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DIKTAS

Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System

ENVIRONMENTAL IMPACT INDICATORS IN SYSTEMATIC MONITORING OF KARST AQUIFER – DINARIC KARST CASE EXAMPLE

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Project aim & task

DIKTAS (Protection and Sustainable Use of the Dinaric Karst Transboundary Aquifer System) is an on-going GEF project implemented by UNDP and UNESCO's IHP, initiated to improve the understanding of shared water resources and to facilitate their equitable and sustainable utilization, including the protection of

dependent ecosystems in the four countries of Dinaric karst.

Geographical and geological boundaries

The Dinaric system (Dinarides) is a long, NW-SE oriented orogenic belt, parallel to the Adriatic Sea, with numerous intermountain depressions, large karst poljes, and valleys created by perennial and sinking streams.

It extends over the territories of six countries of former Yugoslavia: Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, and FYR of Macedonia.

In total, eight TBA are selected for detailed analyses: Una, Krka, Cetina, Neretva, Trebisnjica (all shared by CRO and B&H), Bilecko Lake and Piva (B&H and MNE) and Cijevna/Cemi (MNE and ALB). Six of these TBAs belong to the Adriatic Sea catchment area and only two (Una,Piva) are part of the Black Sea basin. The TBAs comprise of in total a surface area of 12,000 km^2, which is around 10% of the entire study area. The surface area of individual TBA varies from 668 km^2 (Krka) to 3,455 km^2 (Cetina).

Sensitive areas

- Some of the selected TBAs, such as Una, Krka, Neretva or Cijevna/Cemi, are of particular importance because they represent designated protected zones, or wetlands, or the habitat for endangered species. In Una catchment there is the Plitvice Lake, Croatian national park also protected by UNESCO as the world heritage site. Krka is another Croatian national park, while Neretva deltaic marsh is an important biodiversity area. Finally, the Cijevna/Cemi aquifer drains into the Skadar Lake, an important bird settlement included in the Ramsar list.
- One of the tasks of the DIKTAS project was to prepare a proposal for the creation of a **new Groundwater Monitoring Network** in designated areas of transboundary concern which will fully respect specific karst behaviour.
- Monitoring data are to be used to verify risk assessments and complement human impact assessments.

- Therefore, knowledge of GW distribution, flow pattern and extraction rate is essential for sustainable development of the studied karst aquifers and dependent eco systems. The preliminary analysis indicated that water extraction was still far below aquifer's replenishment potential, and there is no evidence of significant over-exploitation in studied TBAs. However, already proven connections between ponors and certain important springs in the territory of the neighboring country (e.g. Plitvice-Klokot, Trebisnjica-Ombla) require strict respect of established sanitary protection zones and respective measures. Principles of EU WFD regarding ecological flow for downstream consumers also have to be fully respected.

Recommendations for GW monitoring

- The WFD does not specify the minimum duration or frequency of surveillance monitoring. Operational monitoring, however, must be conducted at least once a year, during the interval between surveillance monitoring cycles.
- WFD the following core set of determinants must be monitored on all GW bodies: dissolved oxygen, pH-value, electrical conductivity, nitrate, ammonium,
- As for the transboundary groundwater bodies, beside the core set of parameters they shall also be monitored for those parameters which are relevant for the protection of all of the uses supported by the groundwater flow.
- ICPDR recommends that temperature and a set of major (trace) ions should also be monitored.

German experience -
Qualitative monitoring / Sampling frequency

Scenarios	Frequencies					
	Monthly	Quarterly	Half yearly	Yearly	2 Years	5 Years
Shallow groundwater (depth to table ≤ 3 m), unconfined porous aquifer	(x)	x	x	(x)		
Deep groundwater (depth to table ≥ 10 m), unconfined porous aquifer				(x)	x	x
Shallow ground-water (depth to table ≤ 3 m), unconfined fractured aquifer	(x)	x	x	(x)		
Deep groundwater (depth to table ≥ 10 m), unconfined fractured aquifer		(x)	x	x		
Karst aquifer (without more or less imperme-able cover)	x	x	x			
Karst aquifer (with more or less impermeable cover)	(x)	x	x	(x)		
Confined groundwater (with more or less im-permeable cover with thickness < 2 m)				x	x	(x)
Confined groundwater (with more or less im-permeable cover with thickness > 2 m)				(x)	x	x
High rate of recharge		(x)	x	x		
Trend assessment			x	x		
Season-dependent human activities		(x)	x	(x)		

General recommendations for the development of groundwater monitoring – Sava Commission experience

- Establishment of legal background for groundwater monitoring (where it does not exist), with clearly defined objective, scope, types of monitoring, monitoring parameters, monitoring frequency, applied standards, responsible institutions
- Systematic integration of water supply companies (and other water users) into the national wide groundwater monitoring system by a legal solution; groundwater monitoring must also be the task of water users such as public and industrial water suppliers, using groundwater for drinking and process water purposes.
- The network should have a balanced spatial density which considers the conceptual understanding of the natural characteristics and of the pollution risks of the groundwater body, to help focusing monitoring activities in areas where significant pressures combined with higher vulnerability exist. This approach requires preparation of land use maps and vulnerability maps.
- List of monitoring parameters should be adjusted to the WFD requirements, (core parameters: oxygen content, pH value, conductivity, nitrate, ammonium + parameters which put GW body at risk of failing to achieve good chemical status. Transboundary water bodies shall also be monitored for those parameters which are relevant for the protection of all of the uses supported by the ground-water flow.
- The number of monitoring stations and sampling frequency should be proportional to the complexity of status assessment of the groundwater body and presence of pollution trends

- In the GENESIS project, Preda et al. (2012) classify the following indicator packages:
- - indicators of hydrogeomorphological units including groundwater: environmental tracers, water balance components, GW level and pressure, GW vulnerability, GW quality, river flow;
- - indicators of physico-chemical components or even physico-chemical parameters as indicators: temperature, electrical conductivity, chlorophyll, concentration of different chemical compounds, dissolved oxygen, NO_3, NO_2, NH_4, PO_4, metals;
- - indicators of biological compartments / trophodynamic modules: species richness of phytoplankton, macroinvertebrates, fish, diversity indices, indicator species, multimetric indices.

- Water dependent ecosystems are essential components of the watersheds which are under increasing pressure from human activities. In karst, dependent ecosystems are exposed to greater potential hazard if they depend on water from aquifer.
- Although the problem of aquifer over-exploitation is often exaggerated (Custodio, 1992, Burke and Moench, 2000) variable water regime and low water flows during periods of maximal demands (summer months) can cause stress in many aquatic systems.
- The problem is much more sensitive when it comes to the area of transboundary concern (Chilton, 2002; Puri & Aureli, 2005).

How to properly establish sanitary protection zones and monitoring of TB aquifers?

Sensitive areas

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- Therefore, knowledge of GW distribution, flow pattern and extraction rate is essential for sustainable development of the studied karst aquifers and dependent eco systems. The preliminary analysis indicated that water extraction was still far below aquifer's replenishment potential, and there is no evidence of significant over-exploitation in studied TBAs. However, already proven connections between ponors and certain important springs in the territory of the neighboring country (e.g. Plitvice-Klokot, Trebisnjica-Ombla) require strict respect of established sanitary protection zones and respective measures. Principles of EU WFD regarding ecological flow for downstream consumers also have to be fully respected.

Environmental status indicators

- A part of the diagnostic analysis is a prepared list of environmental impact indicators which includes 23 different parameters for assessing pressures on GW quantity and quality, ensuring sustainable water use and protecting the status of dependent eco-systems.

Environmental indicators

No	Group	Indicator	Expressed as	Unit
1	**Water Resources Availability (Pressures on Water Quantity)**	Renewable freshwater resources	ratio: Total flow of surface and groundwater in the study area vs. Total rainwater in study area (TBA catchment)	mM^3/year : mM^3/year or %
1a		Renewable freshwater resources in recession (drought) periods	Sub-indicator: As above but in critical drought periods (summer-autumn)	mM^3/4 critical months : mM^3/4 critical months or %
2		"Domicile" (and "External") freshwater resources	ratio: Total flow of surface and groundwater generated in the part of TBA inside each country vs. Total flow of surface and groundwater in the entire TBA catchment	mM^3/year : mM^3/year or %
3		Renewable GW resources (Dynamic reserves)	ratio: Total flow of groundwater in the studied TBA catchment vs. Total rainwater in the studied TBA catchment	mM^3/year : mM^3/year or %
3a		Renewable GW resources (Dynamic reserves) in critical periods	Sub-indicator: the same as above but in critical drought periods (summer-autumn)	mM^3/4 critical months : mM^3/4 critical months or %
4		Water exploitation index	ratio: Total water amount utilized for different purposes vs. Total renewable freshwater resources	mM^3/year : mM^3/year or %
5		Groundwater exploitation index	ratio: Total groundwater utilized for different purposes vs. Total flow of groundwater in the study area	mM^3/year : mM^3/year or %

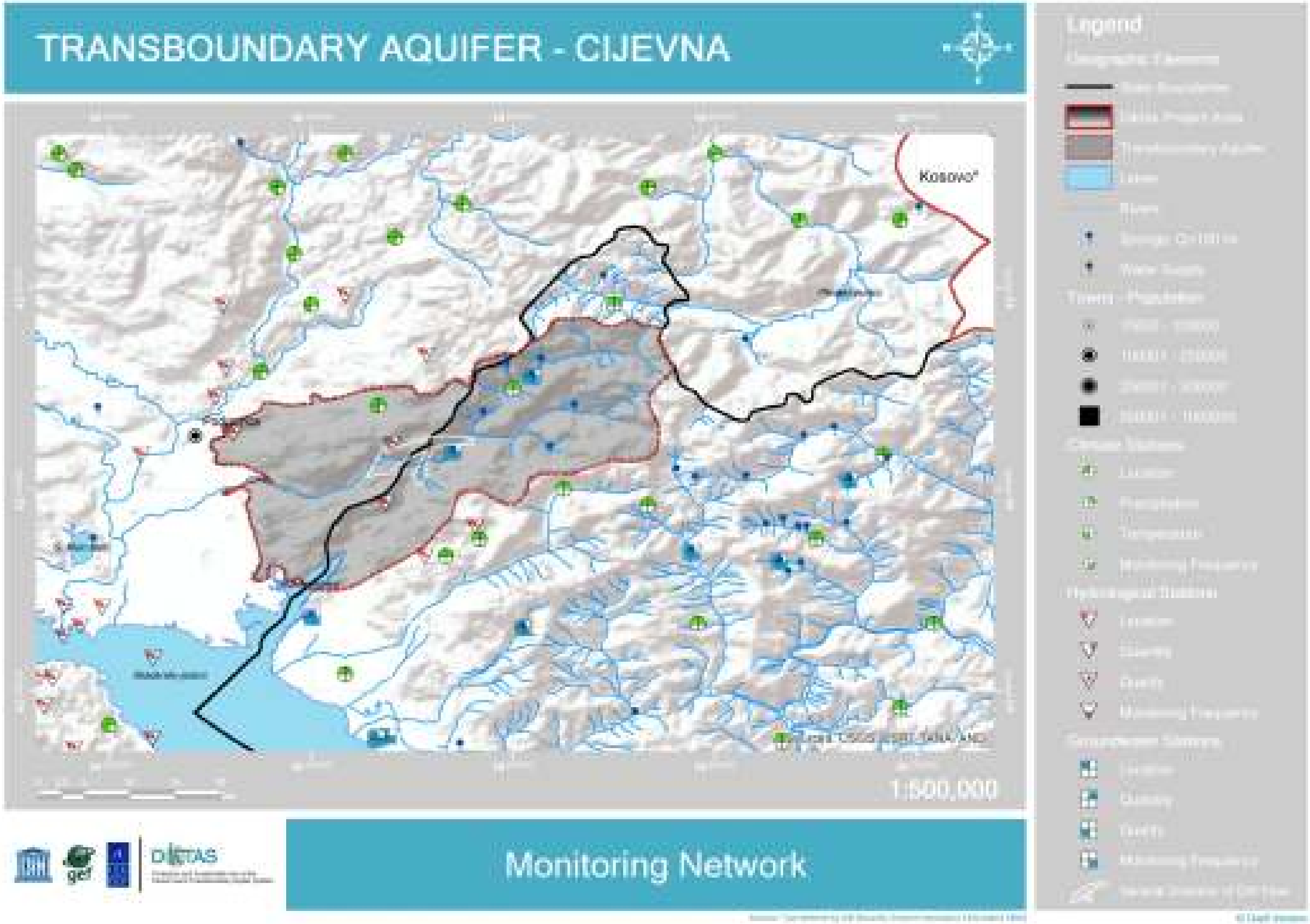
6		Water demands (availability)	ratio: Total water demands for different purposesvs. Total renewable freshwater resources	mM^3/year : mM^3/year or %
7		Drinking water demands	ratio: Total water demands for drinking purpose vs. (1) Total renewable freshwater resour-ces and vs. (2) Total flow of groundwater in the study area	mM^3/year : mM^3/year or %
8		Water available per capita	Water available (household water access) calculated per capita per year	m^3/cap/ year
9		Irrigation water demands and use	ratio: Total water used for irrigation purpose vs. Total renewable freshwater resources	mM^3/year : mM^3/year or %
10		Hydropower water use	ratio: Total water used for HP vs. Total renewable surface water resources	mM^3/year : mM^3/year or %
11		Groundwater depletion	Annual depletion of groundwater table (av. value) due to over abstraction. Punctually measured at selected points	m/year
12		Losses	ratio: Total water losses (non-utilized) from the systems constructed for different purposes vs. Total tapped renewable freshwater resources	%

13	**Pressures on Water Quality**	Drinking water quality	ratio: Number of samples of raw drinking water (from the sources) with inappropriate qualityvs. Total number of the controlled samples	no : no or %
14		Industry waste water index	ratio: Flow of untreated industrial (incl. mining) waste water (returned to recipients) vs. Total flow of waste water generated in study area	mM^3/year : mM^3/year or %
15		Household waste water index	ratio: Flow of untreated domestic waste water (returned to recipients) vs. Total flow of domestic waste water in study area	mM^3/year : mM^3/year or %
16		Specific pollutants index	ratio: Concentration (average) of selected component (pollutant) vs. maximal permitted level of the same component (pollutant) in drinking water	expressed in mg/l : mg/l (permitted level) or µg/l : µg/l (permitted level) or % of samples of inappropriate quality of cpec. comp. vs. total samples
17		Fertilizer index	ratio: Amount of mineral or organic fertilizers used per unit of arable land	kg/ha or tones /ha
18		Pesticide index	ratio: Amount of pesticide used per unit of arable land	kg/ha
19		Landfill status	ratio: Number of inhabitants in study area without sanitary proper solid waste dumps vs. Total population in study area	.000 : .000 or %

20		Water reuse	ratio: Reused or recycled water vs. Total flow of waste water in study area	mM^3/year : mM^3/year or %
21		Salt water intrusion (in coastal aquifers)	ratio: Total water flow - already salty, brackish or under direct threat of intrusion vs. Total renewable freshwater resources	mM^3/year : mM^3/year or %
22		Protected habitat	ratio: Total surface of protected area vs. Total surface of study area	km^2 : km^2 or %
23		Water demands of dependent eco system	ratio: Total water demands for downstream dependent eco system vs. Total renewable freshwater resources-dynamic, or Total water demands for (WDES) vs. Minimal discharge	mM^3/year : mM^3/year or %
23a		Specific species Sub-indicators: Specific endemic and endangered species (list)	Specific water demands (flow) for endangered species throughout the year (e.g. trout)	Presence of protected endemic species – List

To observe all indicators? Mission possible?

- Not all the mentioned indicators have to be determined and followed; selection has to be made in accordance with local conditions. Some indicators are proposed to be observed on an annual basis such as: Renewable groundwater resources; Groundwater exploitation index; Groundwater depletion;
- Others need frequent monitoring such as Specific pollutants index; Drinking water quality (by observing selected critical parameters);
- They should be observed continuously in an established GW Monitoring Network due to the specific intensive and variable regime of karstic aquifer systems.


TRANSBOUNDARY AQUIFER - CIJEVNA
Kosovo*
Legend
1:500,000
Monitoring Network

Conclusions

- Although the Dinaric region has the most intensive water budget in all of Europe, there are numerous problems for sustainable utilization of GW. The main problem is the great annual variation of natural flows and the vulnerability of aquifers to pollution which comes mostly from still unregulated waste water discharges.

- It is therefore important to quantify the water reserves of transboundary aquifers, ensure ecological flows in sensitive areas, eliminate sources of pollution, improve the quality of water and establish proper water monitoring systems.

- *Rainfall* and other climate elements (air temperature, humidity, wind, evaporation) observed on a daily basis.
- *Riverflow* observed on a daily basis – limnigraphs for automatic recording or classical gauging stations installed on major rivers and streams in each country sharing TBA (entrance / exit stations).
- *Springflow* observed on a daily basis – as above, the limnigraphs for automatic recording or classical gauging stations installed on major springs within TBA.
- *Groundwater table* observed on a daily basis – automatic data logger ("diver") for groundwater table recording installed in piezometers properly selected to represent aquifer system in recharge/discharge areas in both countries sharing TBA. In addition, a classical manual recording of the groundwater table on a daily/weekly basis (depending on wet/dry seasons) should also take place on the piezometers of the 2nd rank.
- *Water quality* control is to be organized in compliance with EU WFD requirements for surveillance and operational monitoring. Sampling frequency and the number of observed parameters (salinity, chemistry, turbidity, biology, specific components and pollutants) are to be adapted to local circumstances and pollution risks.

- To be able to define other environmental impact indicators in addition to the above “hydro” parameters, relevant information on surface waters and groundwater regime (quantity and quality) should be collected and provided on a regular basis *to the responsible authorities and local water management institutions* such as water agencies, hydrometeorological surveys, health and sanitary control centres, and municipalities. Groundwater monitoring and data collection must be the task of all those using groundwater for drinking and process water purposes.
- User measure!

Conclusions

- Some demonstration sites in Dinaric karst are already identified and proposed for the installation of a modern monitoring network for observation of karstic groundwater and for climate elements and surface waters regime.
- Establishment of similar national water information systems,
- Data exchange protocol,
- Synchronization of legislation in the water sector,
- Harmonization of criteria for GW protection,
- Definition of ecological flow, and
- Experts working group are some of the proposed activities to take place beyond DIKTAS project.

Thank you for your attention

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