources and a flexible price is required.

The protection of the environment is important to avoid the pollution of surface and ground water which is not an unlimited resource, this means that more than 90% of the population to be connected to a safety water resource and treatment plants in order to control and reuse this resource. It demands even more investments for this and for the cleaning technology. Romania has important water resources but these must be well used and reused, and a great agricultural potential that requires pumped water to have the optimal production. The challenges are multiple, but with hard work they can be accomplished. The highest priority should be the national and international database platform.

All the private water and wastewater companies and national authorities should cooperate and concentrate their attention for the future database which is important for the development.

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