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9. Systemic analysis of Danube Delta drinking water in the context of potable water management

NICHERSU I. Iuliana*, MIERLĂ Marian, TÖRÖK Zsolt, TÖRÖK Liliana

Danube Delta National Institute for Research and Development: 165 Babadag street, Tulcea - 820112, Romania; e-mail: office@ddni.ro
**Address of author responsible for correspondence: Danube Delta National Institute for Research and Development: 165 Babadag street, Tulcea - 820112, Romania, e-mail: iuliana.nichersu@ddni.ro*

Abstract: This study presents the drinking water supply system quality analysis in the context of the presence and distribution of eukaryotic assemblage, specifically the presence of algae in 10 specific sites (water treatment plants and fountains) from the Danube Delta.
The analysis comes with a new approach based on stakeholders involvement and understanding of the new emerging problems generated by the presence of algae in the water supply system. In order to upgrade the water quality it is needed an improvement on the management of the water supply systems, with direct connection to the management of presence of algae or the occurrences of algal toxins in drinking water sources. Taking into consideration that Romania have no regulation dealing with the occurrence or the presence of algae or algal toxins in recreational or drinking water sources, it is important for all the stakeholders (local communities, local authorities, regional and national authorities etc.) to be informed about the the possibility of their occurrence in drinking or recreational waters, by creating a virtual space where they have access to the researches in this area.

Keywords: drinking water, operational system, management

INTRODUCTION

Danube Delta is the most deficient in terms of access to drinking water. Groundwater is found at depths of 2-5m, but because of the nature of the Danube Delta sedimentary soil, water is rich in many substances generated by decomposition sediment, such as sulfides in Ceatalchioi area, for example. In this context, residents of areas lacking quality water fountains have the habit of consuming untreated water directly from the Danube after its prior boiling. This applies to 17% of local residents lacking running water. In areas lacking centralized water supply, schools and town halls have their own deep wells with variable water quality. (MDRAP, 2016)

In the latest survey conducted at the request of the World Bank in 2014, the rate of connection to water supply systems reached 95% of the total population, the major problem being reported in the villages C.A. Rosetti and Ceatalchioi. Channeling is provided mostly in villages based on individual schemes and their connection to centralized systems is irrelevant in many cases, because of low density of population. There are still small villages, especially in the north-east of the heart of the Delta, which is not connected to the drinking water network. Water supply is an essential service of human and economic development of their major impact on health, environment, tourism, agriculture, and transport and disaster risk management. (MDRAP, 2016)

Sources of water supply in localities in Tulcea County are represented both by the surface water and the groundwater. Thus, the Danube arms and complexes, adjacent channels and lakes Razim and Babadag, are the sources of surface, groundwater sources are represented by the wells front Bogza and boreholes located in Tulcea County.

According to data presented in the Report on the state of environmental in Tulcea County in 2013, only 60% of the rural population consumes drinking water from greater depth that is within the accepted values for drinking water quality and fountain or average depth, while 10% consume water directly from the Danube, 20% use water fountain or small depth springs that does not fall in the legal accepted values, and 10% of the rural population consumes treated water, but it does not comply with the potability values of microbiologically analysis. Regarding the state of drinking water quality according to monitoring carried out by the Public Health Departments Tulcea and Constanta, there have been breaches of the parameter nitrate above 50 µg/l (up to 200 µg/l) in water distributed to population trough the centralized system, the value of the maximum allowable concentration according to Law. 458/2002 being 50 µg/l.

There is a European Directive regarding "quality of water intended for human consumption" (COUNCIL DIRECTIVE 98/83/EC of 3 November 1998) which stipulates: that the "objective shall be to protect human health from the adverse effects of any contamination of water intended for human consumption by ensuring that it is wholesome and clean". "Member States shall take all measures necessary to ensure that regular monitoring of the quality of water intended for human consumption is carried out, in order to check that the water available to consumers meets the requirements of this Directive and in particular the parametric values set in accordance with Article 5. Samples should be taken so that they are representative of the quality of the water consumed throughout the year. In addition, Member States shall take all measures necessary to ensure that, where disinfection forms part of the preparation or distribution of water intended for human consumption, the efficiency of the disinfection treatment applied is verified, and that any contamination from disinfection by-products is kept as low as possible without compromising the disinfection." (Official Journal of the European Communities, 1998)
All the quality data regarding the drinkable water should be made public in order that all the stakeholders to be informed.

The biggest challenge that we face today and will face in the future is ever-increasing complexity. This applies to economics (projects, strategies, products, technology, organization), politics (ecology, the economy, culture, demographics), society and also to our private lives (5-year-plan, life balance, family, relationships). Their success all depend on our ability to see the factors involved and how they are interconnected. (Neuman, 2011)

Today's decision makers seldom use tools. There are several reasons for this. Some fear transparency, many don't know that there are methodologies and tools available to them and others simply don't understand how to use them. Most of us shy away from making the effort it takes to reflect on the complex challenges we are faced with. Therefore it is common to rely on our gut feeling/intuitive intelligence and best practices. However, our gut feeling is emotionally deceptive (Kahneman, 2011) and cannot predict the future (Gigerenzer, 2007), and best practices are in most cases recipes that worked in the past and in a different context. If best practices always worked when we applied them, everything would always be successful to the same degree. (Neuman, 2013)

There are different tools available as decision support—mostly computer software—that offer so-called qualitative modeling or quantitative modeling methodologies, e.g., cross-impact matrix, fuzzy cognitive maps, Ishikawa diagrams, neural networks, agent based modeling and system dynamics. They are not topic of this paper, but regardless of the tool we use (and even if we use no tool at all) it is crucial that we always include the decisive factors into our models and think of the important relations that exist between these factors. We can refer to systems theories in this regard.

Systems thinking basically means that we try to gain a better understanding of something by reflecting on the interactions of the crucial factors that define it. We look at a system in a so-called model. Systems theories should help us to come up with a useful model. As George E. P. Box noted: "Every model is basically wrong, but some are useful". There are numerous fields of systems theory, ranging from cybernetics and systems psychology to systems engineering and systems biology. Also included are concrete principles that should describe how systems work.

KNOW WHY Thinking is really this simple. We don't even have to explicitly ask for how integration and development are involved—all we need to do is continue asking WHY, the same way that children do until their parents tell them that something is the way it is because it just is—unless, of course, they suggest that the child go ask their mother or father for the answer to their question. The need for integration and development for everything in the world is a kind of meta-systemic explanation. It is not quite holistic, but since it does not provide a fixed answer to anything and only helps you to come up with individual answers, it is less reductionist than other system theories are (Neumann, 2013).

MATERIALS AND METHODS

The analysis conducted by the projects' team started in 2016 with the collection of data and identification of the relevant factors in the exploitation of potable water system that may cause health problems. A social analysis were conducted in the present study were selected 10 villages located in the Danube Delta Biosphere Reserve (Figure 1).

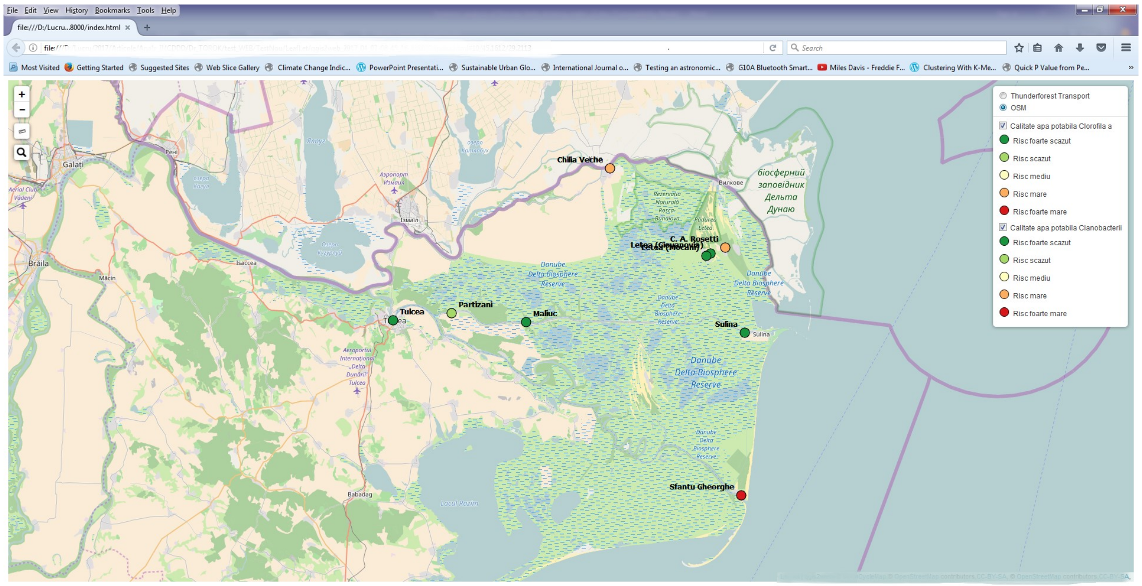

Figure 1. Distribution of the selected locations

In this respect, were interviewed the people responsible with the management and administration of the water supply system, based on several predetermined questions, such as:

- What is the water source of the village?
- Is the source unique? Do people have access to potable centralized water system or are they using wells?
- Is the water from Danube considered a source for potable water? Is the pluvial water used in any way? (For drinking water or other purposes)
- Is the potable water influenced by the pluvial waters?
- Are there any treatment methods applied in the water supply system?
- Who is the manager of the water supply system?
- How is the water quality monitored? By whom?
- How many potable water users are in the system?
- Is there a statistics on the water use?
- Are there any complains on the water supply system? Were there any incidents reported?

Using the Know-Why method in systems approach, next step in the study was the system analysis based on the answers received, but also on relevant bibliography and previous studies. The system was described using iModeller tool (developed by Consideo GmbH, Germania).

In principal, any conceptual model can be developed and drawn on a piece of paper. However, to identify, interpret and analyse loops, causal chains and potential impacts of factors, the classical pen and paper method reaches its limits. Having the support of computer tools becomes essential at a certain point. There are quite a few visualisation tools available on the market, mainly in the area of system dynamics and the preparation/visualisation of SD models. In the case of qualitative modelling, there are only very few visualisation and assessment tools available. Worth mentioning are so-called "fuzzy cognitive maps", which can be drawn as simple block diagrams, assessed with Excel tools and evaluated with network theory. In this study we used the iModeler. Qualitative modelling with the use of Consideo is a further development bringing together elements of CLD (system dynamics) and fuzzy cognitive maps. Although the algorithms are the same, the iModeler is web oriented and allows for cloud computing and collaborative modelling. (Lorenz and Haraldsson, 2014)

The iMODELER helps to gain insights, explore how things are interconnected and enhance the brain's capability to tackle complexity. It offers a revolutionary way to both visualize and analyze (via its unique Insight Matrix) complexity, thus allowing for better planning, decision-making and communication. This is applied systems thinking, and making qualitative modeling using natural language and the KNOW WHY Method extremely easy. (http://www.consideo.com/imodeler24.html)
The KNOW WHY Method is fairly simple. All you have to do is place a factor in your model and then list which factors either cause or hinder the integration of this factor to the left of it, and which factors either cause or hinder the development of that factor to the right of it. In the center, right above the factor, you should place those factors that cause both integration and development. Especially when you beginning to model, it is important to think of as many factors as possible—not only considering the most common ones, which are hardly ever the underlying reasons that a project will fail. Using KNOW WHY means asking what factors will influence a project in the near future, and what the affects of those factors might be. This method ensures that not only profitability will be considered, but also strategic benefits and the possibility that capacity will be limited when the core business rebounds. (Neumann, 2011)

It is important that all the stakeholders (local communities, local authorities, regional and national authorities etc.) to be informed about the quality of the water for drinking. For this, samples from different places from Danube Delta Biosphere Reserve, were taken in order to be analyzed to establish the concentration of Cyanobacteria and Chlorophyll-a as potential water quality indicators (***. 2016). All the values were assimilated to points of the sampling station with coordinates in order to create a map of their distribution. To make their distribution visible for all the stakeholders it has been used a Geographical Information System (GIS) software to produce a webmap.

RESULTS AND DISSCUSSION

Qualitative modeling build-up

All social processes, economic activities and drivers of change in ecosystems must be properly understood at different temporal and spatial scales. For instance, the scale of drinking water demand, a critical driver for water intake and for freshwater conservation, depends, among other factors, on the population size, the number of households and family income (Pletterbauer et al., 2016).

Thus, management must focus on control variables, such as the number of households using water from a particular source, the size and the structure of water prices, settlement regulations, development plans, local regulations, etc.. Manageable factors are essential to understand why and how the same activity drinking water provision can be sustained or not depending on local ecosystems availability and the efficiency with which these services are used. Similarly, to a large extent, advances in technology are independent of short-term local water management. But local water management is essential to understand the rate of adoption and speed of diffusion of new technologies once they become available. All this depends on incentives, resource constraints and water regulations that can only be understood at a local scale. (Pletterbauer et al., 2016).

The combination between the systemic analysis and biochemical analysis is a new and innovative approach that enhances the results of the study and the opportunities for the stakeholders involved, in order to improve the management of the water supply systems.

In iModeler were introduced the factors (figure 2), according to the description of the situation in the case study, as it was identified on the field. The factors were first introduced based on bibliography, and the final diagram as it is presented in this study was actualized with the expert knowledge collected from a series of questionnaires during the field collection of water samples. Starting from the source (the first drop of the water in the potable water system) – coming from Danube or groundwater- the system follows the water supply transportation pattern all the way to the end user. In this manner, were identified the main points were the system could reveal problems and influence the water quality.

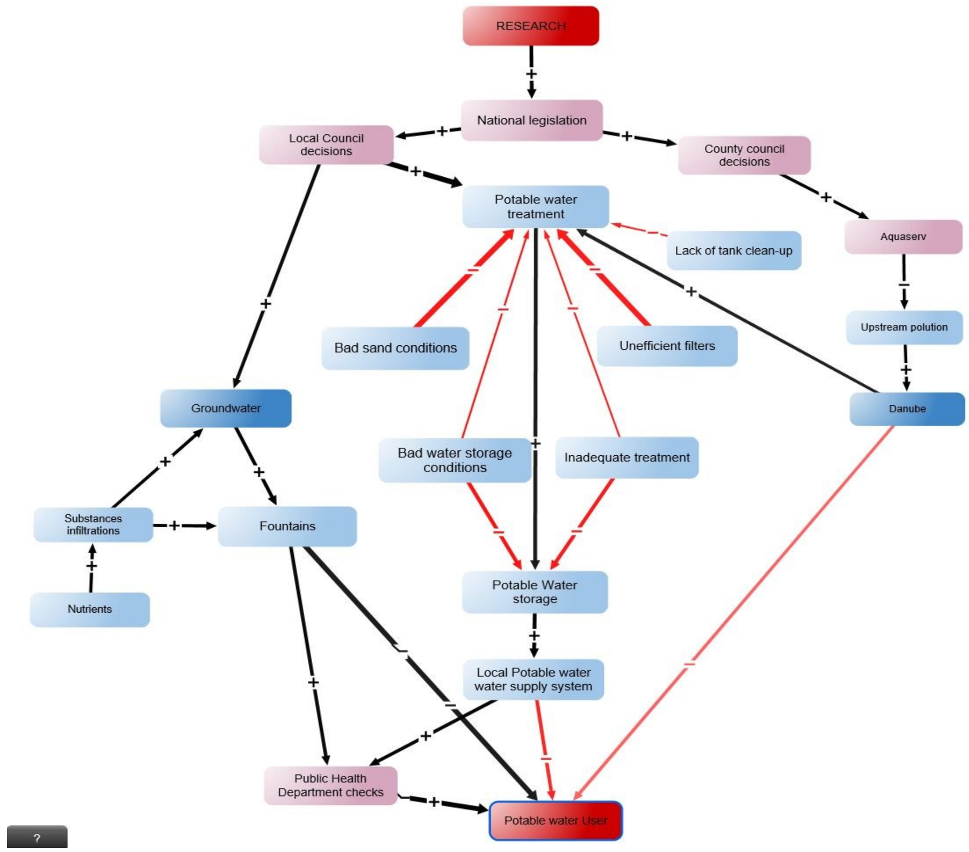

Figure 2. Potable water system analysis diagram

For example, the tank decantation factor can be influenced by a lack of clean up, but in the same way, the sand filtering step in the system, can be influenced by inefficient filters or bad sand conditions. Following the water path, the treatment phase could also be a source of problems if the treatment is inadequate, or, in the next step, if the potable water storage has bad conditions for short or long term storages.

An important aspect in the use of cognitive maps it's that the information collected on the field is fully stored in the diagram, by converting the information in the factors and connections. The connections store the information related to the time (short, medium and long term relations) and type influences. In this diagram, from the data collected, it can be detailed that the 'Public Health department checks' factor has an immediate positive influence on the 'potable water user' factor.

On the other hand, in the system analysis diagram are also marked the 'check-up points': the relevant stakeholders that influence the water quality in the system and that have a certain control on the entire system.

To exemplify, if the Public Department checks are strict and correct and reveal a problem in the system, than the User may not be affected by the problems or the problems can be solved more efficiently.

Incidents in deteriorating health status of the population are a dangerous and serious public health issue and the drinking water status it's one of the most fragile points in the system. It is required regular and strict monitoring of drinking water quality by the identified relevant stakeholders that provide and manage the water supply system in the studied areas, respectively Aquaserv SA Tulcea, County Council Tulcea, Local Councils and, the most important, at the basis of the system, the Public Health Department. In the current situation, the monitoring on the quality of water from wells by the Public Health Department is also mandatory. In localities where there are no water supply system it is necessary to achieve and extend it to ensure public drinking water needs.

The entire diagram is showing the potable water flow through the administrative and physical system of water administration. Based on the stakeholder information and actual legislation and procedures, the cognitive maps support the activity of water quality research by offering an easier understanding to the

decision makers on the water quality needs and limits.
The study can be continued by extending the analysis with the unique ‘Insight matrix’ that the iModeller offers to the system analysis, depending on the general objectives of the study.

Systemic analysis using the insight matrix
The next step in the drinking water system analysis is the interpretation of the insight matrix results of the cognitive map presented earlier. The Insight Matrix provides important information on the evolution of the system and how the factors interact directly or indirectly, in the short, medium or long term. Using the iModeler program (Consideo), the insight matrices of all the factors in the system can be extracted and the influences of the other components of the system in relation to a chosen factor can be presented, thus giving a better understanding of the system interactions and synergies.

The result of the qualitative modeling is the unique Insight-Matrix modeling that is obtained through the contextual menu for each factor. It compares the impact that other factors exert on the chosen factor. The matrix shows the x-axis horizontally between direct and indirect influences. Vertically, the y-axis shows the (R) and balance (B) reinforcement effect. A positive x value, and a positive y value, gives a steadily rising effect. A positive value x and negative y means a growth effect that diminishes over time. The x and y negative values show a decrease in factors, while a negative and x y positive means that the decreasing effect decreases over time. By doing so, it is possible to compare the short, medium and long-term influences of the factors. (Neuman, 2011)

The qualitative modeling used in this case makes visible the links that exist between the components or factors that include information on the direction of impact, type of impact (positive or negative), intensity (weak, medium or strong) and any possible delays in terms of time (short, medium or long term). Together, these connections can then be analyzed in so-called "Insight Matrices" that make possible the comparison of the impact on short, medium and long-term and, therefore, to see what factors are involved in creating small or larger impact. (Nichersu, 2016)

In this study, the Insight matrices of the ‘Potable Water User’ factor will be presented. Figure 3 represents the short-term internal matrix, and Figure 4 shows the medium-term system evolution.

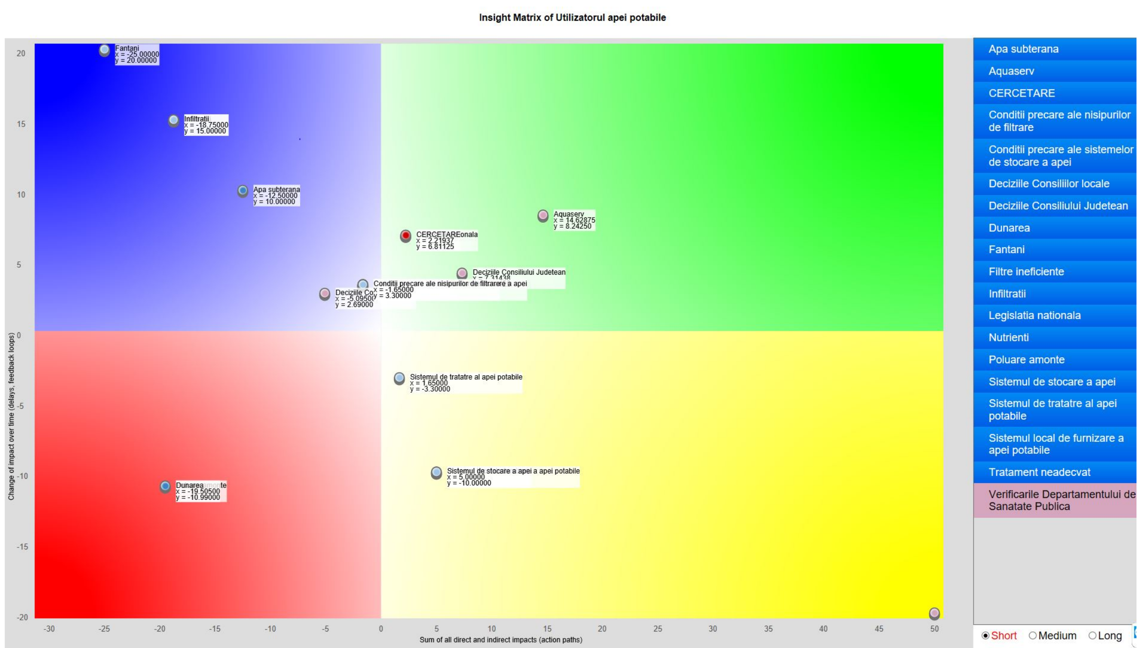

Figure 3 Insight Matrix of „Potable water user”- short term impact

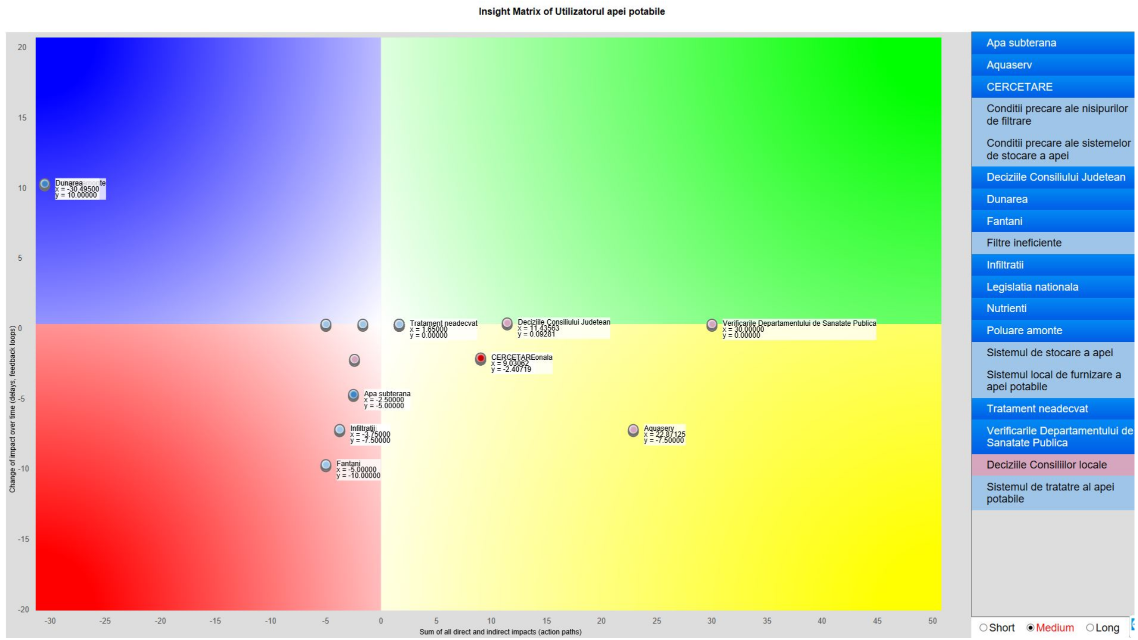

Figure 4 Insight Matrix of „Potable water user"- medium term impact

Thus, using the insight matrix, important information is extracted about how the system reacts in certain situations (taking into account the factors with greater impact, immediate interventions can be made on them). It can be seen from this that the factors that can cause the highest risks related to potable water quality to the user are related to the quality of the Danube water and the risk of upstream pollution ('Danube' and 'Upstream Pollution' factors).

On the other hand, the factors "The Public Health Department", "Aquaserv", "Research" and "Decisions of the County Council" are factors that strongly influence the quality of drinking water in a positive manner.

The position of matrix factors is also very important for understanding the system. Important in this analysis is the position of the Factors "Fountains" and "Infiltrations", which, by their position in the 2nd quadrant (blue) reveals a major change in the negative temporal influence. This cautions decision makers about the importance of infiltrations towards the drinking water user.

Another significant observation is that, passing from the short to medium term, the factor with the greatest influence on water quality remains "the public health department checks", but the values of the influences increase significantly over time.

Analysis of the drinking water supply system

The main problem in the Danube Delta is the transmission and distribution of treated water and, of course, collect and transport of the wastewater to the treatment plant (where applicable). Given the level of groundwater and degree of dispersion of villages, there are used appropriate solutions for the transport and distribution of treated drinking water (most likely with a central tower water, feeding then residents based on gravity) and collection of wastewater (either by re-pumping sewage or vacuum). If the villages have very scattered population, individual collection and treatment of sewage in situ could be considered for a household or a group of households. (SIDDDD, 2016)

Results of the Drinking Water Report 2013, prepared by the Public Health Department Constanta indicate chemical nonconformities for nitrates in settlements Corbu, Mihai Viteazu and Săcele. There are also problems in terms of providing drinking water in the study area due to lack of water supply systems and water fountains quality non-compliance. An example of this can be the village C.A. Rosetti who does not have a water supply system and wells cannot provide enough water because of the inconsistent quality. The measures proposed by the Public Health Department Tulcea where values are exceeding the parameters analyzed include:

- Cleaning, washing and disinfection of tanks and drinking water supply network;
- Verification of leaks in pipes;
- Disinfection and cleaning / emptying wells;

For overruns concentrations of nitrates in the public network, local authorities are notified the need to ensure drinking water from authorized sources for the age groups at risk, informing the population and build a compliance plan that includes an investment program with a timetable and realistic costs regarding the identification of a new sources of water suitable in terms of quality.

To avoid risks that can affect drinking water quality, the Public Health Department recommends the application by manufacturers / distributors of water of the following measures:

- Evaluation of the technical condition of drinking water systems for the rehabilitation and improving their quality;
- Providing sanitary protection perimeters for all elements of the water system;
- Steps to the introduction of the centralized water supply in all areas of the county where there are only individual local systems of water supply (wells, springs);
- Drilling of new sources will be preceded by hydrogeological expertise of the area;
- Ensuring the disinfection of drinking water as provided by law standards;
- Drinking water supply continuously, avoiding interruptions in water supply or distribution by schedule;
- Investment in water treatment systems.

(EPC, 2016)

The implementation of an Open Street Map (OSM) (Fig.1) via internet from all the interested persons is an ongoing process in which the stakeholders will be involved.
On the left part of the webmap there are three tools that are useful in the process of viewing the map: one is the zooming tool, the second is the distance measurements and the third represents the search tool. The search tool is important for searching the location of a certain point of sampling in order to have a focus on it. On the right side of the webmap there is a legend that is not shown until the mouse pointer is on it. The expanded legend shows the background maps (OSM and Thunder forest Transport) and also the risk level threats taking into account the Cyanobacteria and Chlorophyll-a concentration as indicators for the drinking water quality.

For each point from the map (that represents the sampling station) there is a popup information regarding the information about the Cyanobacteria and Chlorophyll-a concentration.

CONCLUSIONS

In this study, the Know-Why method and causal loop diagrams offer the support in the research of potable water quality to integrate the information in the administrative system framework for public health issues. The results of the analysis show the importance of knowledge transfer from researchers to decision makers, from the laboratories to legislation, but most of all, from research to everyday potable water users. Using the information from this type of studies, decision makers can update the water quality parameters, so that they cover all types of indicators (Cyanobacteria and Clorophyll-a).

An important contribution in the systemic analysis and a basic tool for the knowledge transfer from research to water quality legislation is the webmap developed for the improvement and understanding of the real situation. By visualizing the indicators values on the map, decision makers could be always updated with the field situation and act accordingly.
The insight matrix analysis of the causal diagrams associated to the potable water system reveals the necessity to involve Medium and Long-term initiatives – studies (Research) to ensure the quality of drinking water in the Danube Delta (with the possibility of extending to a Europe wide dimension by updating the international legislation), but also shows the great importance of using the available tools to reduce the lack of communication between science and decision making (in this study by using cognitive charts and webmaps).

Using the system diagram presented in this study, the user understands better how the system works and the water management process could be improved. The diagram presents the key points and vital connections of the system, where the users (the decision makers) could fit important changes in the water flow, so that the final user of the water could benefit from improved (standardized) water quality. In combination with a visualization tool for the water quality and a rigorous water analysis, the results of the study will offer the basis for the efficient potable water management in Danube Delta.

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