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HOW TRUTHFUL ARE WATER ACCOUNTING DATA?

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Abstract: Water accounting is an important tool for water managers. Many studies use official water accounting data or similar data for their assessment. In particular, large-scale studies or water footprint studies have limited opportunities for "in-situ" data collection. In many cases, the processors of studies do not know the origin of the data and their limitations. Water accounting data are very often used for decision-making process, water resource management, and planning in the water sector. This article tries to answer the question "How truthful are water accounting data?" For this task water accounting in the agriculture sector in the Czech Republic was selected. The data on water withdrawals for the agriculture purposes was analysed and compared with water needs estimation based on additional data on agricultural production.

Keywords: The Czech Republic, water use, water accounting, case-study, agriculture water withdrawals

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INTRODUCTION

Water is essential for human life, nature, and the economy (EC, 2012). In connection with the growth of world population and economy, as well as the expected impacts of climate change, the number of studies dealing with future water demand in different regions and sectors is growing. In particular, the studies covering a large area must be based on available data sources and cannot use the individually collected data specifically focused on the needs of the study. In such cases, the data from official water accounting are usually preferred, either the data from the national or supra-national statistical offices or data from the relevant government or international institutions.

However, each of these sources has its own methodology and data collection purpose. These data are not always useful for some types of studies; see, for example, the conclusions of the US Government Accountability Office (GAO, 2009, p. 50). Unawareness of the limits of the data used or omission of the validation of the data used can lead to incorrect partial or even overall conclusions of the study. For example, the partial results of the Water Scenarios for Europe and Neighbouring States (SCENES) project, which was implemented from 2006 to 2011: For the power engineering sector, the SCENES project is based on data from International Institute for Applied Systems Analysis (CESR, 2011). These data do not include withdrawals for the Temelin nuclear power plant, which was put into operation in 2002 (construction started in 1985). As a result, the projection of the SCENES project states the water demand for 2005 to the value of 416.9 Mm^3; the official statistics of the Czech Republic state the value of 806.1 Mm^3 (MoA, 2005). Another example is a study modelling the water demand for livestock production in Europe (Mubareka *et al.*, 2013). The authors of the study validate the modelled data for livestock with the data on water consumption throughout the entire agricultural sector according to EUROSTAT and FAO. It is striking that, despite the diametrically opposed figures of the model and both databases, the authors conclude "thus the consumption of the livestock may be correct according to our estimates". In response to the study of Mubareka et al. (2013), data validation of the water demand for livestock in the Czech Republic was conducted.

WATER NEEDS IN AGRICULTURE

The biggest user of fresh water in the world is the agricultural sector (Grafton & Hussey, 2011) with a share of approximately 70%. In Europe, agriculture accounts for approximately 33% (EEA, 2012); however, in some regions such as Western, Central and Eastern Europe, according to FAO (2014) the withdrawals for agriculture represent only 5–10% of all withdrawals. EUROSTAT (2016) presents withdrawals for agriculture as well as overall withdrawals in individual countries. The EUROSTAT data show that agriculture in various countries contributes to water withdrawals very differently, and for some countries data is not available. The importance of data availability and quality is growing with possible significant increases in water demand for agriculture due to increasing global food demand and the promotion of biofuels, together with the impacts of climate change (EEA, 2012). "Without improved efficiencies, agricultural water consumption is expected to increase by about 20% globally by 2050" (WWAP, 2012, 2014).

Water demand in agriculture can be divided into two categories: the demand for livestock production and the demand for crop production. Each category is further divided into two components. The first component is the water necessary for the development and growth of crops and animals, including ensuring all physiological processes and protection against heat stress. Limited water availability leads to reduction in both animal and plant production (Utley *et al.*, 1970; Pelleschi *et al.*, 1997; Pandey *et al.*, 2000; Farré & Faci, 2009; Viola *et al.*, 2009; Abioja *et al.*, 2010). However, controlled restrictions of water availability may be used to reduce water demand in agriculture in arid areas (Fereres & Soriano, 2007; Farré & Faci, 2009). The second component is the 'process' water used for rinsing agricultural machinery and equipment, sanitation of animal housing, milking parlours, etc. Existing data sources on water use in agriculture usually do not distinguish between these two components and the reported figures include both physiological water and 'process' water.

Irrigation is used as an additional source to achieve optimum soil water regime, maximum crops, and to limit the losses due to water deficit (Debaeke & Aboudrare, 2004). Optimization of irrigation can lead to higher economic income even with reduced water availability (Nelson & Al-Kaisi, 2011), especially in areas with increased costs of irrigation.

Livestock products provide one-third of humanity's protein intake (Steinfeld *et al.*, 2006), and they are important water users in many countries. Globally, livestock uses about 31% of the total water used for agriculture (Herrero *et al.*, 2009). The amount of water used for livestock is almost as high as the amount of water used for irrigation (Flörke & Alcamo, 2014). Livestock water requirements are affected by many factors, including rate and composition of gain, pregnancy, lactation, productivity, activity, type of diet, feed intake, and environmental conditions (National Research Council, 1996). Good water quality and cleanliness can increase water intake and improve livestock production. The criteria most often considered in assessing water quality are organoleptic properties, physiochemical properties, presence of toxic compounds, excess minerals, and bacterial contamination (National Research Council, 2001). Free drinking water (mainly blue water) typically supplies the majority of demand but for grazing ruminants or those consuming silage, water in or on feedstuffs (green water) becomes a proportionately greater part of total consumption (Beede, 2012).

MATERIALS AND METHODS

Agriculture water accounting data in the Czech Republic

There are two primary sources of measured information on water use in agriculture in the Czech Republic. The first source is the register of withdrawals of surface water and groundwater in accordance with Decree no. 431/2001 Coll. (MoA, 2001b). The data for the register of withdrawals and discharges must be provided by all entities which abstract more than 6000 m^3 from surface water or groundwater in a calendar year or more than 500 m^3 in a particular month. The data are transferred annually. The transferred data include the economic activity code of the customer, the total individual monthly withdrawals, the total annual withdrawals, and information on the use of the abstracted water, divided into flow cooling, circulation cooling, irrigation, livestock production; industrial technologies; water supplies (for public consumption); other withdrawals. The data on water use are expressed only as annual totals.

The other primary source of information is property and operational records of water supplies and sanitation in accordance with Decree no. 428/2001 Coll. (MoA, 2001a). All operators of water supply and sanitation systems for public use are required to keep property and operational records. Selected data is then forwarded to the Ministry of Agriculture. Until 2014 these selected data also included information on the amount of invoiced water divided into households, agriculture, industry, and others.

After data adjustment, these two primary sources are the basis of the statistical summaries of the Czech Statistical Office provided in various reports, such as Reports on the state of water management in the Czech Republic (MoA, 2015), State of the Environment Reports (MoE, 2015), etc. (see **Table 1**).

For the analysis of water withdrawal in agriculture (direct blue water withdrawals) both primary sources were used, i.e. the evidence of withdrawals and discharges plus selected data from the property and operational records of water supplies and sanitation. The time span was limited by the availability of property and operational records data that were only available for analysis between the years 2005 and 2013.

Withdrawals included in the register of withdrawals and discharges were analysed in terms of which individual sector they belong to and in terms of the use of the abstracted water. Only one economic activity code (NACE) is assigned to each withdrawal, according to which it is assigned to either the power engineering sector (NACE 35), public water supply (NACE 36), industry (NACE 05–33), agriculture (NACE 01–03) or the so-called other withdrawals (NACE 38–96). The NACE code expresses the prevailing economic activity of the customer but does not necessarily reflect the actual use of the abstracted water. Moreover, water taken from one withdrawal is often used for multiple purposes. Therefore, individual withdrawals were also analysed in terms of the information on the use of abstracted water. In parts of the withdrawal reports the data on the use of abstracted water are not filled in or are inaccurate. Where possible, data have been corrected (shifted decimal point, correction of duplicate values, etc.). If it was not possible to clearly determine the cause of the data error, the data was kept in its original form.

In addition to direct withdrawals from surface water and groundwater, drinking water from public water supplies is also used in agriculture. As the price of water from public water supplies is several times higher than the withdrawal rate of surface water or groundwater, it is likely that water from public water supplies will be primarily used as drinking and sanitation water in

Table 1. Agriculture water use in the Czech Republic in different data sources

Year	Czech Statistical Office: withdrawals for agriculture, hunting, forestry and aquaculture		Ministry of Agriculture: Reports on water management in the Czech Republic		EUROSTAT - water abstraction for agriculture
	Groundwater	surface water	groundwater	surface water	fresh surface and groundwater
	Mm³				
2005	8.505	10.916	8.6	11.0	19.4
2006	9.654	13.786	9.8	13.8	23.4
2007	10.489	19.285	10.5	19.3	29.8
2008	11.369	21.722	11.4	21.7	33.0
2009	11.290	28.976	11.3	29.0	40.3
2010	11.480	25.272	11.5	25.3	36.7
2011	11.696	27.311	11.7	27.2	39.0
2012	12.089	31.132	12.1	31.1	43.2
2013	12.897	31.143	12.9	31.1	44.0

livestock production. In crop production, the water from public water supplies will be used as water for employees, possibly also as irrigation water in such cases where it is not cost-effective or technically feasible to build their own water source. This assumption, however, cannot be realistically verified.

Based on data of the property and operational records on the produced water, the total amount of invoiced water and amount of water invoiced for agriculture, the amount of produced water for agriculture was determined. The ratio between the amount of water abstracted from surface water and groundwater used in public water supply and the amount of produced water was further determined. Using this ratio, the amount of water abstracted from surface water and groundwater provided by public water supplies to agriculture was determined.

Datasets of livestock in the Czech Republic

Livestock numbers are measured based on a sample survey of the Czech Statistical Office "Livestock census" and determined within the extent of active farmers (excluding hobby activities) registered in the Farm Register. The statistical unit for livestock production is determined as farms with the number of livestock from 1 head of cattle, 2 heads of pigs, 4 heads of sheep and goats, 50 heads of poultry, 100 heads of rabbits, and/or 100 heads of fur animals (CzSO, 2014b).

A selection of the data is data are then published; detailed information on the structure of livestock is also available (CzSO, 2015; **Table 4**). Similar data in a slightly different breakdown and rounded to the nearest thousand animals are published in the Statistical Yearbooks of the Czech Republic. For individual livestock categories the average daily demand of water for drinking and cleaning were determined (see **Table 2**). The initial source of information was the Czech national standard for the design of animal housing water supply (CSI, 2001) and other methodological materials used in the Czech Republic (Doležal & Černá, 2004; Malá *et al.*, 2011).

Dairy cows represent a very important category of livestock in the Czech Republic in terms of water consumption. The water consumption of dairy animals is directly proportional to their performance. There are several empirical relationships that describe the dependence of water demand in dairy cows on milk yield and other factors, such as daily food intake, temperature, etc. (Castle & Thomas, 1975; Murphy *et al.*, 1983; Holter & Urban, 1992; National Research Council, 2001; Cardot *et al.*, 2008; Kramer *et al.*, 2008). For easier estimates, approximate values can also be used. Beede (2012) indicates a demand for 2.0 to 3.4 litres of water to produce 1 litre of milk. Harner et al. (2013) consider a demand for 3 litres of water per 1 litre of milk, Doležal and Černá (2004) provide the same value as approximate. Potts (2012, p. 32) indicates a demand for 2.82 litres of water per 1 litre of milk. Doležal and Černá (2004) also provide approximate water demand depending on the performance for the cattle in the open, thermally uninsulated barn. From these data we derived an approximate **Eq. (1)** for dairy cows:

Table 2. Average daily water demand for livestock

Livestock category	Average water demands for drinking	Average water demands for cleaning
	l/animal/day for poultry l/1000 animals/day	
Calves aged up to 1 year	20	10
Young cattle aged over 1 year up to 2 years	30	10
Bulls over 2 years of age, incl. bullocks	50	10
Heifers	30	10
Dairy cows	80	40
Cows without market milk production	50	10
Piglets up to 19 kg live weight	1	0.23
Young pigs weighted over 20kg up to 49 kg live weight	3	0.25
Fattening pigs	6.5	0.28
Boars	16	0.2
Sows after first service	14	0.25
Sows before first service	23	3.7
Gilts after first service	13	0.23
Gilts before first service	9	0.23
Sheep	4	0.5
Female goats	6	2
Male goats	4	0.5
Foals aged up to 1 year	11	2
Horses aged over 1 year up to 3 years	26	2
Horses aged over 3 years	35	2
Donkeys, mules, hinnies	15	2
Chickens for breeding	120	
Chickens for fattening	110	
Hens	280	
Cocks	280	
Geese, ganders, goslings	1000	
Ducks, drakes and ducklings	500	
Turkey hens, turkey stags and poults	1050	

$$FWI_{avg} = \begin{matrix} 25 + 3.25 \times MY; MY \in \langle 10; 20) \\ 40 + 2.5 \times MY; MY \in \langle 20; 40) \end{matrix} \quad (1)$$

where: FWI_{avg} = Average Free Water Intake in L/day,
MY = Milk Yield in L/day

Afterwards, we used this equation for calculating water demand for dairy cows. Information about the average milk production per cow was taken from Statistical Yearbooks of the Czech Republic.

A considerable part of water demand on dairy farms is the water used in milking parlours. In the Czech Republic in 2007, 78% of dairy cows were milked at various parlours and about 21% in the animal housing into the pipeline (Vegricht *et al.*, 2008). Many authors discuss the quantification of water demand in milking parlours, for example Harner (2013, pp. 96–97). Even though the amount of water needed for cleaning and sanitation is stated by the manufacturers of the technologies used, the actual amount of water used in milking parlours may vary considerably. Rasmussen and Pedersen (2004) demonstrated markedly different water demand of various automated milking systems on 17 farms in Denmark. The human approach is also an important factor that can significantly affect the amount of water consumed. In the average agricultural practice, the values may vary depending on the employees' approach. The amount of water in milking parlours in the Czech Republic was discussed by Vegricht et al. (2008). For the purpose of cleaning and sanitation of milking equipment in a milking parlour, according to its type and size, 3.4 to 6.7 litres are consumed per dairy cow per day inclusive of sanitation solutions. Another quantity of water is necessary during the sanitation of equipment destined for milk cooling and storage to the amount of 5.0 to 7.0 litres of water per 100 litres of milk cooled and stored per day (everyday milk collection). For the continuous cleaning of the milking parlour, milking equipment and washing of lacteal gland in the course of milking, it is necessary for at least 3 to 5 litres of water per dairy cow per day (milking twice a day). For everyday cleaning of walls and floors of the milking parlour, assembly points of dairy cows and passages at least another 2.4 L/m^2 is necessary. These data were verified in practice: the average water consumption per dairy cow in the monitored parlour was 19.55 L/day, of which 21% was for washing udders and continuous parlour cleaning, 15% for cleaning the parlour after milking, 14% for cleaning the assembly points after milking, 15% for parlour sanitation, 6% for cleaning the dairy, 5% for sanitation of refrigeration equipment and 24% for sanitary facilities of the parlour and other unspecified needs. There are no available data in the Czech Republic for quantification of water demand in milking parlours. Based on the data of Vegricht et al. (2008), the number of dairy cows and the amount of milk produced, the potential water demand in the milking parlours in the Czech Republic were estimated.

In addition to the annual statistical monitoring, a detailed collection of data is also performed within structural survey in agriculture (CzSO, 2001, 2004, 2006, 2008, 2011, 2014a). Within the structural survey in agriculture the quantity of items is monitored, including farm size, stabling, grazing method, and other factors that affect the water demand of livestock.

In the Czech Republic, loose cattle housing prevails with 85.3% of stall capacity. Cattle housing with bedding forms a dominant share in both tethered housing and loose housing with a total share of 85.3% of animal housing capacity. The standard for the design of stall water supply (ČNI, 2001) distinguishes the type of housing into tethered and loose only for dairy cows, whose water demand in loose housing is 80 L/day and in tethered housing 75 L/day. When introducing the assumption of the same proportion of loose and tethered in all categories of cattle, the average water demand per dairy cow in the Czech Republic would be 79.4 L/day, which in comparison with a value for loose standing represents a decrease of 0.7%. As a solution we used the value of loose housing of dairy cows, i.e. 80 L/day.

Pig housing is dominated by slatted floors with a share of 75.2% of animal housing capacity. In laying hens the housing is dominated by battery cages with 67.6% of breed capacity, while loose on deep bedding represents 31.0% of the breeds (CzSO, 2011). At high concentration of animals in breeds, a large capacity of the water source is required, determined by the concentration of a large number of animals in a small area, and in the case of non-bedded housing a further demand of water for the removal of excrement. Consequently, the total water consumption in farms with a high concentration of animals may mean an increase in water consumption by 50 to 100% compared to bedding housing (Novák *et al.*, 2014).

The standard for the design of animal housing water supply (CSI, 2001) does not distinguish the type of housing of pigs and poultry in terms of water demand. In 2010, 28.9% of cattle were on pastures with an average grazing time of 8 months. For goats it was 59.3%, horses 67.1% and sheep 83.4%. The average grazing time in these categories of animals was 9 months (CzSO, 2011). According to the standard for the design of animal housing water supply (CSI, 2001), grazing goats and sheep need about 50 to 67% less drinking water than non-grazing animals. For horses the demand of grazing animals is lower by 20 to 33%. In contrast to Table 2, the average drinking water demand weighted by the ratio of grazing animals and the number of months of pasture decreases for sheep by about 30 to 40%, for goats by 20 to 30%, and for horses by 10 to 15%. For dairy cows we estimate the impact of grazing on the reduction of water demand of the whole category (i.e. grazing and non-grazing cows) at a level of 0 to 3%, for other cattle at a level of about 5%.

One of the items monitored within the Farm Structure Survey (CzSO, 2001, 2004, 2006, 2008, 2011, 2014a) is the number of animals on farms. The amount of water demand which is not registered in withdrawals from surface water and groundwater can be estimated from these data. CzSO provides information on the number of animals on farms only in an aggregated form with the basic categories of animals (cattle, cows, sheep, pigs, sows, goats, poultry, hens) and the size of the business. The disadvantage of these data is that they are provided for each category of animal individually, so it is not possible to detect cases where the business breeds, for example, dairy cows as well as other cattle categories, etc. As the data on the breed size are only available for the main categories of livestock (cows, cattle, goats, sheep, pigs, sows, hens, poultry) without more detailed information on the breed structure, it was necessary to determine the specific water demand for these categories of animals. This determination must reflect both the diversity of the age composition of animals and various animal performance and other factors. From detailed information on water demand in **Table 2**, the weighted average was set in which the weights were the data on the number of animals according to the categories listed in **Table 2**.

The actual estimate of the amount of water which is not included in the figures on water use in livestock production is based on calculations of the average amount of drinking and process water in one business in the respective size category. The businesses were divided into three groups according to the amount of stated water demand. The first group includes businesses with consumption of less than 4000 m^3/year. In this size category it can be assumed that even when considering the possible variance of values (number of animals in the business, specific needs of water demand of an animal) the business does not reach the limit of 6000 m^3/year and therefore the data from these businesses are not included in the records of the water balance with stated water use for livestock production. The second group includes businesses which according to calculations exceed the limit of 6000 m^3/year. Considering possible variance of values, the limit boundary was shifted to 7000 m^3/year. For these businesses it is assumed that their withdrawals are in any case included in the register of the water balance. The last group are businesses with a demand of 4000 to 7000 m^3/year. For this category, it is expected that due to the variance of the real values a certain part of the businesses exceeds the limit of 6000 m^3/year for inclusion in the register of water balance and a part of them does not.

RESULTS AND DISCUSSIONS

Analyses of datasets of water withdrawals

The sum of the amount of waters in the register of withdrawals with the stated use in the monitored period 2005–2013 is lower by 12.49% than the figure for annual withdrawals and in the individual years it is lower by 7.54 to 17.84%. However, the situation is very different in the individual sectors. For withdrawals with NACE code 01 or 02 (i.e. in the agricultural sector without withdrawals for aquaculture) the amount of withdrawals without filled in water use is 0.42% on average, or 0.00 to 2.07% in the individual years. Withdrawals for irrigation or for livestock production in the individual years in the group of withdrawals with NACE code 01 or 02 were 80.73 to 96.38%, while the withdrawals for irrigation slightly exceed withdrawals for livestock production (see **Table 3**). It is evident from the data that the amount of water used for irrigation abstracted outside the agricultural sector represents on average only about 7.5% of the amount used for irrigation, and the amount of water used for livestock production abstracted outside agricultural sector represents about 14% of all water use for livestock production.

The amount of water abstracted in the sector of public water supplies and delivered through public water supply systems to agriculture ranges between 10.01 to 14.04 Mm^3 (see **Table 3**), which in individual years represents from 28.66 to 67.52% of water withdrawals used for irrigation or livestock production. The declining share of agriculture supply from the public water supply systems is caused by two factors. The first factor is the significantly higher price of water from public water supplies compared to the withdrawal rate of surface water or groundwater; the second factor is the accelerated growth in the prices of water compared to the growth of the rates of surface water withdrawals, the rates for withdrawals of groundwater do not actually increase at all.

Overall, 33.57 to 48.95 Mm^3 which were abstracted from surface water and groundwater in the individual years were used for livestock and crop production. Compared to the numbers reported in the official statistics there is an obvious difference in values caused by the three following facts. Firstly, the official data include all types of water uses within the withdrawals assigned according to NACE code to the agricultural sector (NACE 01–03). On the contrary, withdrawals used in agriculture which according to NACE are assigned to another sector of the national economy (NACE > 03) are not included in official statistics. Thirdly, water supply from public water supply systems is not included in agriculture. As our analysis shows, 1/3 to 2/3 more water registered in the register of withdrawals is used in agriculture than is reported on the basis of NACE.

Table 3. Usage of water withdrawals for irrigation and livestock in Mm^3/year (data source: evidence of withdrawals)

Items	2005	2006	2007	2008	2009	2010	2011	2012	2013
WU for irrigation (NACE 01 or 02)	10.87	13.60	15.42	16.17	23.31	19.73	21.60	25.29	13.89
WU for livestock (NACE 01 or 02)	7.22	8.07	8.72	9.37	9.41	9.48	9.69	9.90	10.73
Total WU (NACE 01 or 02)	19.17	22.89	26.06	27.08	34.56	31.08	33.01	37.17	37.99
Water withdrawal (NACE 01 or 02)	19.40	23.38	26.23	27.32	34.56	31.08	33.01	37.17	37.99
WU for irrigation (all NACE without 03)	11.88	14.20	19.33	16.97	24.50	20.69	22.67	26.58	15.47
WU for livestock (all NACE without 03)	8.16	9.10	9.99	11.05	16.49	16.69	17.44	11.47	12.35
WA in the PWS sector and delivered through the PWS system to agriculture	13.53	14.04	12.83	12.42	12.34	11.57	10.94	10.90	10.01
WA from surface water or groundwater and used in agriculture (without aquaculture)	33.57	37.35	42.15	40.44	47.60	43.32	45.05	48.95	37.81

WU: Water used; WA: Water abstracted; PWS: public water supply

However, when considering the size of withdrawals that were delivered through the public water supplies to agriculture it is important to realise the limits of the method used in this study. From the current data it is not possible to determine how much of the supply through the public water supplies is used for irrigation and crop production, how much for livestock production and how much for aquaculture. However, we expect that deliveries to aquaculture will represent only a fraction of supplies from public water supply systems to agriculture. Furthermore, average values of losses in the water supply network in the Czech Republic were used to determine the withdrawals delivered through the public water supplies for agriculture. However, water losses in the water supply network are different in different regions of the Czech Republic and between the individual operators of the public water supply systems. When considering the average losses in individual regions of the Czech Republic the accuracy of the stated data can be estimated at ± 10%. Since even the regionally available data have already been aggregated, it is better to assume the accuracy of the derived data at ± 15 to 20%.

Another limitation of the conducted analyses is the limitation of withdrawal evidence by 6000 m^3/year or 500 m^3/month. The purpose of these limit values is to reduce the administrative burden on customers, assuming that the sub-limit withdrawals represent only a fraction of the total amount of abstracted water and it is possible to ignore these withdrawals in the overall balance. Therefore, customers who abstract sub-limit amount from surface water and groundwater are not even registered. On the other hand, some of these customers will not be supplied from surface or groundwater sources, but from the public water supplies.

Water demand for livestock in the Czech Republic

We divided water demand for livestock into two parts. The first part is water needed for livestock breeding (drinking water, cleaning and animal housing sanitation). The second part is the water needed for cleaning milking parlours, milking equipment and dairies.

The analysis demonstrated that the water demand for livestock represents 36.18 to 39.37 Mm^3 and mainly consists of water needed for cattle (over 80%) and especially for dairy cows (nearly 50% of total water demand). Another important group is the water needed for breeding pigs, which in the monitored period needed 7–12% of the total water demand for breeding, while in the last years of the monitored period the demand ranged around 7–8%. The last group with statistically more significant water demand includes poultry breeding, which according to the analysis needs about 4% of all water demand for livestock breeding. The demand of other individual species is less than 1% of total demand and in total represents 1.4 to 2.2% of water demand. Water needed in milking parlours was set at 2.1 to 2.3 Mm^3 of water per year. Quantification of water demand in the individual years is shown in **Table 4**.

Even in quantification of water demand in livestock breeding it is necessary to consider the limits of stated values. For calculation of water demand for drinking and animal housing sanitation the tabular values of standards for the design of animal housing water supply were used (CSI, 2001). It can be assumed that the standard will include a certain reserve, so the actual demand may be slightly lower. Compared to calculations by empirical relationships, tabular values do not include differences in breeds, the amount and composition of food, performance, temperature conditions, etc. Therefore, the accuracy of the stated values can be estimated at +10% to –20%. Even greater uncertainty exists for determining the demand in milking parlours. For water demand in milking parlours the accuracy of stated values can be estimated at ± 40%.

Estimate of water demand in livestock production not included in the register of withdrawals

Comparing data on water demand with data on withdrawals used in livestock production, it is clear that the demand for water exceeds the withdrawals used in livestock production 3 to 4 times. Even when considering the full use of the water supplied to agriculture through public water supply systems, 10 to 20 Mm^3 per year are still missing in the demand. When

Table 4. Estimation of water demand for livestock – drinking water and sanitation; milking parlour (Mm^3/year)

Category	2005	2006	2007	2008	2009	2010	2011	2012	2013
Dairy cows	19.055	18.839	18.469	17.863	18.399	17.704	17.529	17.829	17.561
Other cattle	13.254	13.021	13.532	13.807	13.408	13.466	13.621	13.750	13.860
Pigs	4.824	4.767	4.769	4.084	3.311	3.164	2.867	2.670	2.595
Sheep	0.230	0.244	0.277	0.302	0.301	0.323	0.343	0.363	0.362
Goats	0.021	0.024	0.026	0.028	0.029	0.036	0.038	0.040	0.040
Horses	0.227	0.255	0.268	0.306	0.315	0.337	0.350	0.378	0.393
Donkeys, Mules, hinnies	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.002
Poultry	1.760	1.682	1.657	1.826	1.728	1.597	1.429	1.338	1.606
Milking parlour	2.276	2.220	2.174	2.173	2.148	2.066	2.053	2.077	2.070
Total	41.647	41.052	41.173	40.390	39.640	38.694	38.231	38.446	38.489

considering the use of only half of the supplies from public water supply systems to agriculture for livestock production, 15 to 27 Mm^3 is missing to cover the demand. If such an amount of water was provided by sub-limit withdrawals, which do not get into the register of withdrawals, then that would mean that the limit for register of withdrawals is set incorrectly. On the basis of information on the size of businesses, we estimated the amount of water that is not included in the register of withdrawals.

Analysis of the size of businesses showed that companies focused on breeding small ruminants (sheep and goats) are not large enough to be reflected in the records of withdrawals. For businesses with cattle or dairy cows, these operate in size categories 0–10, 11–50, 51–100 animals. The water demand of these businesses ranges between 11–14% of the demand of all businesses breeding cattle, and 17–22% of water demand of businesses breeding dairy cows. Businesses breeding pigs range in size categories of 0–10, 11–50, 51–100, 101–500 and 501–1000 animals. These businesses need 11–14% of water demand of all businesses aimed at breeding pigs. Businesses breeding sows range in size categories 0–10, 11–50, 51–100 and 101–500. Businesses in the size category of 501–1000 sows are among size groups in which we assume that part of the businesses exceeds the limit for register of withdrawals. Smaller businesses breeding sows which are estimated not to exceed the limit for register of withdrawals need 43–49% of water demand of all businesses breeding sows. Businesses breeding laying hens are not included in the register of withdrawals in the size category 0–100, 101–1,000, 1001–10 000 and 10 001–50 000. Businesses in the size category 50 001–100 000 are within the category in which we assume that part of the businesses exceed the limit for register of withdrawals. Businesses in which we estimate to have sub-limit withdrawals need 14–19% of water demand of businesses breeding hens. Businesses specialising in breeding other categories of poultry are not included in the register of withdrawals in the size category 0–100, 101–1 000, 1 001–10 000. These businesses need 2–3% of water demand of businesses breeding poultry.

These figures should be taken as a theoretical upper limit because many businesses breed a mixture of animals and may have other activities that require water, so their total withdrawals will exceed the limits for inclusion in the register of withdrawals. Some businesses will abstract water from public water supply systems. Realistically, we estimate that withdrawals that are not included in the register of withdrawals, either in the form of excessive withdrawals or in the form of delivery through public water supplies, do not exceed 10% of water demand in livestock production.

When considering the probability of values of water demand and water supplies it would be possible to say that our analysis gives similar results for both the demand as well as sources. However, such an argument is very close to a non-objective interpretation of results, which scientific papers should avoid.

CONCLUSIONS

Water accounting data are often the only source of information for research and decision-making. However, as we have shown in the example of the Czech Republic, the real data may often significantly differ from the official statistics as statistical data are collected in accordance with the established methodology.

Furthermore, we conducted an estimate of water demand for livestock production, i.e. for animal drinking, animal housing sanitation and water needed on dairy farms for milk production. Estimated values significantly exceed the amount of water that is delivered to livestock production. Therefore, we made an estimate of the amount of water that is not covered by official registers under current regulations in the Czech Republic. Yet it appears that the expected water demand is still higher than our estimated recorded and unrecorded “water sources” for livestock production. This may be due to a number of reasons. The first reason may be the use of excessively high values of specific water demand in livestock production or inappropriate methods of their processing. The second reason may be omission of a certain significant "water source", for example reuse of waste water, advances in technology, etc.

Our study showed that the use of data files, including the official statistics, may be very misleading without the knowledge of the methodology of collecting and processing these data. It is not always possible to obtain detailed information about the method of collecting or processing the data; in such cases a multi-level cross-validation of the used data is necessary. And as the conducted study showed, even cross-validation may not confirm the accuracy of existing data or processes of derivation of new data sets. The research sector in particular must focus on verifying the validity of the used data, and every time there should be an estimate of the accuracy of the results. Otherwise there may be an unintentional influence on decision-makers.

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