Abstract. With regard to the adverse manifestations of the recent climatic conditions, Europe as well as the world have been facing the problem of dry periods that reduce the possibility of drawing drinking water from the underground sources. The paper aims to describe artificial ground water recharge (infiltration) that may be used to restock underground sources with surface water from natural streams. Among many conditions, it aims to specify the boundary and operational conditions of the individual aspects of the artificial ground water recharge technology. The principle of artificial infiltration lies in the design of a technical system, by means of which it is possible to conduct surplus water from one place (in this case a natural stream) into another place (an infiltration basin in this case). This way, the water begins to infiltrate into the underground resources of drinking water, while the mixed water composition corresponds to the water parameters required for drinking water.

1. Introduction
Drought and drought-related problems have been some of the contemporary issues in the Czech Republic as well as world-wide. According to Brázdil et al. [1], drought may be considered the most catastrphic natural event in the Czech Republic to have the most prominent effect on the national economy. Drought may be defined as a phenomenon arising due to a temporary deficit in rainfall in a given area, which manifests via a decrease in the available water in the soil (agricultural drought), surface and ground water (hydrological drought), which may impact the environment as well as the needs of the population (socio-economic drought).

To mitigate the effects of dry periods, the paper approaches the problem of a lack of ground water resources and suggests using artificial ground water recharge with water from natural streams in order to restock the geological environment and the existing ground water resources. Artificial ground water recharge, as a mitigation measure during dry periods, has been supported by the government of the Czech Republic as well as by the Ministry of Agriculture of the Czech Republic. This support issues from an approved document “Preparing the implementation of measures to mitigate the negative impacts of drought and water shortage”. The design of the artificial ground water recharge system depends on a number of aspects, namely geological, geochemical, hydrogeological, biological and engineering [2]. Next, its application is also conditioned by the spatial circumstances, requirements for water supply, composition of the recharged water, etc. [3].
2. Technology Principle of Artificial Ground Water Recharge

The basic principle of artificial ground water recharge is explained in the schemes in Figure 1. Using a pumping station, water from a surface source (e.g. a natural stream) is conducted into the technological process of pre-treatment. If required, pre-treatment is used to treat the pumped water from the natural stream to meet the parameters stipulated in Decree 48/2014 Coll., implementing the Act 274/2008 Coll., i.e. Act on Water Supply and Sewerage Systems [4]. From the technological process of pre-treatment, the water is pumped or lifted by gravity into the site of infiltration (e.g. infiltration basin). The recharged water later mixes with the water in the underground source. The water pumped from the underground source is finally treated to comply with the legal requirements set for drinking water in accordance with Decree 252/2004 Coll., laying down hygiene requirements for drinking and hot water and the frequency and extent of drinking water checks [5].

![Figure 1](image)

**Figure 1.** Scheme of artificial recharge from a surface stream into an underground source with pre-treatment and infiltration basin (A), without an infiltration basin with direct charging of the underground source (B), with infiltration by means of gravity recharge with no pumping or pre-treatment (C).

3. Description of the process

For the purposes of designing artificial recharge systems, figure 2 gives an overview of the basic factors that influence or may influence the recharge process. Other specific factors may arise from a given situation.

A water source for the ground water recharge is a place on the ground surface, where there are available amounts of surface water of a required quality for artificial infiltration. In general, the recharge water sources may be natural water courses (rivers and streams), accumulated rainfall in the natural or artificial morphological depressions, anthropogenic or natural water basins, etc. Huber et al. [6] adds that these may also be water from the agriculture and water from wastewater treatment plants [11]. It applies to all
the sources that they must comply with the physical-chemical, microbiological and biological requirements for the quality of water recharged into ground water sources. Next, it is important to ensure sufficient amounts of the conducted water (discharge stability) and a relative constancy of its composition. It is also the character of the permeable geological environment and the distance through which the water shall pass during the recharge process that are also decisive in artificial infiltration. Considering the advantages of surface water source application, one of them is a relatively high spatial availability. This is given by the evenly distributed rainfall in the geographical conditions of the Central Europe. As for availability, certain boundary conditions must be met, especially the water holding capacity. Another advantage is easy handling, which means that the application and related mounting of required facilities may be immediate. This, however, does not apply to ground water. Another advantage in surface water sources is a wider variability in infiltration designs in terms of different technological systems.

| SOURCE | INTAKE STRUCTURE/ PUMPING STATION | PRE-TREATMENT | ARTIFICIAL GROUND WATER RECHARGE | SOURCE OF GROUND WATER/ POST-TREATMENT |
|--------|-----------------------------------|---------------|----------------------------------|----------------------------------------|
| Surface water suitable for infiltration/ ground water recharge | Technical facility for drawing and transport of surface water from a source into pre-treatment (filtration) | Technological process ensuring the removal of water components undesirable for infiltration (preventing of clogging) | Technical facility for the infiltration of surface water into ground water | Technological process ensuring water quality in line with drinking water legal requirements |
| Surface water | Yield | Quantity of drawn water | Type of pollution in surface water | Type of pollution in drawn water |
| | Quality | Surface water level | Pollution concentration | Pollution concentration |
| | Accessibility | Bank and bed stability | Spatia availability | Legal requirements |
| | Availability in time | Initial and operational costs | Initial and operational costs | Space availability |
| Water from wastewater treatment plants | Intake structure for running water: River intake | Mechanical: Sedimentation, filtration | Infiltration in the site of water use | Mechanical: Aeriation, filtration |
| | River bottom intake | Physical-chemical: Coagulation/flocculation, ion exchange | Infiltration in infiltration basins, infiltration ponds | Physical-chemical: Coagulation/flocculation, adsorption |
| | Protected-side intake | Chemical: Oxidation/reduction, pH modification | Seepage basin | Chemical: desinfection |
| Water from the agriculture | Water intake structures for reservoirs: Intake towers | Biological: Bio-filtration, membrane bioreactors | Underground dams |
| | | | | |
| Surface water | Rainfall | Infiltration in the site of water use and transformation: Bank infiltration |
| | Water from wastewater treatment plants | Infiltration in infiltration basins, infiltration ponds |
| | Water from the agriculture | Seepage basin |
| Water from the agriculture | \( \text{Space demands} \) | Space demands |
| | \( \text{Initial and operational costs} \) | Suitable pre-treatment must be designed for each locality |
| | | Possible increase in the infiltration rate |
| | | Storage of surplus surface water |
| | | Upgrading the ground water quality (dilution) |
| | | Complying with the drinking water legal limits |

**Figure 2.** Descriptions of the different processes of artificial ground water recharge systems

As for the disadvantages of surface water sources for artificial infiltration, they may be more susceptible to variations in discharge during the year. In this respect, they cannot be sometimes used for artificial infiltration. Still, at the times of drought, there is a certain reserve in water volumes that may be used for ground water recharge.
Another disadvantage is the more prominent chemical, microbiological, biological and physical instability of surface water as opposed to ground water. In this respect, it is important to be more cautious and its parameters during artificial infiltration must be observed.

Considering the operational conditions, during the artificial infiltration it is vital to ensure the monitoring of water quality, prepare a related water sampling plan, sample the water and to monitor the water levels.

The intake structures and pumping stations for water courses and reservoirs are technical facilities for the draw-off (intake) and transport (pumping) of surface water from a source into the pre-treatment facility. In running water sources, water intake is ensured by means of river intakes, river-bottom intakes, or protected-side intakes. Intake towers are used for the water intake in reservoirs.

To ensure the function of the intake structure and pumping station, the boundary conditions of sufficient drawn water quantity and sufficient surface water level must be met to ensure the required capacity for artificial infiltration. Next, it is vital to ensure the stability of banks and bottom in order to prevent the damage of the facility and ensure the function of the intake structure. The consideration of the initial and operational costs of the intake structure and pumping station is also necessary.

As for the advantages, there is the possibility of regulating the draw-off from the source as well as regulating the feed into the pre-treatment. The crucial condition is, however, the minimum water capacity as for artificial infiltration.

The disadvantages concern the fact that the intake structure and the pumping station may be demanding in the space requirements. Another disadvantage are the relatively high initial and operational costs.

To ensure the operational conditions we must define the required water discharge volume and ensure the monitoring of water levels. Next, it is vital to determine the conditions for draw-off interruption, when for example the water chemistry is unacceptable for the functionality of artificial ground water recharge, or the pumped water capacity is insufficient. Among other conditions, there is trapping of the floating solids carried by the water flow (e.g. solved by filters) and suspended load from the bottom (e.g. solved by a sedimentation basin near the intake structure). At the same time, it is important to propose the maintenance mode.

Pre-treatment is a technological process that removes the undesirable constituents from water during infiltration as such constituents could cause clogging. Another aim of pre-treatment is the possible optimisation of the chemical composition of water to reach the required water quality for artificial infiltration.

Clogging influences, the infiltration rate and slows it down significantly [8, 9]. According to Hofkes and Vischer [9] and Greskowiak et al. [10], during surface water infiltration into ground water it is necessary to take into account a number of biological, chemical and physical processes. The surface water is in the contact with the atmosphere (adsorption of oxygen, release of CO2). Apart others, it also contains a number of microorganisms that are removed during infiltration in the first several decimetres of the infiltration zone. Suspended solids are removed via the processes of sedimentation and adsorption on solid surface. Next, there are processes of dissolution, precipitation, ion exchange, biodegradation, etc. [3]. As follows from the work by Hofkes and Vischer [9], the “cleaning process” is the most active in the upper section of the infiltration zone.

According to Asano [7] and Huber et al. [6], we distinguish the solutions of mechanical treatment (sedimentation, filtration), physical-chemical treatment (coagulation/flocculation, ion exchange), chemical treatment (oxidation, reduction, pH modification) or biological treatment (bio-filtration, membrane bio-reactors).

As for the boundary conditions of pre-treatment functionality, it is important to duly select the type of treatment based on the surface water pollution and the requirements for removal or reduction of such pollution. The pre-treatment technology must be designed for a particular range of possible water pollution concentrations to be treated. The space availability and the initial and operational costs also play an important role in pre-treatment.
The advantage of a suitably designed pre-treatment technology may be the capacity to suppress clogging. This relates to the increase in treated water infiltration rate within the geological environment. The convenient pre-treatment may also prolong the life of the artificial infiltration system.

Stating the disadvantages, it is important to mention especially the space demands for the pre-treatment facility. In addition, the complications lie in the necessity to design the pre-treatment for each locality separately based on the local conditions, as well as in rather high initial and operational costs.

Considering the operational conditions, we must define and ensure the reagent doses, and provide for the monitoring of input and output water quality in the pre-treatment process. The other tasks are to determine the holding time in the pre-treatment process, and to decide on the maintenance mode and waste disposal.

Artificial infiltration is a technical solution recharging ground water with required amounts of surface water. The dimensions and shape of the facility correspond to the character of the permeability of the geological environment between the site of infiltration and the ground water source.

Classifying the different types of artificial infiltration, it may be implemented by means of infiltration at the site of water use (surface water seeps at the site of the ground water source), infiltration outside the ground water source or by means of an infiltration basin, bank infiltration, infiltration ponds, seepage basins and underground dams. In all the infiltration types, we distinguish different shapes, bottom depths or dam heights. For example, Balke and Zhu [3] mentions the size of infiltration basins from 100 to 10 000 m² including 50 to 100cm filtration sand beds on the bottom. All the stated types of artificial infiltration may have different modifications.

As for the boundary conditions of artificial infiltration, it is vital to reach a certain infiltration rate, aquifer geometry and its hydraulic conditions. Next, space availability must be taken into account, including the property rights and position in relation to the artificial infiltration implementation. When we choose, for example, an infiltration basin of certain dimensions, the piece of land must be of a correspondingly adequate size. The initial and operational costs, set by the artificial infiltration design, may also play a decisive role.

Among the advantages, the artificial infiltration permits the storage of surplus surface water which would otherwise pose problems, for example by flooding the land, uncontrolled run-off, etc. In specific cases, thanks to artificial infiltration, the quality of the ground water with worse parameters may be upgraded by the charged surface water and their dilution. In many cases, there may be positive impacts on the hydrogeological conditions in the given locality.

To mention the disadvantages of artificial infiltration application, it may negatively interfere with the aquifer, cause clogging of the geological environment, or aggravate the ground water source quality (Asano, 1985) [7]. Next, certain amounts of the charged water may be lost due to water flow loss as the water does not always arrive in the due place. The related initial and operational costs may be high. Still, other methods to provide for drinking water require due investment.

As for the operational conditions, it is vital to ensure the required infiltration rate, monitor the water levels and quality, to plan water sampling and ensure the maintenance mode. The part of the ground water source and transport is given by the doped capacity of the existing ground water source in the corresponding quality and complying with the legal requirements for drinking water.

Final treatment is sometimes required to meet the drinking water legal requirements. The technological processes of final treatment include the mechanical treatment (aeration, filtration), physical-chemical treatment (coagulation/flocculation, adsorption) and chemical treatment (disinfection). The applied final treatment helps to comply with the legal limits for drinking water, but disadvantages the facility with space demands and customised design for each locality.

The operational conditions are analogous to the technological process of pre-treatment with minor differences arising from their sequence in the process.

4. Conclusions

The process of artificial ground water recharge with surface water may be a possible solution in case of drinking water shortage in the periods of drought as a nearby suitable source of surface water, e.g. a
natural stream, is used. Via pumping and treatment of the water from the natural stream in the artificial infiltration technological facility, e.g. an infiltration basin, we achieve the water recharge into the geological environment. The natural flow enriches the existing source of ground water suffering from a lower water level and yields in the dry periods. Overall, this leads to an enriched source of ground water that must meet the drinking water requirements. If not, final treatment must be incorporated downstream the technology, which optimises the process and ensures the final cleaning to reach the drinking water parameters. The dimensions and shape of the artificial infiltration facility correspond to the character of the geological environment permeability between the site of infiltration and the source of ground water. The better the capacity of the geological environment, the lower the requirements for water quality. The same applies to the distance. The longer the distance between the site of infiltration and the ground water source, the higher potential of due treatment to reach the required water quality parameters.

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