# Transport of Emergency Drinking Water Supplies to Population

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The importance of emergency supply of drinking water with the emphasis on its transport. Transport of drinking water to the population affected by emergency event and state of crisis using various transport alternatives for supply. Organization and regulation of supply of drinking water, with an emphasis on speed and security of supply. Proposal to minimize security risks of supply of drinking water.
**Keywords:** drinking water, emergency supply, transport of drinking water.

## 1. INTRODUCTION

In every country there is a part of the infrastructure that can be referred to as critical and that has a decisive significance for the functioning of the state in any situation, i. e. under safe, extraordinary but also under critical conditions. Due to the above reason it is necessary to pay utmost attention to this topic mainly from the point of its protection. Critical infrastructure protection is a process that, when taking into account all risks and threats, focuses on securing the operation of critical infrastructure subjects and relations among them. [1]

The aim of critical infrastructure protection and security is to reduce the risk of threatening the existence and stability of critical infrastructure elements or divert the attack on critical infrastructure elements or on the system of their protection and safety.

One of the most important subsectors of critical infrastructure is to supply safe drinking water to population with emphasis on its transportation. When critical infrastructure elements are disrupted in the area of drinking water supply under emergency and critical conditions, it will be necessary to provide the population and selected objects of public administration and entrepreneurial sector with supplies of required quantity of safe drinking water mainly with the help of mobile elements of critical infrastructure subsector in the area of road transport. From what has been said so far one can notice that there is a close cohesion between them to which extraordinary attention should be given. This attention is to be accented also due to the fact that in case of extraordinary events and crisis situations either in case of natural disasters, terrorist attacks or war, the mentioned objects will be considerably damaged or they will be adversely affected as first ones within the critical infrastructure.

## 2. INFLUENCE OF SAFE DRINKING WATER SHORTAGE ON LIFE AND HEALTH OF POPULATION

Drinking water is valuable and limited resource inevitable for sustainable development, economic growth and social stability. Already in the 6$^{th}$ century a greek philosopher thales was aware of the importance of water when he declared “water is the basis of all life“. At present, water has become a limiting factor. Although water is the most

[1] ŠENOVSKÝ, M., ADAMEC, P., ŠENOVSKÝ, P.: *Protection of critical infrastructure.* Ostrava: Association of Fire Fighting and Protection Engineering, 2007, ISBN 978-80-7385-025-8

common substance on the earth, from the total volume of about 1350 - 1 500 million $km^3$, fresh water represents only about 3 %. From the mentioned volume of fresh water, 99 % is in the form that does not enable its rapid use for drinking purposes in emergency cases. Humans are aware of the importance of water in times of its shortage, which may result in death.

Water is an element that has a wide meaning for society, and environment. Its meaning can be with emphasis on humans, split into the following areas: biological and healthy (human nutrition, personal and public hygiene, climate and soil phenomena and others), economic and agricultural (production, irrigation, transport, change of energetic potential), cultural and aesthetic (country embellishment, recreation and relaxation of humans), political and military-strategic.

When an emergency or crisis situation arises (further only "crisis situation") causing interruption of drinking water supply to some regions, then the situation of drinking water minimum supplies begins. In such cases public administration authorities and other subjects responsible for supplying the population have to regulate drinking water delivery, for example, in the form of announcing water regulatory restrictions, stopping delivering water in some areas and time regulations limiting water supplies to towns and villages. Water supply to the population is then solved in a substitution or emergency way.

In crisis situations in most cases drinking water resources are damaged or regular or substitute water supplies are restricted and it is necessary to provide emergency safe water supplies to the population and selected subjects.

Drinking water is defined as safe if it, either at permanent or any use, does not change health conditions due to the presence of microorganisms and germs or substances influencing health with their acute, chronic or later acting and whose properties perceived through the senses do not prevent from consuming or using it.

It means that water must not be the cause of health disturbances or diseases. It must not contain any poisonous, radioactive or biologically harmful active substances in an amount that might, even after very long time, damage the human organism in any way.

In many countries of the world, mainly in Africa and Asia many water resources have been **contaminated.** It is estimated that [2 3 4]:

- More than 2 milliard people lack access to safe drinking water and 3.25 milliard people do not have access to basic hygienic means and are, therefore, forced to drink contaminated and harmful water that causes a series of serious diseases ending in death:
  - More than 300 million people suffer from diseases causes by contaminated drinking water,
  - Every day approximately 6 thousand people, most of them children up to 5 years, die around the world,
  - Every year more than 5 million people around the world die of diseases caused by contaminated water, approximately 25 thousand of them die from diarrheal diseases caused by polluted water and of hunger,
  - In the year 2030 as many as two thirds of people will be living in countries with critical shortage of drinking water.

According to the data released by the World Health Organization water contains 13 000 potential toxic elements and 80 % of diseases are spread by contaminated water.

**Access to drinking water** in some parts of the world depends, to a great extent, on seasonal temperature changes and frequency of precipitations.

[2] Enviroportal. Drinking water quality [online]. [Cit. 2011-05-03]. Accessible on: http://pitnavoda. enviropor-tal.sk /ukazovatele-kvality-pitnej-vody

[3] KAŠIAROVÁ, S.: *Contamination of ecosystems 1 (University textbook for distance learning course of country ecology)* [online]. [Cit. 2011-06-06]. Banská Štiavnica: Accessible on: http://www.dkubinsky.sk/kniznica /skola/ studijne-materialy/ Kontaminacia_ ekosystemov_1.pdf

[4] Health risks from water [on line]. [Cit. 2011-02-03]. Accessible on: http://www. ruvztv.sk/ doc/voda v kon-texte_vz.doc

It can be said that drinking water has been for a long period a strategic raw material of the 21st century. International non-governmental organizations interested in water supply and water resources quality also expressed their reactions on worsening conditions in water supply all over the world.

Owing to the fact that the world water resources are distributed unequally, the access to safe water represents not only healthy and ecological problem but is a timed bomb. A complicated situation is, for example, in the Middle East that has only 1 % of the world drinking water storages, but, at the same time, 5 % of the world population lives there. Another problem can be various migration waves, some estimations speak of millions of migrants who left their homes due to drinking water shortage.

There are 263 international river basins covering more than 145 countries (about one third of the basins flow through more than 2 countries, 19 flow through 5 countries and more). Most of them are in Europe, where there are 73 such river basins while in South America there are only 7 basins. For example, the river Danube has 17 users; the river Congo, the Nile, the Niger and Rhine have from 9 to 11 users. The shortage of water is also influenced by the fact that on 60 % of 227 largest world rivers there are dams, industrial drainage canals and drying devices.

According to the United Nations Organization data of the year 2003 during last 50 years there have been minimally 507 conflicts initiated by the "water crisis", approximately 40 of them were armed conflicts. Inequalities in water usage led to regional and international tensions and disputes, for example, in the vicinity of the rivers: Nile, Jordan, Euphrates, Indus, Ganges, Colorado, Rio Grande, Paraná etc.

Other factors influencing drinking water shortage are [13, 14, 15]:

- **Draught and extension of deserts** (more than one quarter of the world surface is covered with dry areas, every year the desert extends by approx. 100 000 km$^2$, up to the year 2025 dereliction is expected to increase by 50 % in developing countries and by 18 % in developed countries; up to the year 2050 the world will lose 18 000 km$^3$ of fresh water, which is a nine multiple of the whole amount of water used for irrigation, etc.),
- **Uneconomical use of drinking water** (drinking water is used instead of service water, water consumption has doubled over the last 50 years, industry consumes 22 % of fresh waster, 70 % of fresh water is used for irrigation, etc.),
- **More numerous sources of water resources pollution** (growth of industrial production, use of artificial fertilizers in agriculture):
  - ➢ 12 000 km$^3$ of polluted water in the world due to:
    - ✓ 2 million tons of waste flow into the world rivers and lakes in one day (one litre of waste water pollutes around 8 litres of fresh water),
    - ✓ 300 – 500 million tons of heavy metals, dissolvents and diluents etc. are released into waters every year,
- **Increase of population** (number of inhabitants is expected to be approximately 9 milliard in the year 2050) and the **population will be concentrated** in metropolitan areas,
- **Climatic changes** (global warming, frost that e.g. in the beginning of January 2010 in Ireland caused that the water supply piping broke and 40 thousand people remained without drinking water),
- **Growth of crisis situations** (natural disasters, accidents, catastrophes, etc.).

One of the greatest ecological catastrophe that was recorded in the history of drinking water supply to population in Slovakia was the event of November 1971, when from the company Slovnaft Bratislava nearly 100 000 m$^3$ of petroleum products escaped. Escaped products entered ground water and polluted the water resource in Podunajské Biskupice, from which the west part of Bratislava was supplied. Approximately 95 000 inhabitants of Bratislava had to be supplied by means of water tanks till August 1972.

Other significant factors that considerably contribute to the reduction of drinking water resources are various crisis situation of natural and anthropogenic character (flood, earthquake, tsunami, petroleum supply pipe, etc.) and the way of drinking water supply thus becomes even more complicated than is the one under usual conditions. For example, the floods in Great Britain (July 2007) in southwest county of Gloucestershire caused that approximately 350 000 people remained without drinking water and emergency water supplies had to be provided for the period of 17 days. After the floods in Australia at the turning of the year 2010 to 2011 approximately 70 thousand people were cut off "from the world" and simultaneously also from drinking water resources and military aviation had to participate in their supplying.

Last, but not least, there is also a possibility of intentional disruption of drinking water resources by terrorist attacks.

Drinking water was a presupposition for the first state formation processes. The most famous ancient civilizations formed on the banks of the great rivers Egypt on the Nile, Mesopotamia and, consequently, Babylonian Empire on the Euphrates and Tigris, Hindu Empire on the Indus, and ancient China on the Yellow river.

Water was perceived as indispensable but not short in supply. In some religions is water considered to be the gift of God ("Water is God's gift given to us by God-Creator").

The fact that drinking water was from the very beginning of human existence an important raw material is testified by the saved laws and orders from different periods B.C. in which utmost attention was paid to the topic which can be seen in harsh punishments (for example, in the first historically preserved document of the 18th century B.C. Hammurabi declared: "He who steals a water bowl shall pay 3 shekels. If somebody steals a water wheel his right hand shall be cut off". In the year 1130 B.C. a water thief in Babylonia was sentenced to death). [5]

The consumption of drinking water around the world differs and in the course of the 20th century the consumption tripled when compared with the growth of population. [6]

Drinking water resources are uneconomically used for different purposes, namely approx. 70 % in agriculture, 22 % in industry and 8 % in households.

Suitable for drinking can be every water containing health harmless or for health necessary mineral substances and gases, i. e., water which is healthy and whose appearance, taste and smell are not repugnant and has an appropriate temperature. Drinking water resource can be both ground and surface water and also infiltrated water.

**The most suitable drinking water for population** is ground water and in case of its shortage, surface water is used. All harmful and health impairing substances have to be removed from surface water and it has to be treated properly so that it is similar – as much as possible - to ground water. Water is treated by suitable chemical substances, biological processes and mechanical equipment. The temperature of surface waters changes if water is not collected from a sufficient depth. In summer the temperature is substantially higher than the temperature of ground waters.

**Drinking water** should have an equal temperature ranging from 8 to 12 ºC (if the temperature is permanently higher than 20 ºC, the water is referred to as thermal water); it has to be colourless, crystal clear, without any smell; small numbers of salt and carbon dioxide add it a slightly refreshing taste. It should not contain hydrosulphide (if its content is admissible, it must not be of organic origin), any bacteria, it must not aggressively act on piping and its quality must be constant. The quality of drinking water has to be always assessed by physical, chemical, bacteriological and biological analyses.

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[5] PLECHÁČ, V.: *Water – the problem in the present and future.* Prague: Svoboda, 1989, 327 p., ISBN 80-205-0096-0

[6] State Health Institute. 2003. Crisis drinking water supply [on line]. Jičín: 2002. [Cit. 2011-01-07]. Accessible on: http://www.mujicin.cz/vismo/dokumenty2.asp?u=5954&id_org=954&id=111290&p1=28215

## 3. EMERGENCY DRINKING WATER SUPPLY

Water supply is commonly provided by piped public water supplies. In conditions when this is not possible, water is provided by substitute and emergency supplies by means of water tanks or other means of transport.

According to relation (1) amount of drinking water for the population can be calculated. On the basis of this calculation it is possible to determine the way of supplying and, at the same time, to declare whether it will be possible to use only one system of supply or the combination of these possibilities will be used, or whether any other water resource will be added to provide more efficient and quicker water supplies to the population.

$$V_{NZ} = n_{os} . V_N \qquad (1)$$

where:
- $V_{NZ}$ - total volume of drinking water needed for emergency supply [1],
- $n_{os}$ - number of people to be supplied in a crisis situation [persons],
- $V_N$ - normed quantity of water consumption per one person [l.osobu$^{-1}$].

The function according to which it will be possible to determine the most suitable way of supplying can be expressed by the relation (2):

$$SNZ = f\,(d_o\, k,\, t,\, d_i,\, h,\, c_v) \qquad [-] \qquad (2)$$

where:
- $SNZ$ - way of emergency supplying,
- $d_o$ - access,
- $k$ - capacity of the means of transport
- $t$ - water durability ,
- $d_i$ - water distribution,
- $h$ - hygienic conditions,
- $c_v$ - price of water.

Using relation (3) we can assess which way of supplying will be suitable.

$$\sum_{i=1}^{n} w_i .HK_i \qquad (3)$$

where:
- $HK_i$ - i-th criterion value,
- $w_i$ - weight of i-th criterion,
- $n$ - number of criteria.

Each criterion is given its weight. The condition of weights is $\sum_{i=}^{n} w_i = \;$ .

If $\sum_{i=}^{n} w_i .HK_i < \;,7$ we work with mobile bags or tanks,

$1{,}7 \le \sum_{i=}^{n} w_i .HK_i < \;!{,}4$ cisterns,

$2{,}4 \le \sum_{i=1}^{n} w_i .HK_i$ packed water.

Fig. 1 illustrates possible ways of drinking water supply to the population.

In order to really provide drinking water supply to the population it is necessary to analyze all dangers that can impair this process. **The safety of drinking water supply to the population** can be disrupted by four basic factors:

- **Human factor,** i. e. human with his intentional or unintentional actions (control management, service, terrorist etc.),
- **Technological equipment and technical appliances,** i.e. the quality of used material and technical appliances that are used in individual forms of emergency supplies,
- **Legal documents,** i.e. laws, government decisions and orders, or internal operational regulations,
- **Environment,** i. e. surroundings of the water resource (in which dangerous substances can be found, pipes can be impaired, flooding and others).

Emergency drinking water supplies to the population during crisis situations represent a demanding and complicated process of activities which can be, in a simplified way, expressed as a process starting with the preparation of documents for emergency supply and ending with the plan completing.

The most important element of the whole process of activities connected with the supply, related mostly to the planning and taking preventive measures to supplying sufficient amounts of safe drinking water for the population, subjects of economic mobilization, armed forces, security armed corps, medical services and other components, is the preparation.

Even during the preparation for emergency drinking water supply to the population during crisis situations it is necessary to design and remake various possibilities of drinking water supply to the population and other subjects in compliance with logistics principles. In order to really provide emergency drinking water supply, the responsible persons, bodies and organizations have to fulfil the following tasks:

- To analyze the current situation of drinking water supply,
- To analyze risks, vulnerability and capacities of water resources and technical appliances,

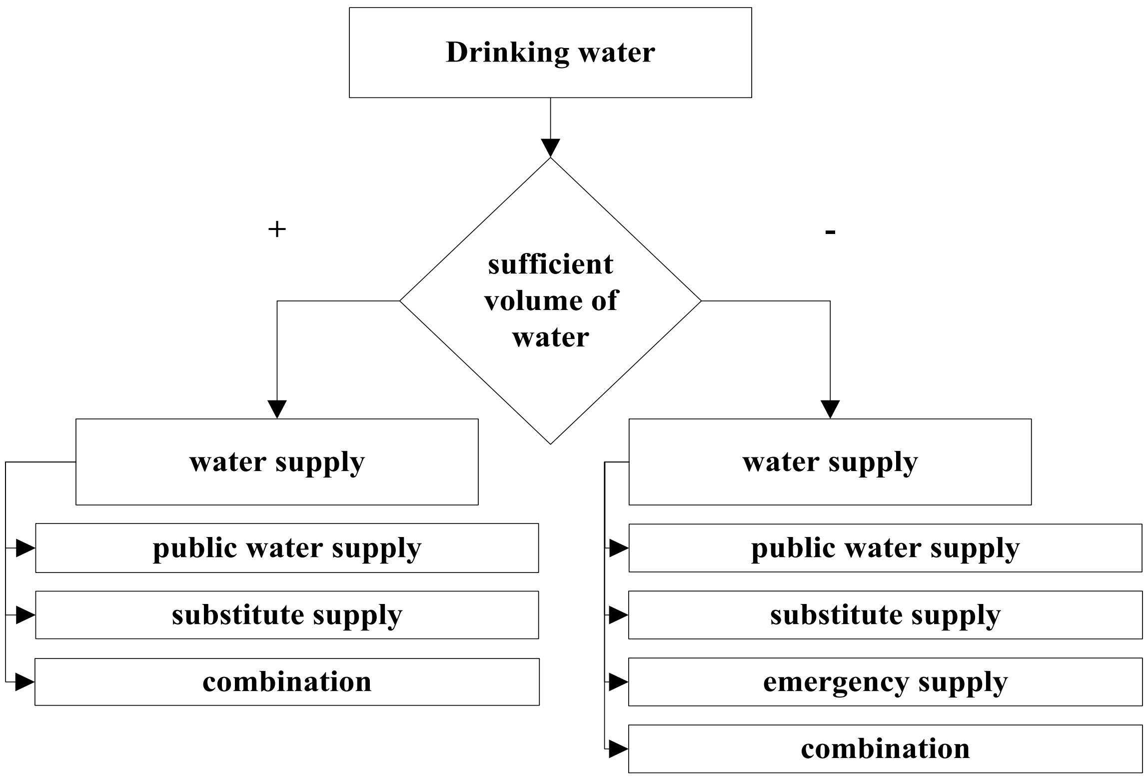


Fig. 1 Ways of drinking water supply [Source: own sources]

- To work out real documentation which solves drinking water supply to the population and in the process of supply to control it in a operative and transparent way,
- To organize preventive measures to divert dangers or to reduce their consequences and impact on people affected by crisis situations,
- To use all the accessible means to inform affected population at the right time,
- To solve exiting problems, suggest measures and assign concrete tasks to responsible bodies, organizations and persons,
- To coordinate the activities of all the components that participate in the solution of given tasks connected with drinking water supply (as for the target, venue and time),
- to operatively solve differences between the planned and real state of supply,

- To broadly support the subjects participating in the solution of supply tasks.

After the preparatory stage for emergency supplies which in fact is in the working out of analyses before the crises situation, there is another, much more demanding stage of the whole activity of emergency supply and that is the supply itself after the crisis situation arose.

The preparation process for water supply when solving the crisis situation consists of certain steps, namely:

- **Analysis of the present state of drinking water supply,** in which:
  - Physical, geographical, and economic and geographical conditions are assessed and characteristics of areas to be provided with drinking water supply and types of supplying are worked out,
  - The current state of drinking water supply is assessed on the basis of data on drinking water delivery for the population, industry, agriculture and on the basis of data on supplying systems,
  - The dependence of drinking water supply on electric energy supply is assessed mainly from the point of view of production and transportation of drinking water to its users,
- **Assessment of safety risks and danger in crisis situations,** where:
  - Strategic resources of economy, industrial and other production objects in individual areas of drinking water supply are considered as possible sources of pollution of water resources and objects in case of their destruction during crisis situations.
  - Natural conditions in the area of supply are assessed with the aim to analyze a possibility of occurrence of natural disasters and accidents which can impair drinking water reservoirs,
  - Sensitivity of used water resources and objects to expected security risks and danger is assessed,
  - A possibility whether decisive water resources and objects can be put out of operation is assessed and after they have been put out of operation, alternative solutions are proposed.
- **Cooperation of bodies and subjects participating in emergency supply based on:**
  - A survey of technical and other means the participating bodies and subjects have at their disposal,
  - Appropriate cooperation between the subjects whose means can be used for emergency supply (for example, neighbouring villages, enterprises and others),
  - Outline of the exact initial cooperation between bodies and subjects to avoid delays in the crisis situation solution due to the initial lack of transparency and problems which arise immediately after the crisis situation begins.

The mentioned data have to be processed into a detailed crisis plan that contains all the necessary information on the region in which the solution of emergency supply is expected: its causes, how many persons will need the help, who will take care of them, what means will be used, who will be cooperating with who…. This plan has to be prepared by the subject of economic mobilization (a water supply company) providing water supply.

Figs. 2 and 3 present the algorithm of emergency drinking water supply to the population.

The solution scheme of emergency supply (development algorithm) can be used also for other types of transport. Then, it is necessary to determine the type of transport which can be used for drinking water transportation. At the same time various factors of choice should be taken into account, e. g.:

- speed of transport,
- damage or complete disruption of transport infrastructure,
- is it possible to use transport (for example, in case of water transport, there should be access to the water way, etc.),
- traffic distance (for example, in case of air transport large aircraft cannot be used for short distances).

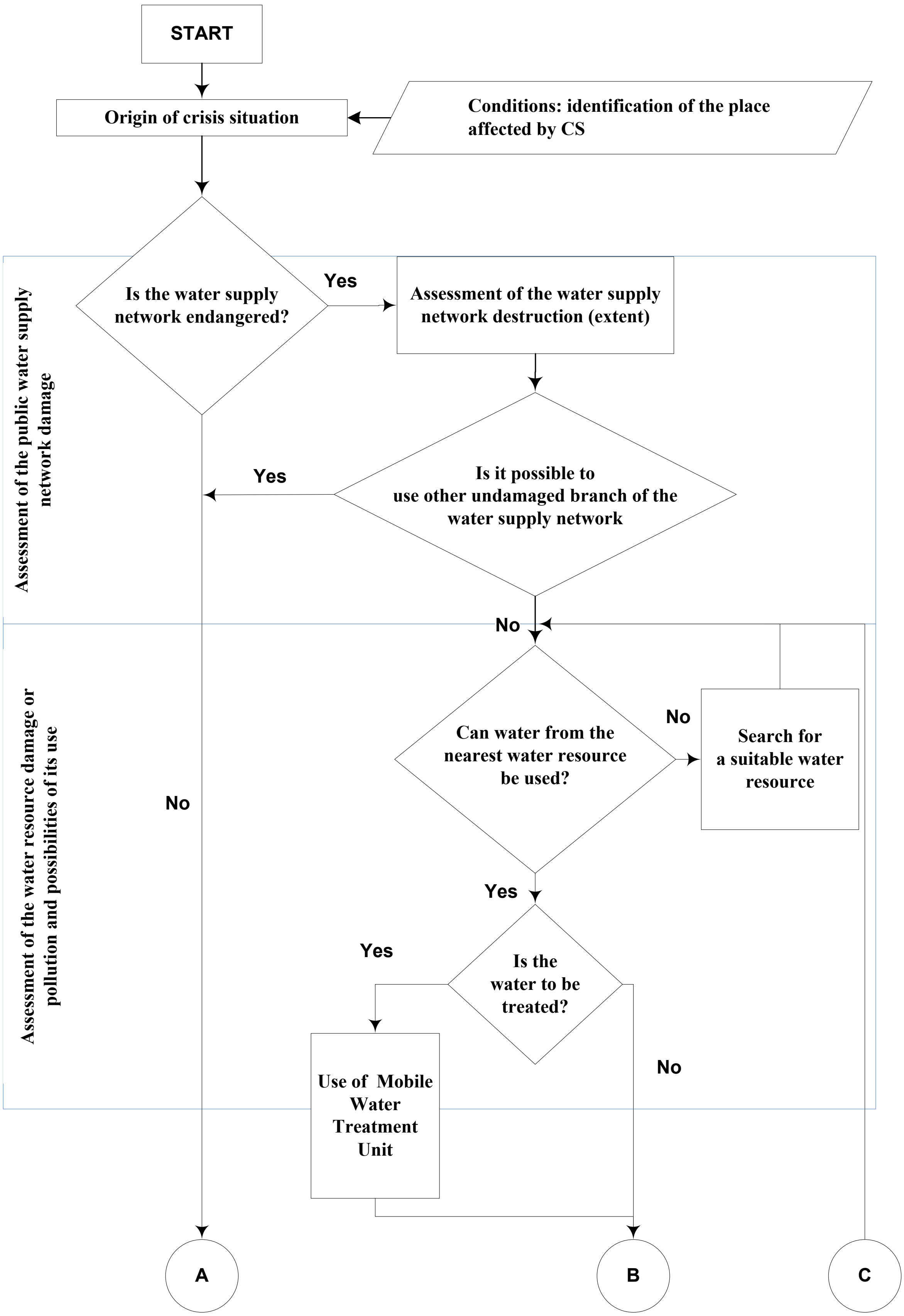


Fig. 2 Solution scheme of emergence supply [Source: own sources]

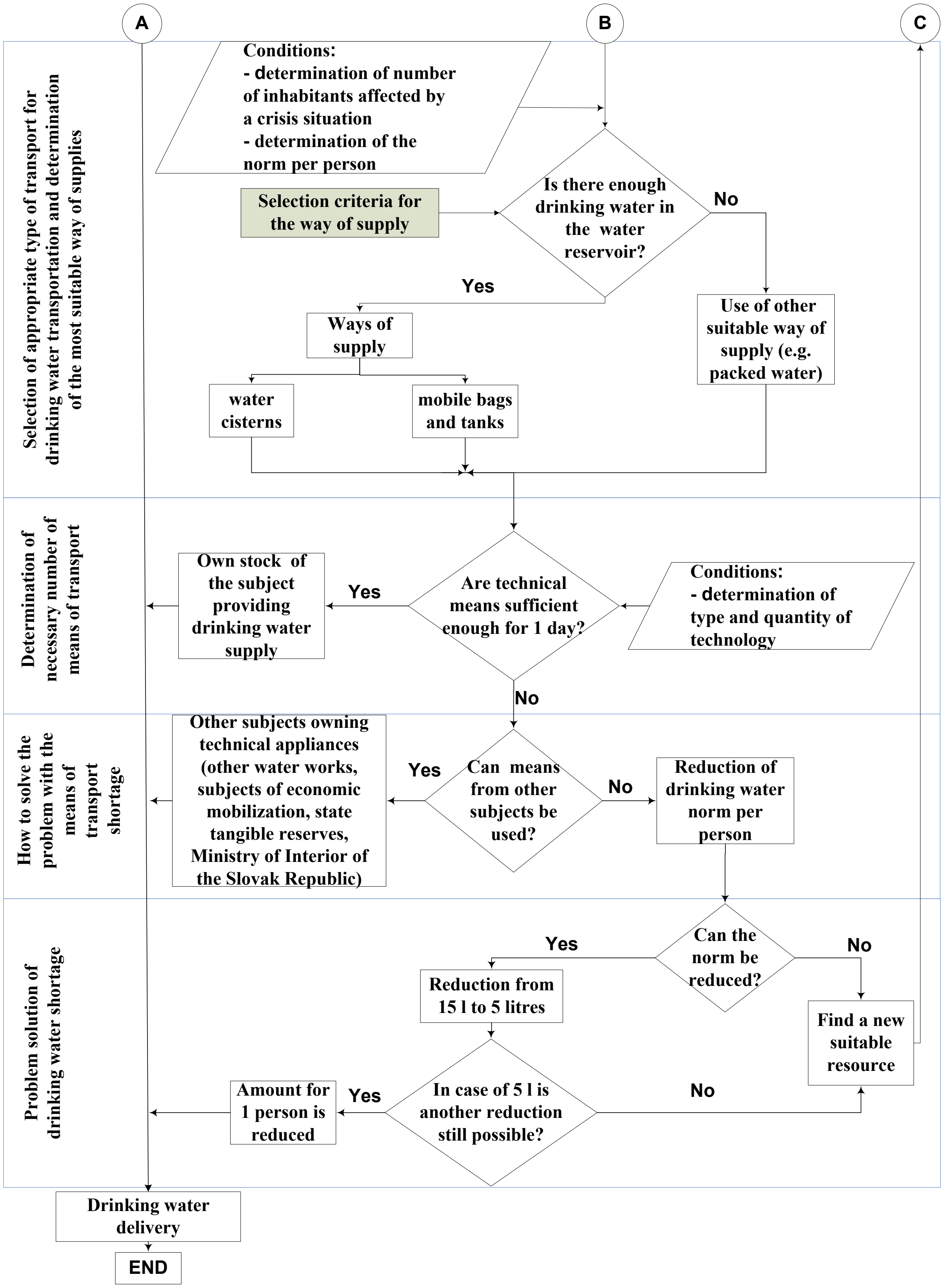


Fig. 3 Solution scheme of emergency supply [Source: own sources]

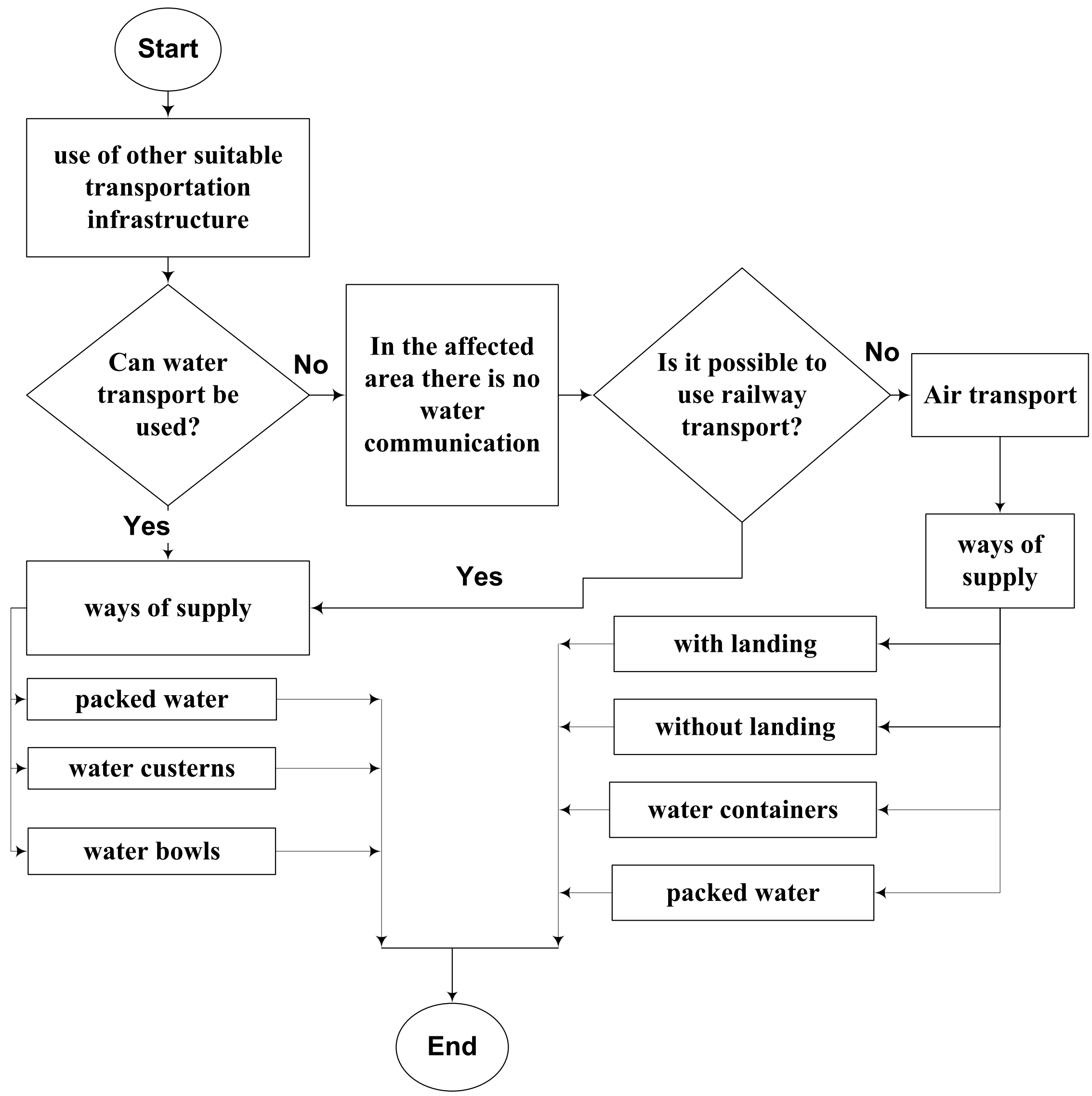


Fig. 4 Development algorithm of other transport choice Source: own sources]

Fig. 4 illustrates a possible choice of kind of transport for emergency supply by means of the development algorithm.

Having determined the type of transport by which drinking water would be transported, it is necessary to choose a suitable manner of drinking water supply which will depend on various factors,

for example, on the capacity of means of transport, water durability, etc.

## 4. TRANSPORT OF EMERGENCY WATER SUPPLY

Emergency drinking water supply to the population covers processes and activities which can be, after proper preparation for the solution of a crisis situation, managed without greater problems. It all depends on the character and extent of a crisis situation. **A concrete emergency drinking water supply to the population in this case covers:**

- increased monitoring and protection of drinking water resources and important technical equipment (pumping, treatment, storage and transportation),
- determination of water consumption norms (depending on a concrete situation),
- fixing ways to economize drinking water consumption,
- inform population about drinking water supply conditions with a special emphasis on the venue and time of drinking water distribution,
- organization of drinking water distribution with emphasis on:
  - who, where and when will water be distributed,
  - in what quantity and in what form,
  - who provides water supply, or who will treat it,
  - who will deliver the water to the destination,
  - efficient usage of means for water storage, transportation and distribution, etc.

Generally, when planning the whole water supply situation it is recommended to carefully prepare it. Each step intended to be taken should be well prepared.

The main step to begin the solution of drinking water supply with is **the assessment of situation**. Its content is:

- to find out the reason why the public water line was put out of operation,
- to characterize the situation from the point of view of securing the drinking water delivery; this part should contain information on:
  - the public water supply line providing drinking water supply in the place (name of the water works, total capacity of the water supply line and number of supplied inhabitants),
  - number of private wells that meet the requirements for hygienic checking and can be used after water conditioning from the point of view of hygienic and medical at drinking water delivery,
- to analyze the extent of damages on the water supply line and estimation concerning the putting of water supply network out of operation,
- to determine the number of population who are to be provided with drinking water supply (in this step also the quantity of water for subjects of economic mobilization where we can mention food production, and from other objects we could mention food service establishments, etc.).

Variants of **emergency drinking water supply** to population include the following possibilities:

- **interconnection of individual water piping of the water supply network,**
- **distribution of drinking water by water tanks,** here, it is necessary to determine the venue and schedule of distribution and the water tank capacity,
- **distribution of packed drinking water**, equally as in the previous case, the venue of distribution and the number of supplied inhabitants,
- **use of private wells** that must have gone through veterinary, medical and hygienic checking,
- **use of substitute long-distance pipeline.**

**The organization of emergency drinking water supplies covers**:

- determination of venues of drinking water distribution specifying:
  - venue of drinking water distribution,
  - possible capacity of means designed for drinking water delivery,
  - way of drinking water distribution,
  - schedule of water distribution,
- determination of number of inhabitants and other subjects to be supplied,
- appointment of a person responsible for drinking water distribution,
- appointment of representatives of the settlement responsible for coordination and cooperation:
  - with a drinking water supplier,
  - with a responsible authority securing drinking water supply,
- determination of the way of drinking water provision by means of the subject operating at a given location,
- determination of time within which emergency drinking water supply will have to be provided.

Calculations (quantities of drinking water, of means of transport, etc.) are also organizational components of emergency supplies, as illustrated in Tables 1 and 2.

Calculating the necessary quantity of drinking water one should forget to include other important subjects of economic mobilization and other subjects (for example, food service establishments, bakeries, hospitals, etc.).

On the first day of supplying, apart from using water cisterns to deliver drinking water to population another form can be used – it is delivery of packed water as introduced in Part 3. When packed water is used for emergency supply it is necessary to sign contracts with wholesale trade, shops or other suppliers who are able to provide quick and safe supply of packed water.

Table 1 Quantity of drinking water supplied from water works by water tank vehicles

| **Subject (distribution venue)** | **Number of persons to be supplied** | **Quantity of drinking water (litres)** | | | | **Responsible person** |
|---|---|---|---|---|---|---|
| | | **for 1st day** | **for 2nd day** | **for 3rd day** | **for next days** | |
| Venue No1 | 2 300 | 11 500 | 11 500 | 11 500 | .... | **....** |
| Venue No 2 | 560 | 2 800 | 2 800 | 2 800 | .... | .... |
| Health centre | - | 2 300 | 2 300 | 2 300 | .... | .... |
| Food service establishment | - | 1 500 | 1 500 | 1 500 | .... | .... |
| **Total** | **2 860** | **18 100** | **18 100** | **18 100** | **....** | |

[Source: adapted according to [7]]

Table 2 Number of packaged drinking water

| **Subject** Venue | **Number of persons to be supplied** | **Quantity in 5-litre packages (pieces)** | | | | **Responsible person** |
|---|---|---|---|---|---|---|
| | | **for 1st day** | **for 2nd day** | **for 3rd day** | **for next days** | |
| Venue No 1 | 2 300 | 2 300 | Water cisterns are used, packed water can also be used | | | .... |
| Venue No 2 | 560 | 560 | | | | .... |
| ...... | .... | .... | | | | .... |
| **Total** | **2 860** | **2 860** | | | | |

[Source: adapted according to [8]]

[7] Methodological instructions of the section of crisis management and civil protection of the Ministry of Interior of the Slovak Republic for unification of district authorities procedures aiming at coordination of villages when providing economic mobilization in the section of emergency drinking water supply [on line]. [Cit. 2011-06-06]. Accessible on: http://www.minv.sk/ swiftdata /source/ verejnasprava/obutrencin/ formulare/okr/2-Met-pokyn-Pitna-voda.doc

[8] Methodological instructions of the section of crisis management and civil protection of the Ministry of Interior of the Slovak Republic for unification of district authorities procedures aiming at coordination of villages when providing economic mobilization in the section of emergency drinking water supply [on line]. [Cit. 2011-06-06]. Accessible on: http://www.minv.sk/ swiftdata /source/ verejnasprava/obutrencin/ formulare/okr/2-Met-pokyn-Pitna-voda.doc

For the first three days there is limit of 5 litres of drinking water per person and day; on the fourth day the limit is 15 litres per person and day. Table 3 shows the total growth of drinking water quantity for the first four days in dependence on the number of population to be supplied.

The survey of venues of distribution at emergency supplies should be processed in tables containing concrete data (for example, about the venue of drinking water distribution, capacity of a drinking water cistern, etc.) as introduced in Table 4.

Table 3 Growth of total required volume of drinking water for population for four days

| **Number of inhabitants to be supplied** | **Growth of total required volume of drinking water for population for 1 – 4 days** (l) | | | |
|---|---|---|---|---|
| | **1st day** | **2nd day** | **3rd day** | **4th day** |
| 500 | 2 500 | 5 000 | 7 500 | 15 000 |
| 1 000 | 5 000 | 10 000 | 15 000 | 30 000 |
| 2 000 | 10 000 | 20 000 | 30 000 | 60 000 |
| 3 000 | 15 000 | 30 000 | 45 000 | 90 000 |
| 4 000 | 20 000 | 40 000 | 60 000 | 120 000 |
| 5 000 | 25 000 | 50 000 | 75 000 | 150 000 |
| 10 000 | 50 000 | 100 000 | 150 000 | 300 000 |
| 50 000 | 250 000 | 500 000 | 750 000 | 1 500 000 |
| 100 000 | 500 000 | 1 000 000 | 1 500 000 | 3 000 000 |

[Source: own sources]

Table 4 Survey of venues of drinking water distribution within the framework of emergency delivery

| **Venue No** | **Venue of dis-tribu-tion** | **Capacity of a water reservoir** | **Number of persons to be supplied** | **Water reservoir type** | | **Distribution for popula-tion** | **Time of dis-tribu-tion** | **Distribution will be provided by** |
|---|---|---|---|---|---|---|---|---|
| 1. | street | | | A | CKV-7 | of streets, town area, settlement | from-to | |
| 2. | | | | A | CAV-11 | | | |
| 3. | | | | B | KCA X B | | | |
| 4. | | | | C | storage 500 liters | | | |
| Note: reservoir type a - mobile (cistern), b - mobile (cistern superstructure), c - collapsible cistern | | | | | | | | |

[Source: adapted according to [9]]

[9] Legislation in the area of epidemiologically relevant activities for work in water treatment plants and at water supply handling [on line]. [Cit. 2011-06-06]. Accessible on: www.ruvznr.sk /hv/skusky voda.pdf

**Drinking water** for population and other subjects is **provided** (Fig. 5):

- from the public water-supply line (undisturbed water supply lines or their parts and possibilities of their temporary connection),
- from undisturbed wells,
- by water conditioning using mobile water treatment units,
- by distribution of drinking water by means of water-tanks (on lorries, by water cistern trailers, cistern superstructure),
- by distribution of packed drinking water,
- by transportation using substitute long-distance pipelines,
- by a combination of above types.

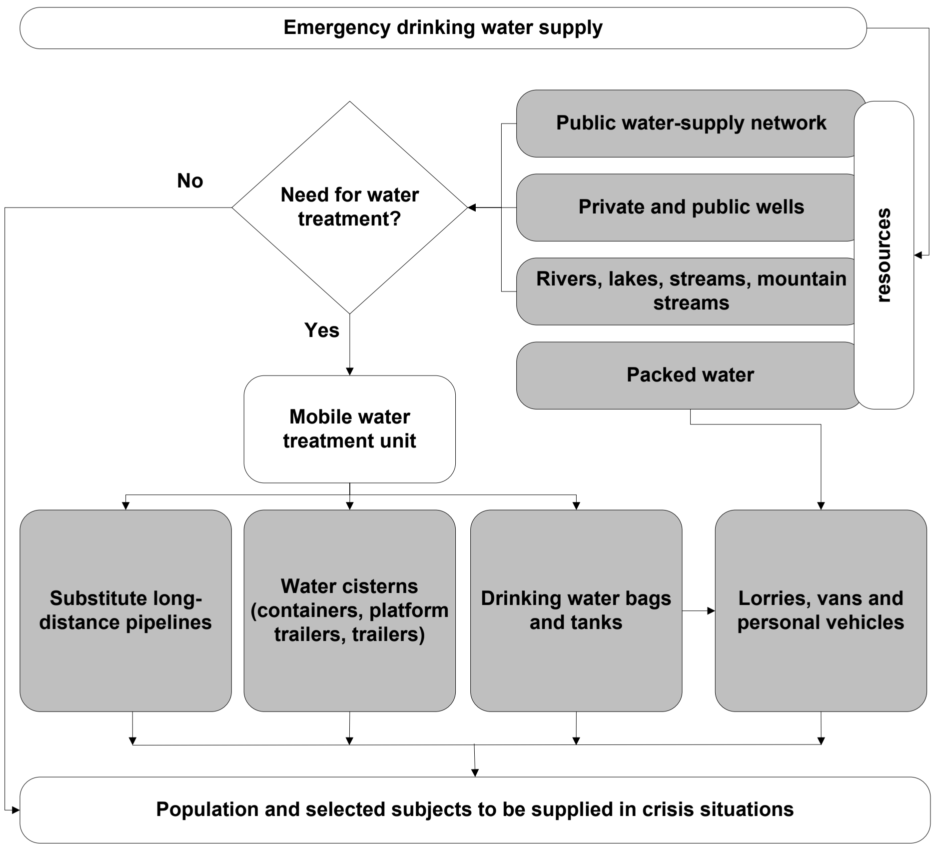


Fig. 5 Resources and means of emergency supply [Source: own sources]

### *3.1. USE OF CISTERN MEANS OF TRANSPORT FOR EMERGENCY SUPPLY*

Emergency drinking water supply solved from the point of view of **drinking water transportation** can be provided by various kinds of transport. Actually, technical means of all kinds of transport can be used for transportation of drinking water. To reach the final consumer, i. e. population affected with the crisis situation, a subject of economic mobilization or given organization (establishment) the following **means** can be used:

- Road transport mainly:
  - Cistern vehicles, cistern superstructures, cistern trailers, cistern platform trailers, cisterns with an exchangeable container (further only “cisterns“),
  - Lorries with appropriate load-carrying platform,
  - Personal vehicles and vans,
- Air transport: various types of helicopters, or cargo airplanes,
- Water transport: various boats,
- Pipe transport: mobile substitute pipeline.

Cisterns play the most important role in the process of emergency supply. They are also the most frequently used. These means of transport are in majority of cases used as first. They serve for the safe transportation and partly also for the storing of drinking water in the areas affected by a crisis situation.

For example, in Great Britain in July 2007 during the floods cisterns provided drinking water supplies to more than 1 000 venues of distribution. In order to fulfil thoroughly all the delivery tasks performed by **cisterns** it is necessary **to calculate:**

- With the largest possible capacity of the cistern vehicle due to efficiency requirements,
- With good vehicle driveability when driving in difficult terrain,
- With drinking water cisterns only (exceptionally also vehicles used for transportation of milk, beer, etc.).

There is a whole series of cisterns that can be used for emergency supplies to population. In Slovakia the most frequently used cisterns are the following types CAV- 11, CKV-7, Man NCS7 and CITRA-M. Their significant technical parameters are shown in Table 5.

The number of persons to be supplied by means of cisterns depends on the capacity of the tank. For the purpose of comparison Table 6 shows the number of persons to be supplied with 5 or 15 litres of drinking water by means of chosen types of cisterns within one cycle.

On drinking water supply to the population by cistern vehicles certain **basic measures and hygienic principles** have to be kept:

- Cisterns have to be used for drinking water transportation only,
- Cisterns must be provided with a “Drinking water“ sign; it is recommended to put a complementary notice near the output tap, in case it is necessary to boil the water or any other notice according to a concrete situation,
- pumped water has to meet the requirements put on high quality drinking water,
- the tank has to be disinfected before being used,
- the cistern should be located in the terrain, which is, if possible, in clean, dust-free environment; in summer it should be located in the shade,
- the water in the tank is usable for the period of 48 hours; in hot summer, the period is shorter while in winter the period can be prolonged up to 72 hours,
- If possible and if conditions are suitable, water should be changed every day,
- Before the tank is re-felled, it is necessary to empty it and remove everything from it,
- A sanitary day should be fixed once a week when the tank is mechanically cleaned, and disinfected,

The quality of water is checked in compliance with possibilities or decisions of responsible authorities.

### *3.2. MEANS OF TRANSPORT FOR PACKED WATER TRANSPORTATION*

In case of shortage of water tank vehicles another most appropriate solution is to use packed water for emergency drinking water supply to population. For the transportation of packed water there is a relatively wide range of types of means of transport that can be used depending on the quantity needed: personal cars, vans, platform trailers. **Quantities of transported packed drinking water will depend** on:

- Shape and dimensions of load-carrying platform of the means of transport (in personal cars and small vans on the capacity of the interior),
- Load capacity of the means of transport,
- Vehicle driveability in difficult terrain,
- state of communications leading to the venues of distribution,
- number of persons to be supplied,
- number of days to be supplied.

Packed water can be transported in plastic bottles of bowls having the volume from 0.25 litres up to 18.9 litres. Glass bottles are not to be used. On emergency supplies the amount of transported packed drinking water will mainly depend on:

- volume of the used bowl (bottle),
- shape and dimensions of load-carrying platform,

- vehicle load capacity,
- vehicle driveability in difficult terrain,
- number of bowls (bottles) on the pallet etc.

**Plastic bottles** will be put on appropriate handling units, so call EURO wooden pallet having dimensions of 1 200 x 800 mm, as a rule in four layers (depending on the type of bottle) having the height of about 1.4 – 1.6 metre. The total volume of drinking water and quantities of drinking water in different packages that can be found on EURO pallet can be seen in Table 7.

For the transportation of drinking water only those means of transport that are able to carry the required amount of drinking water should be used.

To decide which way of supply will be chosen it is necessary to find out which way will be the most appropriate for the given crisis situation. Water tank vehicles are not always the most appropriate choice for drinking water supply, and, on the other hand, the supplies of packed water only will not always be the best solution. It is not always possible to make use of the complete load-carrying platform, or load capacity of the used means of transport. When choosing a type of the means of transport for drinking water supply, it is necessary to come out mainly from the numbers of means of transport the organizations mostly have at their disposal and are expected to be used for transport provision of a crisis situation.

Table 5 Technical data on chosen cisterns

| Chosen technical data | CAV 11 | CV 7 | Mercedes Atego 1528 4x2 PCA-7.0H | MAN 9.180 4x2 PCA-4.5H | Man NCS 7 | Cistern vehicle CITRA - M |
|---|---|---|---|---|---|---|
| Nominal volume (l) | 11 000 | 7 000 | 4 500 | 4 500 | 5 800 | 7 000 |
| Pump capacity ($l.min^{-1}$) | 520/630 | 200 | 800 | 800 | 800 | 216 |
| Total mass (kg) | 22 400 | 21300 | 15 000 | 9 500 | 11 990 | 24 300 |
| Kerb weight (kg) | 11 460 | 13 950 | 7 600 | 4 900 | 5 990 | 15 870 |
| Load capacity (kg) | 10 940 | 7 350 | 7 400 | 4 600 | 6 000 | 8 430 |

[Source:own sources]

Table 6. Number of persons to besupplied by cistern vehicles

| Vehicle type | Nominal capacity (l) | Number of persons to be supplied | |
|---|---|---|---|
| | | 5 l | 15 l |
| CAV 11 | 11 000 | 2 200 | 733 |
| CKV 7 (Citra – M) | 7000 | 1 400 | 466 |
| Man NCS 7 | 5 800 | 1 160 | 386 |

[Source:own sources]

Table 7 Volume and mass of selected packages of drinking water on a EURO pallet

| Volume of bottles (l) | Number | | Total number of bottles on a pallet (pcs) | Number of layers on the pallet | Total volume of drinking water on the pallet (l) |
|---|---|---|---|---|---|
| | Bottles in consumer packing (pcs) | Consumer packing on a pallet (pcs) | | | |
| 0.5 | 4 | 324 | 1296 | 6 | 648 |
| | 8 | 216 | 1296 | 6 | 648 |
| | 12 | 108 | 1296 | 6 | 648 |
| 0.7 | 6 | 125 | 750 | 5 | 525 |
| 1 | 6 | 100 | 600 | 4 | 600 |
| | 12 | 55 | 660 | 4 | 660 |
| 1.5 | 6 | 84 | 504 | 4 | 756 |
| | 6 | 76 | 456 | 4 | 648 |
| 2 | 4 | 56 | 224 | 4 | 448 |
| | 4 | 96 | 384 | 4 | 768 |
| | 6 | 64 | 384 | 4 | 768 |
| 2.5 | 6 | 48 | 288 | 4 | 720 |
| 5 | 1 | 120 | 120 | 3 | 600 |
| | 1 | 160 | 160 | 4 | 800 |
| 10 | 1 | 72 | 72 | 3 | 720 |

[Source: own sources]

Table 8 Basic technical data on chosen trailers and platform trailers

| Platforms trailers /trailers | | | | Number of persons to be supplied | |
|---|---|---|---|---|---|
| Name and type | Dimensions of load-carrying platform (mm) | Number of pallets (pcs) | Load capacity (kg) | 5 l | 15 l |
| Standard | 12 200 x 2 440 | 30 | 24 000 | 4 800 | 1 600 |
| Euro | 13 620 x 2 440 | 34 | 24 000 | 4 800 | 1 600 |
| Trailer | 6 100 x 2 440<br>8 200 x 2 440 | 35 | 7 500<br>16 000 | 1 500<br>3 200 | 500<br>1 067 |
| Jumbo-trailer | 6 100 x 2 440<br>8 200 x 2 440 | 35 | 7 000<br>16 000 | 1 500<br>3 200 | 500<br>1 067 |
| Transmaxi -trailer | 6 100 x 2 420<br>9 000 x 2 420 | 38 | 7 000<br>16 000 | 1 500<br>3 200 | 500<br>1 067 |

[source: adapted according to [10]]

[10] JAKUBČEKOVÁ, J., TOMEK, M.: *Some aspects of emergency drinking water supply in selected countries of the EU.* In: LOGVD - 2009 Transport logistics and crisis situations [Proc. from 12th international scientific conference]: Žilina 24.-25.9.2009. Žilina: University of Zilina 2009, pp. 139-146, ISBN 978-80-554-0114-0

Table 9 Volume of loaded water and number of pallets

| **Package capacity** (l) | **Vehicle** | | |
|---|---|---|---|
| | AKTIS 4x4 VV | T-815 VVN 6x6 | T-815 VVN 8x8 |
| | **Volume of loaded water/number of MJ** (l/number of pallets) | | |
| 0.5 | 4 320/8 | 6 480/12 | 7 560/14 |
| 1.0 | 4 608/8 | 6 912/12 | 8 064/14 |
| 1.5 | 4 536/6 | 6 804/9 | 9 828/13 |
| 2.0 | 4 608/6 | 6 912/9 | 9 984/13 |
| 2.5 | 4 620/7 | 7 260/11 | 9 240/14 |
| 5.0 | 4 800/6 | 7 200/9 | 11 200/14 |

[Source: own sources]

It is suggested that drinking water transportation will be, as a rule, solved by means of goods transport or by personal cars.

Table 8 shows basic technical data on chosen trailers, and platform trailers, including the number of persons to be supplied.

It is also important to know the quantity, i. e. the maximum number of pallets that can be placed in individual vehicles as it is illustrated in Table 9. The number of pallets is given by the dimensions of the load-carrying platform, it is, though markedly limited by the vehicle load capacity.

The most suitable vehicle for the packed water transportation put on pallets is a terrain vehicle T-815 due to its large load capacity and good vehicle driveability from which its excellent driving in difficult terrain results. 13 pallets with 2 litre bottles having the volume of 9 984 litres of water or 14 pallets of 5 litre bottles having the volume of 11 200 l can be placed on the vehicle.

To decide which way of supply will be chosen it is necessary to find out which way will be the most appropriate for the given crisis situation. Water tank vehicles are not always the most appropriate choice for drinking water supply, and, on the other hand, the supplies of packed water only will not always be the best solution.

Each type of drinking water transportation by means of water tank vehicles and vehicles to transport packed drinking water has it strong and weak points. Table 10 presents some strong and weak points comparing the use of water tank vehicles and use of packed water for drinking water supply to population.

Each of these transportations has its threats that have to be pointed at to improve emergency supply, make it better, faster, safer and more efficient. In case of packed water the space for storing has to be provided. The storage space can be partly damaged or completely destroyed by an extraordinary event and even drinking water can be polluted. Another negative point is also a high financial demand for packed water filling, for bottle production and, of course, for maintenance of storage spaces in which drinking water is stored. As for water tank vehicles it is mostly their technical side, as many vehicles the subjects have at their disposal are relatively old. Again, finance is needed for repairs and hygienic cleaning of these means of transport. One of the threats of this period is terrorism and with it is connected the possible pollution of tanks by poisonous substance or their destruction.

For interventions during crisis situations in the Slovak Republic mostly water tank vehicles are used as each subject that provides drinking water delivery, has to a limited extent of various types of tank vehicles, cisterns and cistern trailers with the capacity from 1 000 litres up to 17 000 litres.

0n emergency drinking water supplies to population it is necessary in close cooperation of authorities of public administration and subjects responsible for drinking water supply **to deal with the following questions:**

- a number of people to be supplied and to appoint a person responsible for drinking water distribution,
- determine the drinking water distribution points with emphasis on:
  - venue of distribution,
  - capacity of means designed for drinking water supply,
  - form and way of drinking water distribution,
  - time schedule of water distribution,
- to appoint responsible representatives of a location for coordination and cooperation:
  - with a supplier of drinking water,
  - with the municipal authority,
- way of providing drinking water by the subject operating in the given location,
- time period within which it will be necessary to provide emergency drinking water supplies,
- way of protecting the drinking water distribution point.

Table 10 Strong and weak points of using tanks and packed water

| **Tanks** | **Packed water** |
|---|---|
| **Strong points** | |
| • transport of large volume of drinking water<br>• a greater number of vehicles than in case of packed water transportation<br>• experience with this type of supply<br>• transportation also in poor terrain conditions<br>• no storage space necessary | • knowledge of water volume in the vehicle<br>• good hygienic provision<br>• comfortable distribution<br>• easy and rapid handling<br>• longer period of storing |
| **Weak points** | |
| • poorer hygienic conditions on distribution<br>• worse technical conditions of vehicles<br>• problems with water distribution and storing<br>• demanding logistics | • shortage of vehicles (platform trailers)<br>• high costs for water packing<br>• transportation of smaller quantities<br>• plastic bottle waste |

[Source:own sources]

## CONCLUSION

Transportation provision of emergency drinking water supply presents a complicated problem that comes out from the interconnection of individual elements of critical infrastructure in subsectors of drinking water supply and road transport. The problem will be even more complicated because in a crisis situation we can expect a partial destruction of decisive elements of critical infrastructure of the mentioned subsectors which will have a significant influence on safe and rapid drinking water supply to the population affected by a crisis situation. To minimize the risks connected with the above mentioned it is necessary to deal now with the topics related to the protection of critical infrastructure in the sectors of transport, water and atmosphere.

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