

# Protecting Groundwater by Mobilizing Communities and Implementing Sustainable Sanitation

Approaches to reduce nitrate pollution – examples from Eastern Europe

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## Abstract

In many parts of Central and Eastern Europe (CEE countries) the water supply and sanitation infrastructure is under-developed or declined after the collapse of the Soviet Union, especially in rural and peri-urban areas. Due to lack of safe water and sanitation, the public health is at stake. This paper describes how WECF and local partners do address these problems in their case studies from Romania and Belarus. In Belarus 55% of the rural population rely on own or private hardly protected drinking sources. In Romania only 15% of the rural villagers are connected to a central water supply system. In general a very high nitrate pollution of the well water was found in countries of Central-Eastern Europe, like Romania, Moldova or Belarus.

The main objectives in the area water and sanitation are in general: mobilising the community with aim of identifying the water quality of their village and minimizing the sources of water pollution. Schools are involved in water monitoring and in developing Water Safety Plans, which are used as a tool for raising awareness about water quality, sources of pollution, possible strategies for better ground water protection; community and authorities are involved in identification of possible improvements of the sanitary conditions.

The projects focus on investigation and the local conditions, identification of water sources and water quality, in which schools and citizens are involved.

The first steps on avoiding the infiltration of human excreta from on site sanitation (unsealed pit latrines) are realized in demonstration projects (urine diverting dry toilets (UDDT)), which leads to an immediate improvement of the sanitary condition in rural areas.

**Keywords:** *groundwater protection, water safety plan, ecosan, nitrate pollution, UDD toilet*

## 1. Background

In the European region, the provision of sanitation facilities is an important public health measure that contributes significantly to reduction in the disease burden of the population. However sanitation facilities have to be properly planned and managed, otherwise one unanticipated outcome may be the contamination of drinking water by faecal matter derived from on site sanitation.

In Eastern European rural areas the infrastructure is partly under-developed or declined after the collapse of the Soviet Union. The drinking water source for the population is often provided by local unprotected wells, affected by households' pit latrines or septic tanks. Hence many water and

sanitation facilities in particular in the rural area are not meeting the safety standards. Nitrate contamination is a widespread problem in the rural areas of Romania, Belarus, Moldova and other Eastern European regions.

For example in Belarus 100% of the population have access to water sources, but 55% of the rural population rely on own or private hardly protected drinking water sources. Only 61% of the rural population has access to sanitation (WHO 2006).

In Romania only 11% of the rural citizens have access to sanitary sewage and 15% have access to central water supply (UN 2004); whereas approximately 10 million Romanian inhabitants use pit latrines without an adequate human waste management.

### 1.1. Pit latrines and risks of groundwater pollution

Pit latrines are principally based on hiding human excreta in deep pits (“drop and store”), as opposed to flushing them away and diluting them in rivers, lakes and the sea (“flush and discharge”). Drop-and-store systems can be simple and relatively low cost but have many drawbacks (UNEP-GPA, 2009):

- Since pit latrines are not sealed to the ground, there is a danger of groundwater contamination by pathogens and nitrate
- They cannot be used in crowded areas, on rocky ground, where the groundwater level is high or in areas periodically flooded
- Require access to open ground and require digging of new pits or emptying of existing ones every few years
- Emptying of pits can be very difficult (may require manual labour, pits may collapse)
- Usually high level of odour and flies
- Toilets cannot be situated in houses, hence lack of privacy, comfort and safety concerns especially during night time and winter

#### 1.1.1. Groundwater

Groundwater is in the saturated layer in the ground, where all pores (the spaces between the soil particles) are filled with water. The top of this zone is called the water table. The layer above the saturated layer is the unsaturated layer, where the pores are at least partly filled with air. The wells are holes in the ground, which reach beyond the water table in the saturated zone and are filled with groundwater (see fig. 1). The saturated zone is called an aquifer if it has the capacity to fill wells and water can be drawn out. The rate in which recharge of the water and leaching of pollutants take place depends on several factors, like soil type, quantity of rainwater or properties of the pollutant.

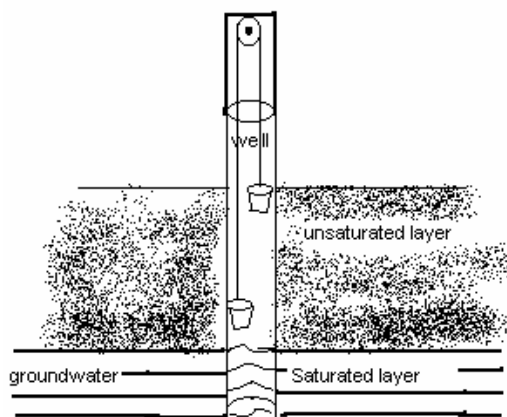


Fig. 1 schematic well (Samwel. A 2004)

### 1.1.2. From human waste to Nitrate and Nitrite: nitrification and denitrification

In general using pit latrines the human waste is released into the ground under the latrines. Human and animal waste contains nitrogen in the form of urea and other organic forms (Chapman, 1992). 95% of the nitrogen in human waste is found in the urine, mostly in the form of urea (Jacks, 1999). Urea ((NH<sub>2</sub>)<sub>2</sub>CO) is readily converted to ammonium (NH<sub>3</sub>) by micro-organisms. Under aerobic conditions ammonium is oxidised to nitrite and nitrate (NO<sub>3</sub><sup>-</sup>) (nitrification), oxygen is used as electron acceptor. This happens in two steps by two different bacteria. Ammonium is oxidised to nitrite (NO<sub>2</sub><sup>-</sup>), and nitrite is oxidised to nitrate. Nitrate and nitrite are both very soluble in water and easily washed out by rainwater into groundwater. Oxygen enters the soil by diffusion and the diffusion is greater in bigger pores than in smaller pores. Oxygen diffuses only very slowly in water. More diffusion of oxygen will take place in sandy soils with big pores than in clay soils, with small pores.

Denitrification takes place under anaerobic conditions where nitrate is used as an electron acceptor. Nitrate is reduced by bacteria first to nitrite, which readily is reduced to the gasses nitrous oxide (N<sub>2</sub>O) and nitrogen gas (N<sub>2</sub>). The gasses disappear in the atmosphere. Parkin (1990) found a significant correlation between soil water and denitrification. So the more water in the soil, the more denitrification takes place.

### 1.2. From Nitrate to Methaemoglobinaemia

The toxicity of nitrate to humans is mainly attributable to its reduction to nitrite. The major biological effect of nitrite in humans is its involvement in the oxidation of normal haemoglobine (Hb) to metHb, which is unable to transport oxygen to the tissues. The reduced oxygen transport becomes clinically manifest when metHb concentrations reach 10% of normal Hb concentrations and above; the condition, called methaemoglobinaemia, causes cyanosis and, at higher concentrations, asphyxia (death). These infants show signs of blueness around the mouth, hands, and feet, hence the common name "blue baby syndrome". They may also have trouble breathing as well as vomiting and diarrhoea. The Hb of young infants is more susceptible to metHb formation than that of older children and adults. With respect to exposure to nitrate, young infants are also more at risk because of a relatively high intake of nitrate (WHO 2007).

Cases of methaemoglobinaemia are reported in countries with severe nitrate-contaminated wells for example in Romania, Moldova and Ukraine.

Controlling nitrate levels in drinking water sources to below around 50 mg/litre is an effective preventive measure avoiding methaemoglobinaemia (WHO 2007).

## 2. Objectives and methodology

In general little or no data are available about water quality and related diseases, hence among the rural citizens little awareness about water quality and causes of water pollution exist.

For the bad state of the wells we can consider not only the pit latrines but as well the animal manure and the extensive agriculture. Both are potential contaminants of the groundwater. Sustainable approaches on reducing the human-made infiltration of nitrate and other pollutants should be developed on national level, but also on local level. Even if deeper aquifers are used as a drinking water source the water has to be protected while water and pollutants don't have borders. In the WECF project villages the sources of groundwater pollution are often caused locally.

The main objectives in the area water and sanitation are:

- mobilising the community
- identifying the water quality of their village,
- raising awareness on related issues and
- minimising the sources of water pollution.

## 2.1 Water Safety Plans

In 2008- 2009 WECF and partner introduced Water Safety Plans (WSP) for small-scale water supply systems in the rural areas of the Eastern European, Caucasus and Central Asian (EECCA) region and in some EU countries. WSP's are developed with involving schools in the villages, whereas a risk assessment of the water supply system, from the catchment to the tap or the point of consumption is carried out. Inventory and mapping of nitrate pollution of drinking water sources in the villages is one of the tasks (Möller, 2009). Further associated health risks of the polluted water and sources of pollution should be identified. Finally, in order to minimize the health risks and the pollution activities should be planned and implemented. Background information on developing WSPs and tools such as questionnaires, checklists and simple tests are teachers and pupils provided, enabling working on the WSP at school level.



*Pupils test the nitrate concentration in drinking water*

## 2.2. Raising awareness - dissemination of the results: Mapping of nitrate concentration – ToNi finder

WECF and local partner collect the results of the nitrate test carried out in the project villages in the rural areas of Central and Eastern Europe, Caucasus and Central Asia. A Google map with results of the nitrate water tests of drinking water sources will be used as another tool for raising awareness on regional, national and international level, of the existing water pollution in rural areas. In addition the locations and some information about the innovative and sustainable urine diverting dry toilets for schools will be showed in a parallel Google map of the ToNi (Toilet-Nitrate) finder (see from autumn 2009: [www.wecf.eu](http://www.wecf.eu)).

In addition the results of the nitrate tests and WSP are published in the local media, or made accessible for the citizens via the town hall.

## 2.3. Demonstration of UDD toilet

Demonstration project on sustainable and safe sanitation approaches serve as examples on how to manage human excreta in a safe way and how to provide households and schools safe sanitary facilities.

In this paper, two project villages in Central Eastern Europe, one in Romania and one in Belarus are selected, serving as an example for many other rural villages of the Eastern European region.

## 3. Nitrate pollution in groundwater in Central and Eastern European villages

### 3.1. Example Belarus

The Belarusian village Smilovichy has about 5800 inhabitants and is located 30-35 km away from the capital Minsk. The socio economic survey carried out showed that only a minority keeps livestock or poultry, but a large majority grows potatoes and vegetables. Most agricultural production (including

livestock and fruits) is for own consumption, including for relatives. Those who have sufficient animals only use what their own animals produce. (WECF 2008).

The village has a central water supply system (cwss), of which water is extracted from 20 -50 meter deep bore holes; however for the connected multi storage houses there is no continuous supply. Many of the households are not connected to the cwss and rely on other water sources such as dug wells or boreholes. Out of the 25 interviewed villagers 8 were connected to the cwss; 17 rely on dug wells for the drinking water and use pit latrines as toilets. In the frame of the project<sup>1</sup> 70 public wells have been tested on nitrate; 41 of them exceed the Belarusian nitrate norm of 45 mg/l. Because agricultural activities and keeping livestock are on a low level, lack of management of human waste should be taken into consideration as a source for the groundwater pollution.

### **3.2. Example Romania**

The Romanian village Garla Mare is located on a hill, on the flanks of the Danube. The village has 3500 inhabitants relying on some 400 wells. All villagers have a pit latrine. One person excretes via the urine in average 5 kg Nitrogen per year (Lange, 2000). Taking the excreted nitrogen of 5 kg per person per year and the number of inhabitants in account, it means in the village some 15.000 kg nitrogen is yearly released via the pit latrines into the soil; an amount sufficient for fertilizing approximately 100 of hectare agricultural field.

The nitrate concentrations in the wells fluctuate from 25 up to more than 500 mg/l, with an average of 120 mg/l (WECF, 2006)

Water Quality baseline survey and Monitoring Program of the World Bank occurred in 2004, and was focused on the measurement of the water pollution from the public wells of some Romanian counties. About 60% of the public wells in the rural areas are polluted with at least one of the following chemicals: nitrate, nitrite and ammonium (WB 2005). It was estimated that pit latrines cause 25% of the nitrate pollution of the groundwater.

#### **3.2.1. Investigation on the relation between nitrate concentration and state of the wells**

In Garla Mare, in 2004, a research was done on the nitrate concentration of the well waters in relation to the state and the depth of the wells. It was found the state of the cement and the presence of a roof were significantly related with nitrate. The better the cement of the well, the lower the nitrate contents. The common and private wells with a cover had significantly lower nitrate content and significantly better cement (Samwel, 2004). It was found the deeper the well, the higher the nitrate. The explanation can be that the longer the urea/ammonia stays in aerobic zones, the more nitrification can take place. The deeper the well, the further the way to the saturated zone and the longer the stay in the aerobic zone. In this case the filter function for nitrate is not apparent. If the filter function were noticeable, less nitrate would have been expected in deeper wells. The deeper the well, the longer the (soil) filter (Jackson, 2001). The wells with high nitrate concentration seem to be clustered to a certain region of the village. Also the deeper wells seem to be clustered at this region.

The region may thus also cause the correlation between depth and nitrate. The centre may be situated on the highest part of the village, so the wells must be deeper and the house density there is probably higher and pollution more intensive. This supports the hypothesis that the latrines are the cause of the pollution; in the centre the latrine density is higher. To get a better sight on the situation and to test the hypothesis that nitrification and/or denitrification play a role, analyses of ammonia and urea in the groundwater are needed to see if nitrification is incomplete when arriving to the anaerobic zone (Samwel, 2004).

The natural nitrate concentration in groundwater under aerobic conditions is a few milligrams (mg) up

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<sup>1</sup> MATRA project Developing multi-stakeholder cooperation in the areas of water, waste and energy efficiency in Belarus, financed by the Dutch Ministry of Foreign Affairs. <http://www.wecf.de/english/projects/01-belarus-citizensinvolvement.php>

to 20 mg per litre and depends strongly on soil type and on the hydro-geological situation.

Summarising: Both the rate of nitrification and denitrification depend on several factors, like the type of soil, water content of the soil, oxygen, organic carbon etc. But the rate in which this factors influence the processes is not yet quantified. Besides the type and properties of soil, also the state of the well influences the nitrate concentration of the well water.

## 4. Results

### 4.1. Identification of water quality and sources of pollution: Water Safety Plans involving schools – Nitrate monitoring

Since November 2008 pupils of several Romanian schools tested the wells water on nitrate, and started with testing several wells on the fluctuations of nitrate during the seasons (fig 2). Citizens and authorities are interviewed on their perception of the local water. Excursion to the water sources were organised, the state of wells was checked and the areas were cleaned. Those activities are first steps for a better well and ground water management; although much time is needed for the final results are visible.

Pupils of the school in Smilovitchy, Belarus tested 70 wells; only 29 were within the Belarusian limit of 45 mg/l. The average of the found nitrate concentration was 175 mg/l.

Taking the low density of the livestock and the low use of synthetic fertilizer in the village in account, the most likely source of the nitrate contamination are pit latrines in peoples homestead and probably leaching sewage pipes.

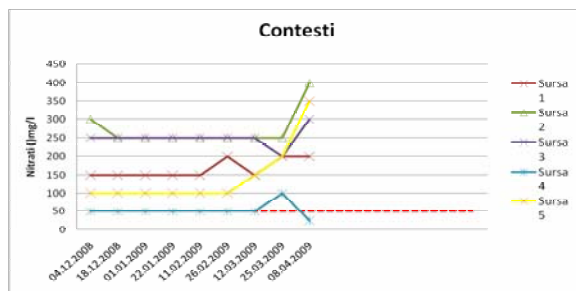


Fig 2. Seasonal fluctuation of the nitrate concentration in 5 wells in the Romanian village Contesti

### 4.2. Sharing information and results – mobilising the community

Schools inserted the results of the nitrate concentration in a village map indicating the locations of the wells and the found nitrate concentration (see annex). The results are used as a tool for raising awareness on water contamination and related health risks, and the causes and approaches of water protection measures. Based on that information, a decision from the Belarusian authorities has been made to give priority extending the central water supply in the village Smilovichy.

Although the Romanian and Belarusian examples of water monitoring are a good start for raising awareness on water pollution and the potential causes of the pollution. However the final steps needed for a long-term recovery of the ground water are difficult and mostly many years are needed to obtain some results.

Contrary direct positive results are to obtain in activities in the field of improving the sanitary conditions of the citizens.

### 4.3. Toni finder

The ToNi finder is an important tool to raise awareness also on local but also on higher level. An example can be seen in fig. 3. Concrete results are difficult to assess and are expected not before end of this year as it starts now.

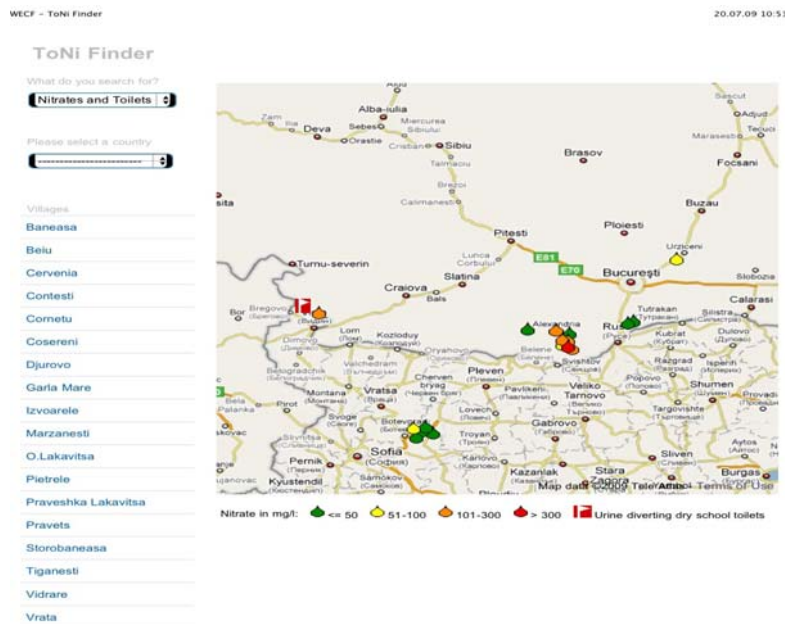


Fig 3. Example of the WECEF ToNi finder: map of Romania and Bulgaria with results of nitrate analyses in drinking water and locations of UDDT

#### 4.4. Implementation of demonstration projects: Sustainable sanitation and water protection

Urine diverting dry toilets (UDDT) – also called ecological sanitation or Ecosan toilets - have four major advantages over flush toilets: they are less expensive, require no connection to a sewage system, do not use (drinking)-water for flushing and avoid faecal material or urine getting into the groundwater and polluting it. After proper treatment and sanitation, the waste matter becomes a high quality fertiliser and can help to close the nutrient loop since urine is rich in nitrogen, potassium and other nutrients. For the villagers, these toilets are a huge improvement over the pit latrines since they do not smell or attract flies and can be built attached to the houses or inside the houses, so there is no need to go outside in the cold winter. Depending on the level of replication of the UDDT, safe management of human excreta and the geo- hydrological conditions of the area, a reduction of the nitrate contamination of the groundwater will be reached in the long term.

#### 8. Conclusions and recommendations

The examples show that immediate improvements in the field of water protection and in the sanitary situation of citizens are necessary and feasible, in particular in areas with no central water supply or sewerage systems.

It is very important to address the nitrate problems from a preventive perspective as the implementation of water filters or drilling deeper wells are not sustainable measures in the long term, while reduction of water pollution at source is crucial. It is essential to involve all sectors and to give the community and children the opportunity and tools to take action themselves. Schools in cooperation with all stakeholders could be the base for achieving a community mobilisation and raising awareness on water pollution, related health diseases, and taking precautionary measures. Governments should develop policies to implement precautionary and comprehensive practices on water protection. They should promote investments and implementation of sustainable sanitation systems such as urine diverting dry toilets for the majority of the rural population that is not connected to a central water supply or sewerage system.

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## Annex: Example of mapping nitrate test results of wells in the Smilovichy village, Belaru

Carried out by Secondary School N2 students and the Ecoproject Partnership Organisation,

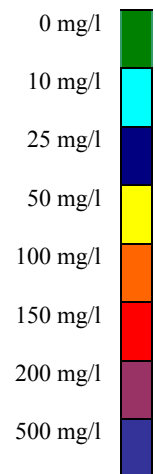
with the support of WECF, using the MERCK indicator strips.

### Результаты обследования колодцев г.п.Смиловичи на содержание нитратов

Обследование выполнено группой учащихся СШ№2 совместно с МОО «Экопроект Партнерство» при содействии голландской организации WECF с помощью индикаторных полос фирмы MERCK.



### Index of nitrate concentration in drinking water\*



\*The highest content of nitrates in drinking water may not exceed 45mg/l. The tests measure the nitrate content level but do not demonstrate the exact concentration level.

Nitrate levels exceeding the set value endanger in particular the health of a newborn baby. Besides nitrates, the drinking water may contain other pollutants. That is why a low nitrate level does not guarantee a good quality of water.