RESULTS OF GROUNDWATER MONITORING IN SOME "HOT SPOTS" IN SERBIA IN PERIOD 1999-2000

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ABSTRACT

Swiss Disaster Relief (SDR), part of Swiss Agency for Development and Cooperation (SDC) took over the program on a bilateral agreement with the Federal Republic of Yugoslavia (FRY) in 5 towns. Investigation covered general parameters (conductivity, KMnO4 demand, TOC, total hydrocarbons, mineral oil and phenols), heavy metals (As, Hg, Pb, Zn, V and Cu), PAH (total and main components), PCB (total and main components), BTEX and chlorinated hydrocarbons. Duration of the program was defined for one year, from November 1999 to the end of the year 2000, and samples were collected every two months. Common findings for all locations are presented.

Key words: environment, groundwater, monitoring, bombing

1.Introduction

Kosovo conflict in spring 1999. has negative effects on the environment, because of the bombing of various industrial plants in several areas of Serbia. Particularly, various storage and production tanks containing toxic chemicals were damaged or destroyed. As a consequence, various chemicals either leaked to the ground or burned in the resulting fire, causing widespread soil and air pollution.

In the second stage, released pollution could also reached the groundwater in the vicinity of the destroyed targets. Therefore groundwater quality could be seriously endangered by the leaked chemicals (various oily products near refineries, mercury and ethylenedichloride at a petrochemical plant...) and/or by the deposition of combustion products in case of fire.

Due to the slow process and migration in the soil, the spreading of the groundwater pollution can take months to reach potable water catchment areas where the ground water is used as drinking water resource. So, a careful and precise monitoring of the groundwater quality had to be implemented in the most endangered areas in order to determine possible long-term effects on that quality.

Swiss Disaster Relief (SDR), part of Swiss Agency for Development and Cooperation (SDC) took over the program on a bilateral agreement with the Federal Republic of Yugoslavia (FRY) in the following towns:

Novi Sad with six sampling points,
Pančevo with one sampling point,
Smederevo with two sampling points,
Kraljevo with three sampling points and
Niš with four sampling points.

Six sampling campaigns have been performed:

- first campaign in November 1999
- second campaign in February 2000
- third campaign in April 2000
- forth campaign from July to September 2000
- fifth campaign from October to November 2000
- sixth campaign from November to December 2000

Investigation covered following parameters: general parameters (conductivity, KMnO4 demand, TOC, total hydrocarbons, mineral oil and phenols), heavy metals (As, Hg, Pb, Zn, V and Cu), PAH (total and main components), PCB (total and main components), BTEX and chlorinated hydrocarbons.
Duration of the program was defined for one year, from November 1999 to the end of the year 2000, and samples were collected every two months.
In every location, samples taken are always raw water samples, before any treatment.

2.Results

2.1. City of NOVI SAD

2.1.1. Potable water supply in the region

The water supply in Novi Sad is based on the catchment of groundwater from the alluvial aquifers in the coastal area of Danube. The water catchment structures, such as tube wells (approx. 20 wells) and horizontal collector wells, have been constructed on the following sites: Kameni~ka ada and [trand on the left bank of Danube river in the upstream part of Novi Sad, Petrovaradinska ada (right bank) and Ratno ostrvo (left bank) downstream from Novi Sad. The wells are located in the intermediate vicinity of the stream. A quantity of approximately 1.2 m^3/sec is collected. After collecting from the ground, the water is treated for removal of iron and manganese as well as dissolves gases (NH_3, H_2S) at the plant "Štrand" (aeration and filtration) and, after chlorination, distributed to the consumers. The most important parts of the system are the source "Ratno ostrvo" with approximately 700 l/sec and "Petrovaradinska ada" with approx. 200 l/sec.
The quality of the water in these sources is directly connected to that of the Danube River. On the other hand, the quality of the groundwater is also linked with the effect from all facilities, and potential contaminants located in the vicinity and the hinterland. The most jeopardized source is the one on the "Ratno ostrvo", in the vicinity of which is located the NIS Oil Refinery and the thermal power plant.
Water distribution system consists of about 1 000 km of pipes with various diameters,
5 pumping stations and 5 reservoirs with a total volume of 30 000 m^3.
The number of people using the potable water produced by the Water works company of Novi Sad amounts to about 300 000 "regular" citizens and about 100 000 refugees and IDPs.

2.1.2. Sampling points

Three different samples were taken from the "Ratno ostrvo" water catchment field:

Mixture of wells BHD 7 to BHD 9
Well BHD 2
Mixture of all wells : BHD 2 to BHD 9

During the second part of investigation two additional sampling areas were added to the program:
Wells 1 and 5 of water catchments area “Strand”. These wells are located directly in the left bank of Danube River.
Well 1 of water catchments area “Petrovaradinska ada”

2.1.3. Comments

2.1.3.1. “Ratno ostrvo”

Global parameters

These parameters are sum parameters indicating the general level of quality and are defined by the analytical method rather than by the chemical characteristics of the analyzed compounds.

- $KMnO_4$ demand: slight increase since the beginning of investigation for well 2, from 2,3 to 5,4 mg/l, but still below MPL for potable water, low value for the other wells (below MPL) for the first part of the project, but larger increase in the second part of 2000. A significant increase has been observed for the all sampling points. A possible explanation could be a seasonal influence.
- Total Organic Carbon (TOC): measured values between 2 and 3 mg/l, indicating some contamination by organic material even if no MPL exists in FRY. For comparison, Swiss regulation states that the quality objective for dissolved organic carbon (DOC) is 1 mg/l. In the second part of the work this parameter could not be analyzed because of an instrumental failure.
- Total hydrocarbons: acceptable, less than MPL value (0.1 mg/l) for all measured wells.
- Total PCB: very low, less than 10 ng/l in all samples (MPL value is 500 ng/l)
- Phenols: less than MPL (0.001 mg/l)

Individual organic components

Polycyclic aromatic hydrocarbons (PAH): below detection limit of 10 ng/l for each component (MPL for total PAH is 200 ng/l) during the whole project duration.

- Benzo(a)pyrene: less then 10 ng/l, which is also MPL

Heavy metals

Except for Zn, all measured values are lower than then the corresponding detection limit of the analytical methods. All measurements are lower or far lower than MPL values.

BTEX (monocyclic aromatic hydrocarbons)

These compounds were analyzed during the third campaign's sampling (April 2000), with all results below analytical detection limits. Because MPL according to FRY legislation are lower than the detection limits for benzene and ethyl benzene, it is not possible to verify the compliance with the official maximum values.
Toluene and benzene were also measured in the second series of samples, with values far below MPL.

Chlorinated hydrocarbons

The Swiss laboratory in the samples taken in November 1999 (first campaign) and in April 2000 (third campaign) analyzed these chemicals.
All measured results were below analytical detection limit and below MPL.

2.1.3.2. "Strand"

Global parameters

These parameters are sum parameters indicating the general level of quality and are defined by the analytical method rather than by the chemical characteristics of the analyzed compounds.

- KMnO4 demand: relatively high values, greater than MPL for potable water, but still lover than MPL for river water (12 mg/l) according to the Yugoslavian regulation.
- Mineral oil: less than MPL value (0.01 mg/l) for two measured wells.
- Total PCB: very low, less than 10 ng/l in both samples (MPL value is 500 ng/l)
- Phenols: less than MPL (0.001 mg/l)

Individual organic components

Polycyclic aromatic hydrocarbons (PAH): below detection limit of 10 ng/l for each component (MPL for total PAH is 200 ng/l) during the whole project duration.

- Benzo(a)pyrene: less then 10 ng/l, which is also MPL

Heavy metals

All measured values are lower than then the corresponding detection limit of the analytical methods. All measurements are lower or far lower than MPL values.

BTEX (monocyclic aromatic hydrocarbons)

Among these components, only benzene and toluene have been analyzed, with results far below MPL.

2.1.3.3. "Petrovaradinska ada"

Global parameters

These parameters are sum parameters indicating the general level of quality and are defined by the analytical method rather than by the chemical characteristics of the analyzed compounds.

- KMnO4 demand: relatively high values, comparable to the ones measured in the samples from Ratno Ostrvo and Strand
- Mineral oil : less than MPL value (0.01 mg/l) for the measured well
- Total PCB: very low, less than 10 ng/l (MPL value is 500 ng/l)
- Phenols: less than MPL (0.001 mg/l)

Individual organic components

Polycyclic aromatic hydrocarbons (PAH): below detection limit of 10 ng/l for each component (MPL for total PAH is 200 ng/l) during the whole project duration.

- Benzo(a)pyrene: less then 10 ng/l, which is also MPL

Heavy metals

Except for Zn, all measured values are lower than then the corresponding detection limit of the analytical methods. All measurements are lower or far lower than MPL values.
Measured concentrations of zinc are higher than for the Strand samples and comparable to those for Ratno Ostrvo, which lies just on the opposite side of the river.

BTEX (monocyclic aromatic hydrocarbons)

Among these components, only benzene and toluene have been analyzed, with results far below MPL.

2.1.4. Summary

According to the analytical results presented here, no particular contamination of the raw water from the Ratno Ostrvo has been detected. Raw water quality, even before treatment in the plant "[trand" is corresponding to the official FRY regulation except $KMnO_4$ values, which increase during Summer and Autumn 2000.

Furthermore, no increase in pollutants' concentrations has been measured between November 1999 and the end of 2000, with the exception of $KMnO_4$ demand and zinc. Nevertheless, measured values for the latter still remain far below MPL.

As a general conclusion, no particular effects of last spring's war have been determined in Ratno Ostrvo water catchment area. But because of the slow migration of the pollutants in the ground, monitoring of the groundwater quality is still absolutely necessary.

2.2. City of PANČEVO

2.2.1. Potable water supply in the region

The area of Pančevo with population of approximately 125 000 inhabitants receives its water supply from two sources that abstract groundwater from the aquifers formed within the alluvial deposits of the Danube and the late Quaternary.
Pančevo receives its water supply today from two groundwater sources. The older source "Sibnica" formed in 1927 with about 400 l/sec raw groundwater abstracted today, which is transported by pipelines to the water treatment plant. Aeration, filtration, ozonization, fluoridation and disinfection are conducted at the plant. The second, new source "Gradska Šuma" is located at the confluence of Tamiš into the Danube, upstream the industrial zone of Pančevo. The first stage is built with capacity of approximately 200 l/sec. The source is conceptualized as an infiltration type source. Depth of the 57 drilled wells was between 35 and 40 meters.
The distribution system consists of two pumping stations, a network totaling 220 km and 5 reservoirs (total volume 13 000 m3.
The public network of potable water extends to the southwest of Pančevo for the supply of the villages Starčevo (7.200 inhabitants), Omoljica (2.800 inhabitants), Banatski Brestovac (3.700 inhabitants) and Ivanovo (1.500 inhabitants). For the last one, the local network of public water supply is not yet constructed, so people of Ivanovo still rely on their private wells, which take water from the underground.

2.2.2. Sampling points

Two sampling points were defined in Pan~evo. The first sample in November 1999 was taken from the older source "Sibnica", while the following samples (second and third campaign) were taken from the new source "Gradska [uma"

2.2.3. Comments

Global parameters

- KMnO4 demand: high values above 9mg/l until August 2000, which is above MPL for potable water (8 mg/l) but can easily be accepted for raw water. Later values (fall 2000) were somewhat lover.
- Total Organic Carbon (TOC): measured values between 2 and 3 mg/l, indicating some contamination by organic material even if no MPL exists in FRY. For comparison, Swiss regulation states that the quality objective for dissolved organic carbon (DOC) is 1 mg/l. The value determinate in December 2000 was lover than that value.
- Total hydrocarbons: rather high in February 2000 for "Gradska {uma", close to MPL (0,09 and 0,10 mg/l respectively) but sharp decrease between April and November 2000 (< 0,01 mg/l) and high value (higher than MPL) measured in December 2000.
- Mineral oil: values decreasing since November 1999, when the concentration was at a maximum (0,022 mg/l, higher than the MPL value of 0,01 mg/l) below MPL between April and November 2000, than sharp increase in December 2000. This behavior is parallel to the one of total hydrocarbons.
- Total PCB: very low, less than 10 ng/l in all samples (MPL value is 500 ng/l)

- Phenols: less than MPL (0.001 mg/l)

Individual organic components

Polycyclic aromatic hydrocarbons (PAH): below detection limit of 10 ng/l for each component (MPL for total PAH is 200 ng/l)

- Benzo(a)pyrene: less then 10 ng/l (MPL value is 10 ng/l) except in April 2000 when measured value was equal to the MPL

Heavy metals

Most of the measured values are lower or even far lower than the corresponding MPL values, with two exceptions:
Arsenic concentrations in all samples analyzed by the IPH, except in August 2000, are exceeding MPL value of 0.01 mg/l, up to 0.022 mg/l, with an increase of the measured values between November 1999 and April 2000. The Swiss laboratory did not measure this parameter. Swiss regulation states a MPL for As at 0.05 mg/l, and according to this, measured concentrations in Pančevo are not problematic for the time being.
Lead concentrations in two samples are equal or slightly higher than corresponding MPL value, but measurements made in Switzerland showed lower concentrations. A decrease was noticed in the two last samples (November and December 2000).

Chlorinated hydrocarbons

The Swiss laboratory analyzed these chemicals in the first sample taken in November 1999 (Sibnica field).All measured results were below analytical detection limits and below MPL.
The measurements performed during the second part of the project all showed value below detection limits, including EDC (1,2 dichloroethane). Therefore, no contamination by chlorinated hydrocarbons has been detected until the end of year 2000.

2.2.4 Summary

According to the analytical results presented here, little contamination of the raw water both for "Sibnica" and "Gradka {uma" has been detected, for two heavy metals, namely arsenic and lead, and presence of total hydrocarbons and mineral oil in December 2000.
The presence of arsenic is somehow difficult to explain. It could be due to natural reasons (composition of the soil) or may be to some industrial pollution. Nevertheless, measured values are not alarming now, in particular because the water treatment will decrease the concentration in the distributed water compared to raw water.
The other heavy metals namely lead, showed a decrease during this project. Its presence during the first part of the project could be explained by natural cause (composition of the ground) or by side effect of the war (deposition of the particles after the burning of the oil refinery, in particular of leaded gasoline).
Contamination of the water catchment field by the polluted groundwater of the industrial zone of Pančevo is rather unlikely because of the hydrogeological conditions (separate aquifers, underground water flow direction) and the distance between both areas.
Regarding the potable water supply of Pančevo, arsenic and hydrocarbons showered concentrations in the raw water higher the MPL values for treated water. Nevertheless, treatment of that water by aeration, send filtration and ozoniztion will decreae these

concentrations and bring them below MPL. It is recomended to pay attention to these parameters in the treated waterand to check the efficiency of the water treatment to decrease their concentration below MPL.
On the other hand, because of the direction of the underground water flow, the contamination from industrial zone of Pancevo could possibly reach the villages situated south of Pančevo. In spite of the fact that most of these villages are connected to the main public water supply of Pančevo, which is probably not very endangered by the ground pollution in the industrial zone, there exists nevertheless important health risks for the dwellings taking their own water from the ground or using it for irrigation purposes. That is the reason why SDC/SDR decided to implement a new program called " Groundwater monitoring and public health risks assessment in the area south of Pančevo".

2.3. City of SMEDEREVO

2.3.1. Potable water supply in the region

The area of Smederevo, with a population of approximately 80 000 inhabitants for the city (28 000 "regular" citizens and about 12 000 refugees and IDPs), could produces drinking water from two sources that abstract groundwater from the aquifers formed within the alluvial deposits of the Danube and Velika Morava .
As a matter of fact, Smederevo relies for its water supply today on only one groundwater source, "Šalinačko polje", which has not the capacity to satisfy all needs, especially during the summer. The older source "Godominsko polje" was disconnected from the water supply system in 1998, for various reasons. It consists of 20-drilled wells (depth 18 - 20 m) but among them only 5 are still active and could be put back into service. Their unit capacity is 50 l/sec; so the maximum capacity is around 250 l/sec. The basic problem of this water catchment field, except technical problems (like pumps and other equipment), is due to the inadequate sanitary protection of that zone, which lies in the middle of a developed industrial area. A large fuel storage, with a capacity of 250 000 m^3, which was bombed and destroyed during last year's conflict, is located only 250 m away from this area. Therefore, there is an important risk of groundwater pollution any time in the future.
The water from the other water catchment field, named “Šalinačko polje “is used today for potable water supply. This new field, put into the function in 1991, consists of 7-drilled wells, with a depth of 50 m, and total capacity of 350 l/sec. Average quantity of about 230 - 280 l/sec of raw groundwater is abstracted today and transported by pipelines to the water treatment plant located in the old field “Godominsko polje”. Aeration, sand filtration (after addition of $KMnO_4$), and disinfection are conducted at the plant.
The plant has possibilities to improve water treatment with coagulation and flocculation, and has also reservation for ozonization.
The distribution network consists of 220 km of pipes, 4 pumping stations and 7 reservoirs with a total capacity of 7 500 m^3.

2.3.2. Sampling points

Two sampling points were defined in Smederevo. The first one is located at the older source "Godominsko polje", and the second one at the new source "Šalinačko polje".
Samples from "Godominsko polje" are taken from the well marked as B-19, which is put into function for this purpose 24 hours before taking the samples.

2.3.3. Comments

Global parameters

- KMnO4 demand: a very important increase of that parameter has been measured at "Godominsko polje" between November 1999 (2.05 mg/l) and April 2000 (7.00 mg/l). However this parameter was always below MPL for potable water. On the contrary, measured values at "Šalinačko polje" were at maximum in November 1999 (first campaign), but much lower in the following campaigns.
- Total Organic Carbon (TOC): measured values at "Godominsko polje", between 1 and 2.3 mg/l, indicate some contamination by organic materials, even if no MPL exists in FRY. For comparison, Swiss regulation states that the quality objective for dissolved organic carbon (DOC) is 1 mg/l. The measured values at "[alina~ko polje" are lower, i.e. between 0.45 and 1 mg/l.
- Total hydrocarbons: a presence was detected in the analyzed samples, but at a level lower than MPL. Concentrations are decreasing with time.
- Mineral oil: a contamination of the groundwater was detected in November 1999 in both water catchment areas, with values above MPL. Since then, the contamination has been disappeared (measured values below detection limit for all subsequent samples).
- Total PCB: very low, less than 10 ng/l in all samples (MPL value is 500 ng/l)
- Phenols: less than MPL (0.001 mg/l)

Individual organic components

Polycyclic aromatic hydrocarbons (PAH): below detection limit of 10 ng/l for each component (MPL for total PAH is 200 ng/l)

- Benzo(a)pyrene: less then 10 ng/l, which is also MPL

Heavy metals

All measured values are very low, except lead in some samples of the water from "Šalinačko polje", which is the only field currently in use. That contamination could possibly originate from last year's conflict.

Chlorinated hydrocarbons

The Swiss laboratory analyzed these chemicals in the two samples taken in Nov 1999 (first campaign). All measured results were below analytical detection limits and below MPL.
The measurements performed during the second part of the project all showed value below detection limits, including EDC (1,2 dichloroethane). Therefore, no contamination by chlorinated hydrocarbons has been detected until the end of year 2000.

2.3.4 Summary

According to the analytical results presented here, a contamination by hydrocarbons and mineral oil was detected in November 1999 in both water catchment areas. That contamination has disappeared since then and later results show a normal situation, with all measured values below corresponding MPL.
Another contamination is the one by lead in "[alina~ko polje". Measured concentrations have just reached MPL values for treated water during the first months of the campaign, but decreased after (last results in December 2000 below detection limit).

Even if the direct contamination observed just after the Kosovo conflict in 1999 has almost disappeared since than, there still exists a danger of contamination for the water catchment areas of Smederevo:

industrial zone of Smederevo,
oil storage facility of "Jugopetrol"
"Šalinačko polje" groundwater coming directly from the Velika Morava river, with little natural purification by the ground

On the other hand, "Šalinačko polje" is the only water resource of Smederevo and, according to the local regulation, effectiveness of the protective area of this water catchment area has to be controlled by a monitoring program which has not yet been implemented.
Therefore, it is necessary to continue the monitoring program in Smederevo to check the possible dangerous to the water sources.

2.4. City of KRALJEVO

2.4.1. Potable water supply in the region

The city of Kraljevo is supplied from alluvion of the Ibar river by ground water catchment at a site immediately near the city. The characteristics of this aquifer are a relatively small thickness (below 10 m) and a fine filtration property. The vulnerability of the aquifer is therefore very high. The total population served by the Water works in Kraljevo comprises about 70 000 inhabitants plus 20 - 30 000 refugees and IDPs.
Two water capture areas are used, one on each side of Ibar river:

"Žičko polje" on the right bank with 12 wells of depth between 7 and 9,5 m (10 drilled, and 2 digged). The yield of this zone is about 20 l/sec. This area has 3 realimentation basins (3 x 4 500 m^2) for artificial realimentation of groundwater, with untreated water pumped directly from the Ibar river.
"Konarevo" on the left bank of Ibar with 11 digged wells of depth about 2,5 m.

Depending on the hydrological situation, a total flow of 250 to 350 l/sec is collected. Before supplying it to the customers, the water is only treated with chlorine (disinfection purpose).
The distribution network includes 300 km of pipes, 2 pumping stations and 2 reservoirs with total volume of about 7 000 m^3.

2.4.2. Sampling points

Three sampling points were defined in Kraljevo. The first sample is taken from the source "Konarevo", the second one from the source "Žičko polje" and the third one from Ibar river, at the place where water for artificial realimentation is catched.

2.4.3. Comments

Global parameters

- KMnO4 demand: rather low values (below MPL) for the two catchment areas, but high and variable values (above MPL) for the Ibar river (up to 15 mg/l), depending on the flow and the amount of sediment.
- Total Organic Carbon (TOC): rather low values (between 1 and 2 mg/l) for the two water catchment areas and somewhat higher value for the Ibar river (up to 3.8 mg/l)

- Total hydrocarbons: rather low, less than MPL level (0.1 mg/l) for the two water catchment areas, except for the Konarevo field which showed a higher concentration in December 2000. For the Ibar river, a contamination was present in November 1999 (0.14 mg/l) with values decreasing since then (below or at MPL).
- Mineral oil: great variability with at times in the mineral oil content. The highest concentrations were measured in December 2000, especially in the "Konarevo field" confirming the observation made for total hydrocarbons. Values are lower now, but still above MPL.
- Total PCB: very low, less than 10 or 50 ng/l in all samples (MPL value is 500 ng/l)
- Phenols: less than MPL (0.001 mg/l)

Individual organic components

Polycyclic aromatic hydrocarbons (PAH): below detection limit of 10 ng/l for each component (MPL for total PAH is 200 ng/l)

- Benzo(a)pyrene: less then 10 ng/l, which is also MPL

Heavy metals

For the two water catchment areas, all measured contents are much lower than the corresponding MPL values. Only for chromium results show significant variation (from 0.003 up to 0.032 mg/l) but still below MPL.
For the Ibar river, lead was present in excessive amount in November 1999 (0.02 mg/l) and to a lower degree in April 2000 (0.01 mg/l),but decrease since than below detection limit.

Chlorinated hydrocarbons

The Swiss laboratory analyzed these chemicals in the three samples taken in Nov 1999 (1st campaign). All measured results were below analytical detection limit and below MPL.
The measurements performed during the second part of the project all showed value below detection limits, including EDC (1,2 dichloroethane). Therefore, no contamination by chlorinated hydrocarbons has been detected until the end of year 2000.

2.4.4 Summary

Based on these results, a contamination by hydrocarbons and mineral oil of the Ibar river water lasts since the beginning of the monitoring, with the highest values detected in November 1999 for the Ibar river, and in December 2000 for the "Konarevo" water catchment area. This contamination is probably the result of the destruction of the important fuel storage facility located in Bogutovac, upstream the Ibar river, at a distance of about 12 km, and may be also from pollution originated in Kosovo.
As a result, mineral oil content in the water catched from both sources could at times exceed the MPL value of 0.01 mg/l.
Another important point was the contamination of the Ibar river water by lead, whose origin was certainly the same as for hydrocarbons (storage of leaded gasoline).
Because of the lasting contamination by hydrocarbons of the water in Kraljevo, the monitoring of the water quality in that area must be extended over a longer period.

2.5. City of NIŠ

2.5.1. Potable water supply in the region

The city of Niš, with its numerous suburban settlements connected to the common system, has based its water supply on the catchment of five karst springs (Ljuberadja, Mokra, Divljana, Krupac, with total capacity of 800 – 1450 l/s, and Studena 220 – 340 l/s) and artificial infiltration source "Mediana" formed in the alluvion of the Nišava River (100 – 200 l/s). On average 1200 – 1300 l/s are collected. Also, a separate system was established to supply several villages near the Morava River (springs Peter, Toplik and Miljkovac, with much less capacity then mentioned above). About 240 000 inhabitants in the towns of Niš and Babušnica and in more then 50 villages are supplied with 85000 – 110000 cubic meters of water per day.

Three main reservoirs are built, with a total capacity of 19450 m3, and many smaller reservoirs for local purposes. This is however not enough to properly cover daily consumption variations.

In view of the extraordinary water quality, only disinfecting is performed before the delivery to the consumers. The purification plant located on Mediana includes pre-chlorinating of row river water (usual quality of II class, according. to Yugoslav standards for surface waters), then treatment with aluminum sulfate in order to decrease the turbidity and the concentration of some pollutants. After rapid- and slow- mixing units, sludge is allowed to settle and the water is passing through two batteries, each containing six fast filtration quartz sand units. Such purified water is used to feed nine infiltration units situated in Mediana area (250 ha), and after two or three weeks of retention in gravel underground layer, the water is collected with a system of numerous wells, chlorinated and pumped into town pipeline. The whole process is conducted at an electronically controlled regime.

Naissus chemical and microbiological laboratory permanently controls the qualities of the river, the spring and the potable water, with a frequency of 40 – 50 samples per day.

In early '90 a serious pollution with easy volatile organic halogenated compounds of Mediana aquifer and a considerable presence of nitrates were noticed. Because of that 1.200 m long and 8 – 15 m deep underground water nonpermeable barrier was built with combination with the drainage system, in order to minimize influence of polluted underground flows in Mediana surroundings.

2.5.2. Sampling points

Locations on Mediana for the sampling of the water, according to the memorandum of understanding:

1. River Nišava (water catchment on Mediana)
2. Treated water before infiltration (purified water after pre-chlorination, treated with aluminum sulfate and filtered)
3. Pumped water from the aquifer (one of two Mediana underground reservoirs), immediately before final chlorination and pumping in town pipeline. This water is collected from wells, after two or three week's storage in underground layer.
4. Drainage system (pump station “Brzi Brod” connected with drainage system around Mediana aquifer. Collects polluted ground water and conduct it to sewage system.

2.5.2. Comments

Global parameters

- KMnO4 demand: quite high for the river water (up to 11,8 mg/l) depending on its flow and suspended matters content, but decreasing in function of treatment steps. Pumped water from the aquifer has values less than MPL.
- Total Organic Carbon (TOC): because of the lack of local equipment at the beginning of the campaign, this parameter was only measured in the samples taken during the first campaign (September 1999) by Swiss laboratory. As for KMnO4 demand, TOC values were decreasing from river water (1.8 mg/l) to pumped water from the aquifer (0.7 mg/l). This latest value is low, even lower than the quality objective defined by Swiss regulation (1 mg/l). Equipment provided by SDC?SDR has proved difficult to be put into service, so no representative values have been obtained until the end of 2000.
- Total hydrocarbons, mineral oil, PAH and PCB were not measured because of a lack of adequate equipments.

Heavy metals

Practically, all measured values are lower than the corresponding detection limits of the analytical methods. All measurements are lower or far lower than MPL values. There is therefore no contamination through heavy metals even in the drainage system collecting polluted groundwater around Mediana aquifer.

Chlorinated hydrocarbons

All measured values in the Nišava river sample are below analytical detection limits.
Concentrations of these chemicals are slightly increasing after treatment, especially chloroform (up to 2.3 mg/l in the sample of pumped water from the aquifer analyzed by Swiss laboratory), but always remain far below corresponding MPL. The reason for these increases is certainly due to the chlorination of the water in the course of its treatment.
Even drainage water shows very small concentrations of chlorinated hydrocarbons

2.5.4 Summary

According to the analytical results presented here, no particular contamination of the different waters in the Mediana aquifer has been established. Water quality is always corresponding to the official standards in FRY.
Furthermore, no increase in pollutant concentration has been measured between September 1999 and March 2000.
Nevertheless, it has to be mentioned that some important parameters like total hydrocarbons and mineral oil have not been measured. These parameters, as well as PAH and BTEX, are therefore included in the new project implemented by SDC/SDR in Niš.

3.Final conclusions

The main results of this monitoring of the groundwater quality in five towns of Serbia show that, one and a half year after, no important contamination of the potable water supplies has taken place because of the Kosovo conflict during Spring 1999.

Analyzed parameters in the raw waters were generally below "Maximum permissible levels" as defined by the Yugoslavian regulation for distributed waters. In some particular cases, only slight excessive values have been determined, essentially for hydrocarbons and/or mineral oil, and sometimes lead.

In the plants where a treatment is applied to water before distribution to the consumers, a possible contamination will be lower in the treated water than in the raw water. Therefore, comparison of raw water characteristics with the values defined for distributed waters necessitates great caution.

For some parameters in some areas, this monitoring program showed that contamination was present just after the conflict and disappeared after one year or so (for example in Smederevo).

On the other hand, another type of situation was the same as above but where contamination reappeared again more than one year later (for example in Kraljevo).

Because of the slow process of migration of the pollutants in the ground, it can take a long period, months or years, for the contamination to reach the aquifers used for potable water production. Such a contamination has not significantly taken place 18 months after the Kosovo conflict. Nevertheless, that doesn't mean that the situation is now safe and that no "collateral damage" will be observed later.

For all above mentioned reasons and results, SDC/SDR has decided to implement additional groundwater monitoring programs in Serbia. These additional programs are mainly justified by the environmental risks posed to potable water resources in different cities.

Some of these new programs are ongoing now, like:

Pančevo: groundwater monitoring outside the industrial zone, especially south of it, in cooperation with IPH of Serbia (project A1),

Smederevo: extension of previous groundwater monitoring, in cooperation with IPH of Serbia (project A7),

Novi Sad: groundwater monitoring outside the refinery, in the area close to the "Ratno ostrvo" water catchment area, in cooperation with waterworks and Institute of Chemistry of Novi Sad (project A2),

Niš: groundwater monitoring and pollution prevention around the Mediana aquifer in cooperation with "Naissus" waterworks (project A4)

These projects, entirely financed by Switzerland, will last until the year 2002.

Few other groundwater monitoring project for Kraljevo and Pančevo are in phase of preparation or will start soon.