Circular economy and supplying the industry with water in the periods of drought

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Abstract. The foreseen climatic changes and thus related changes in the water supplies shall largely concern the industry. The paper reviews the current conditions in the supplies of service water in the industry, and aims to identify the options how to supply the industry with water in the periods of drought. In particular, it focuses on medium-sized companies that require water for their technologies. The paper builds on the knowledge of circular economy to target both financial and raw material savings.

1. Introduction

Recently, the global warming has led to more pronounced climatic changes. The scientific community is in a general agreement over the causes of the climatic changes that manifest in the changes of the hydrological cycle and significant periods of drought. The problem of dry periods is particularly pressing in the Czech Republic (CR) where the water supplies depend on precipitation only. The situation in the CR has been observed in the long-term and has become a subject of interest of both the state and local administrations as well as research workplaces. The government of the CR has issued several resolutions, including the preparation of new legislation. Major attention is paid to the supplies of drinking water. For example, construction of several new water reservoirs is being prepared. There are studies that deal with the interconnection of large water management systems as the experience shows that the periods of drought are distributed unevenly as for the surface area. There are programmes to deepen and enlarge the sources of groundwater, but such a solution may be perceived as temporary. Attention is also paid to the agricultural drought as its manifestations have been striking in the last few years. Research and measures taken also deal with the water retention in the landscape, namely via the construction of ponds and reservoirs, and via modifications of discharge conditions. Close to nature modifications of watercourses are implemented so that some earlier technical measures to accelerate the discharge are redeveloped aiming at slower discharge of water. In terms of environmental protection, there are efforts to re-establish wetlands, swamps, and restrict soil amelioration.

In this respect, the needs of the industry as a whole have been neglected. Some attention is paid to the power plants, particularly nuclear power plants, as the supply of cooling water is vital for their operation. The majority of the industrial branches in the CR need drinking water for the purposes of sanity, service water, and cooling water. Some industrial branches have a very high water consumption, e.g. the chemical, paper-making, and food-processing industries. Therefore, it is important to search for the methods how to ensure the vital supplies of water for the industry in the periods of drought so that they did not have to interrupt production and at the same time the measures did not have negative environmental impacts. There are a number of options how to deal with the water supplies for the industry, including some simple economical solutions of re-use of own treated wastewater, or use of the treated wastewater from other producers.
2. Water balance in the Czech Republic
The only source of water is the annual precipitation, approximately 50 billion m$^3$. The evapotranspiration amounts to 70 – 80 % of annual precipitation and it is going to rise along with the increase in temperatures every year. Considering the annual discharge leaving the territory of the country, the available water sources are 5 000 – 6000 million m$^3$. Out of this, at least 10 % is needed for drinking water supplies (Table 1).

Table 1. Renewable water sources between 2010 and 2017.

| Item                        | Annual values [mil. m$^3$] |
|-----------------------------|-----------------------------|
|                            | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| Precipitation               | 68   | 49   | 54   | 57   | 51   | 41   | 50   | 53   |
| Evapotranspiration          | 46   | 35   | 42   | 38   | 41   | 32   | 40   | 43   |
| Annual inflow 1)            | 781  | 482  | 492  | 845  | 388  | 398  | 402  | 339  |
| Annual runoff 2)            | 22   | 14   | 13   | 19   | 10   | 10   | 10   | 10   |
| Sources of surface water 3) | 8 788 | 5 770 | 5 195 | 6 626 | 5 273 | 3 591 | 4 421 | 4 258 |
| Available sources of groundwater 4) | 1 594 | 1 340 | 1 311 | 1 657 | 1 077 | 939  | 925  | 911  |

Source: Czech Hydrological Institute
Note: 1) Annual inflow into the Czech Republic from the neighbouring countries. 2) Annual runoffs from the territory of the CR. 3) It is determined as the flowrate in the major catchments with 95% provision. 4) It is a qualified estimate; the number is to be confirmed.

The water balance in the industry has been relatively favourable in the past few years. When compared with the year 1990, the consumption of surface water in the industry dropped to 26.5 % of the original quantity. The reasons are economic, such as the ever growing cost of the purchased surface water, and the costs for the wastewater discharge. Next, there were some significant structural changes in the industry, for example, reduction of operations in certain industrial enterprises, especially the metallurgical and textile industries. The construction of modern industrial plants also contributed to a significantly lower water consumption. The drop in the water consumption in the power-engineering industry to cool the power plant operations was caused by the reductions in flow cooling. The water balance of the Czech industry is summarized in Table 2 below.

Table 2. Water balance in the Czech industry.

| In year 2017                      | Power-engineering [mil.m$^3$] | Industry, incl. mining [mil.m$^3$] |
|-----------------------------------|-------------------------------|-------------------------------------|
| Surface water consumption         | 679                           | 220                                 |
| Groundwater consumption           | 2                             | 37                                  |
| Wastewater discharge into water   | 565                           | 257                                 |

The general water balance in the industrial processes (Figure 1) may be divided into water consumption that shows as water in the product, water loss, and water loss due to evaporation. Next, there is water that runs through the industrial process and is discharged back into the recipient. This water may be divided into water that came into contact with the product, and water that did not. According to the level of pollution, the used water is treated either directly in the plant, or it is discharged into the public sewage
system. This provides space for repeated water re-use in dependence on its quality and availability of the water treatment technologies.

Figure 1. General water balance in the industrial process.

The water used in the industry cannot be considered a cooling medium or raw material only. In terms of the new ideas of circular economy, we must look at water as a source of energy, both the kinetic energy as well as energy in substances contained in water. An example of the recovery of kinetic energy are water turbines situated in the inflow systems, when instead of reducing the pressure using reduction valves, pressure is reduced using turbines and energy is recovered this way. The use of substances contained in water is typical for the food-processing industry, and some branches of the chemical and light industry. These are cases when wastewater contains biodegradable organic compounds. Via their anaerobic degradation, biogas containing 70% of methane is obtained, which has a wide range of energy applications. In the sites with a sufficient gradient at the discharge from the industrial plant, the energy potential of the discharged water may be used inserting a turbine.

3. Circular economy

Circular economy is a concept that makes an integral part of sustainable development. It searches for ways to improve the quality of the environment and life through increasing the efficiency of production. In water management it translates as water savings, water reuse, and use of water energy potential. Ensuring water supplies for the industry considering the large diversity of conditions in the different branches is a process comprising of a wide number of technical, organizational, and economic conditions related to water recycling, its reuse in-site, and its reuse elsewhere. The technical-organizational measures are precise water measurements and reductions in water loss, as well as the economic perspective of the overall process.

The strategy of water recycling and its reuse lies in the long-term efforts to reach minimum or zero wastewater. It depends on the type of production process, degree of wastewater treatment, and the requirements for the recycled water quality. The most common examples of reuse are the processes of heating, cooling, extinguishing, washing, and hydraulic transport. Another option is final treatment in the course of technological processes, i.e. water leaving one technological process to be used in another process. This option offers a wide spectrum of advanced wastewater treatment and cleaning technologies that are able to clean the majority of technological and recycled waters. There is a number of procedures for wastewater treatment in the industry, when we combine wastewater treatment processes with physical-chemical process, such as flotation, coagulation, and oxidation processes. If the wastewater contains organic compounds, biological processes may be applied. According to the level of pollution and the requirements for the treated water quality, we may apply filtration, or coagulation filtration with subsequent modifications of pH, and sanitation. Recently, membrane processes have been applied as separation processes, and ozonisation has been applied for the purposes of oxidation and water sanitation. Activated carbon adsorption is used in case of increased requirements for water quality. There are also economic aspects of water supplies. If significant loss due to shutdowns is supposed to be incurred because of water shortage, benefits must be carefully considered. In 2018, only one industrial company was restricted as for surface water supplies from a watercourse as its water levels ranged in critical numbers. It was the case of intense production that relies on water. For these reasons, drinking water was used in the technological process as the reserves of drinking water were sufficient although the price of drinking water is much higher.
4. Water reuse

Water reuse is to mean the use of wastewater that was produced elsewhere. The most frequent source of municipal wastewater treatment plants that treat sewage and municipal wastewaters. These waters have been a rather stable source as they originate from drinking water that was drained into the sewage systems, and drinking water supplies take priority in the periods of drought. Based on the requirements for water quality, it is important to design technological procedures for final treatment, and sanitation. For the ordinary use in the industry, water sanitation using ultra-violet radiation or chlorine is sufficient. Mechanical treatment via filtration may be used upstream the sanitation. In case of higher requirements for water quality, the cleaning process may be applied before coagulation treatment process or clarification with subsequent sanitation using ozone and activated carbon adsorption. Worldwide it is a commonly used process, for example, in the USA, Israel, and some developing countries. These are territories with permanently insufficient water supplies, the problem is becoming even more pressing. Such treated water may be used as service water of a very high quality. It may be used directly, or may be stored in tanks for later use.

There is a trend worldwide when treated water is artificially recharged into the ground in some countries, where it becomes a source of drinking and service water, either separately or diluted with the existing groundwater. Although wastewater reuse is a global trend - see Figure 2 for some options, Czech legislation has not dealt with the reuse of treated wastewater so far.

![Figure 2](image-url). Technology schemes for water re-use and recycling to enrich drinking water sources.

Company Liberty Ostrava uses purified process water from the metallurgical cycle.

5. Conclusion

Climatic changes and unfavourable negative prognoses of dry periods emphasize the necessity to pay attention to water management also in industrial companies, which has been underestimated so far. The problem may be approached with the ideas and benefits of circular economy, which may ensure water supplies even in the periods of drought. Water recirculation enables a cascade-like approach, when the water used for cleaning processes may be reused in the industrial cycle where the requirements for water quality are lower. Alternatively, partial water treatment processes may be applied so that the water need not be discharged into the recipient and could be reused. Another repeated water use is suggested for the cleaned water from municipal treatment plants to be used in the industry. Modern biological treatment processes (food-processing industry) are able to exploit the energy contained in the pollution and the treatment processes thus become energy self-sufficient. Each reduction in water consumption manifests in lower energy demands. All industrial premises are recommended to reuse rain water. Each situation must be assessed based on the specific needs and the fact whether it is a temporary or permanent solution.

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