YOUTH PERSPECTIVES ON

GROUNDWATER QUALITY AND QUANTITY MONITORING

Prepared by: GWYN Scientific Committee - Groundwater Monitoring: Quality & Quantity Group

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GWYN

Groundwater Youth Network

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1. Introduction

Groundwater Youth Network (GWYN) has a target to enhance the engagement of youth in addressing water security issues with objectives to create a youth network of groundwater ambassadors of change and involve youth in all activities and decision–making processes regarding groundwater. GWYN Scientific Committee works on connecting young scientists and researchers in the water management sector, especially involving groundwater issues.

This document is prepared by the GWYN Scientific Committee working group on *Groundwater Monitoring: Quality and Quantity, which started its work in September 2022*. The working group has conducted research via a survey on youth perspective on groundwater monitoring in multiple countries around the world. The main topic was groundwater monitoring with some aspects on emerging pollutants and vulnerability analysis. 80 answers were collected with this survey and are summarized in this report. Brief descriptions of groundwater monitoring regulations in some countries: EU member states (Croatia, Germany, Italy, Slovenia, Spain), Jordan, and India are included.

Within this report, the summarized results of the survey are presented in Section 2, followed by an overview of international regulations on groundwater monitoring in Section 3. Moreover, Section 4 of this report covers case studies providing more detailed information on 7 countries from different continents.

2. Results

The main goal of conducting this study is to collect and analyze the opinion of young professionals and researchers in water science and similar areas to gain insights into national groundwater quality and quantity monitoring activities from different countries. In Figure 1. (a) and (b) range of birth years is shown individually and in range.

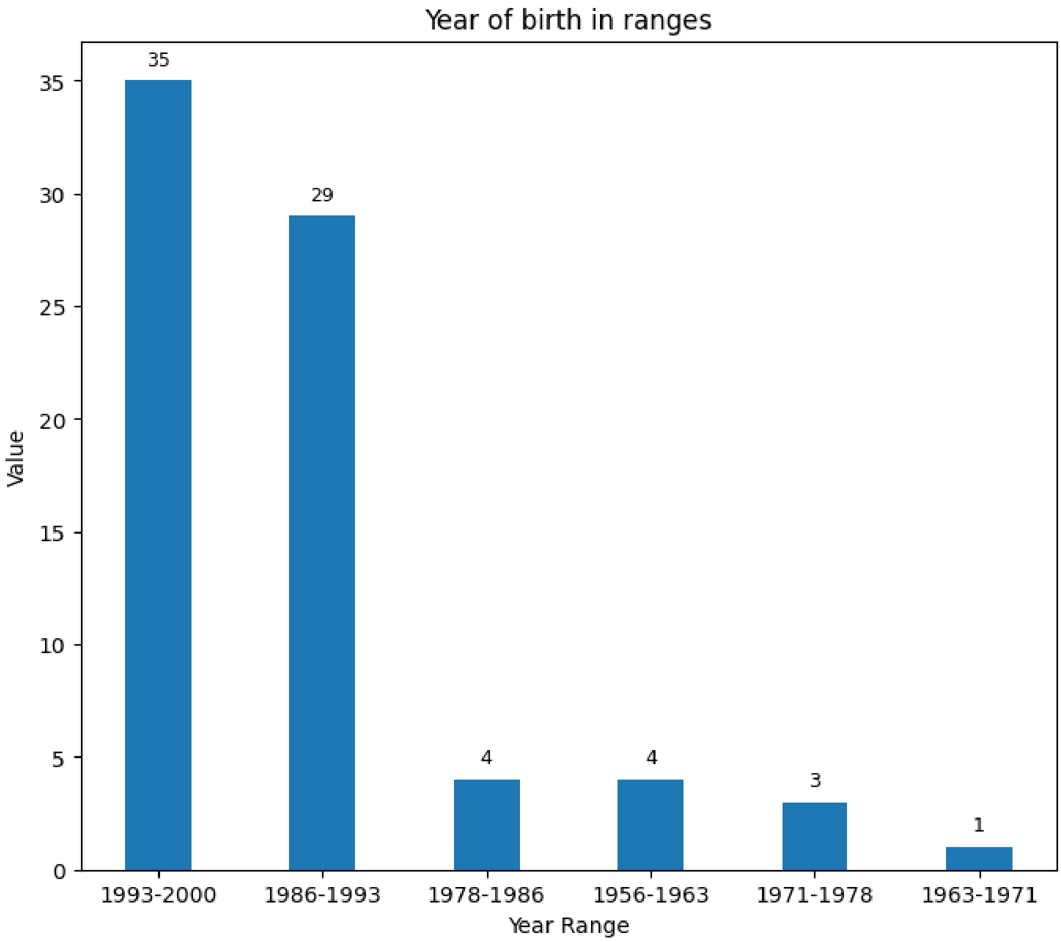

Figure 1. Year of birth of the respondents

As can be seen from Figures 1, most of the respondents are in the range of 1986 to 1993, which means that most of the respondents are in the range of 20 to 35 years old so we can confirm that collected answers represent a young perspective. At least one answer was given by 35 countries, which are listed in Annex A.

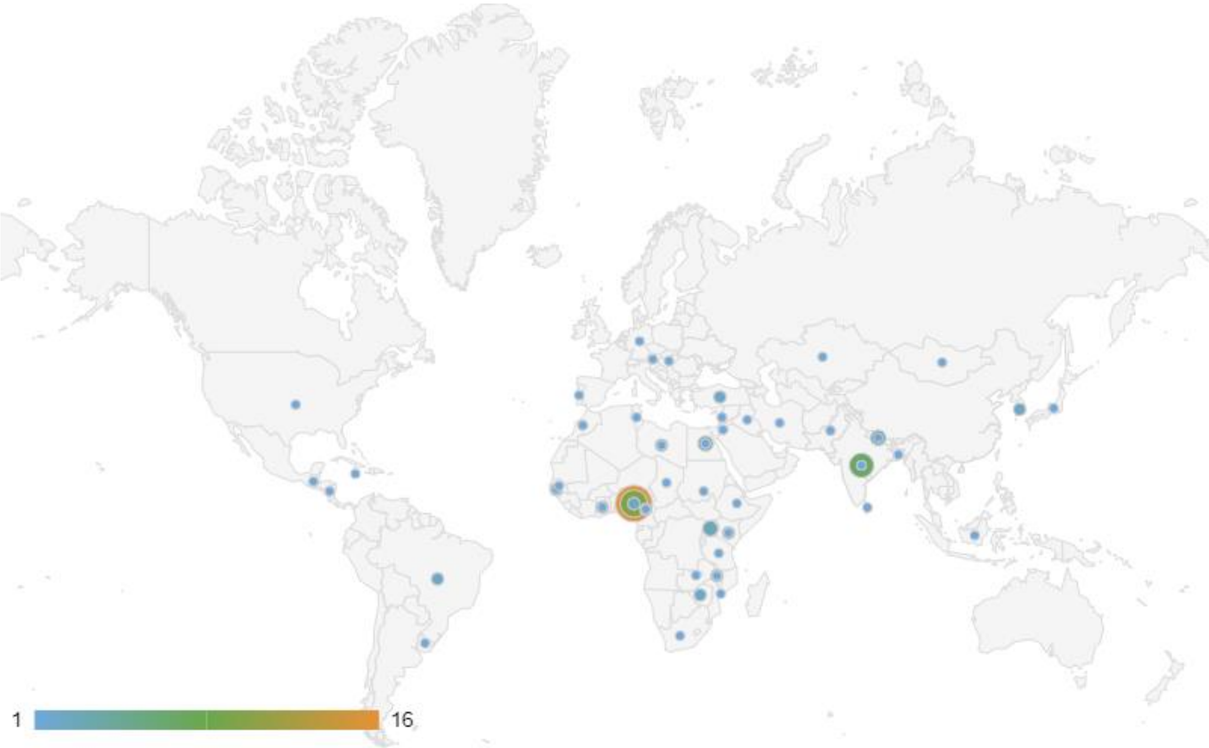

Figure 2. Origin of the respondents and number of answers per country

The answers cover 35 different countries. Figure 3 shows the percentage of answers per country: 18.8 % of the respondents are from India, 11.3 % are from Nigeria, while Kenya and Uganda share the third place contributing to 6.3 % of the respondents each. The following countries have percentages smaller than 5%: Germany, UK, Sierra Leone, Vietnam, Guatemala, Tunisia, Japan, Sri Lanka, Namibia.

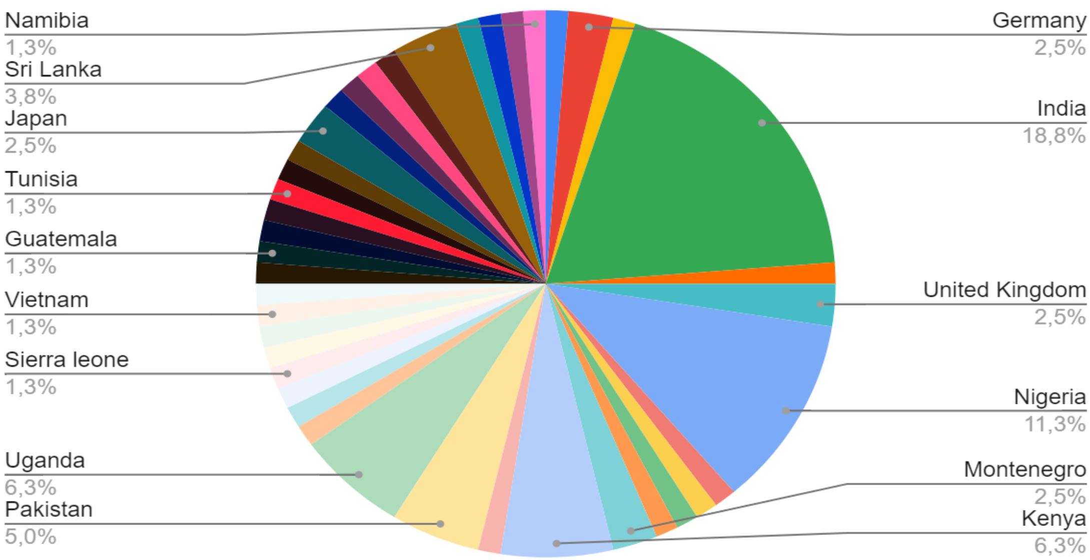

Figure 3. Respondents' percentage by country. Other countries having an equal percentage of 1.3 % are Sierra Leone, Vietnam, Guatemala, Tunisia, Namibia.

52.1 % of respondents answered that in their country there exists a framework for "Groundwater monitoring regulations", 26 % answered that in their country there are no regulations about groundwater monitoring, while 2.3 % said that they don´t know.

The question regarding the spatial coverage of the groundwater monitoring in the country, multiple answers could be given: 49.3 % of respondents answered that in their country there is monitoring established at the national level, 21.9 % at the regional (groundwater basin) level, 26 % at the local level (aquifer), while 11 % have no monitoring networks and the other 11 % don't know that information. In addition, those that have monitoring networks answered that 32.9 % have manual data collection, 2.7 % automatic, 57.7 % have both manual and automatic data collection, while 13.7 % of the respondents don't know that information about groundwater monitoring in their country. Information about the spatial scale of the existing groundwater monitoring network as well as the way of data collection is presented in Figures 4 and 5.

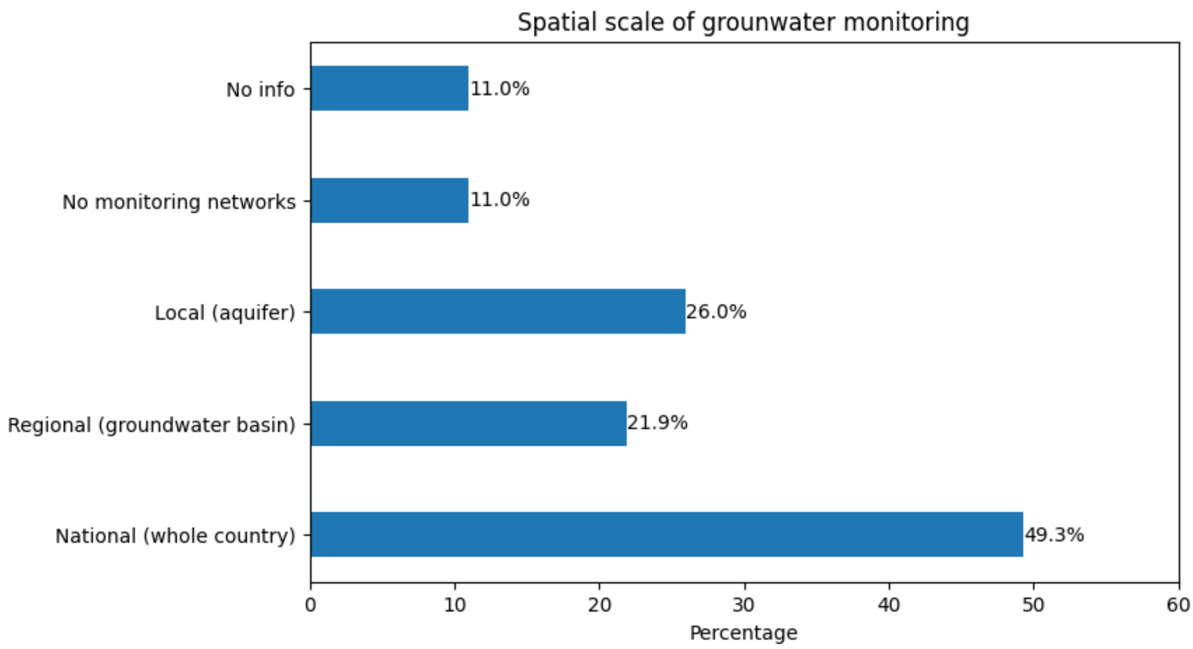

Figure 4. The spatial scale of groundwater monitoring network

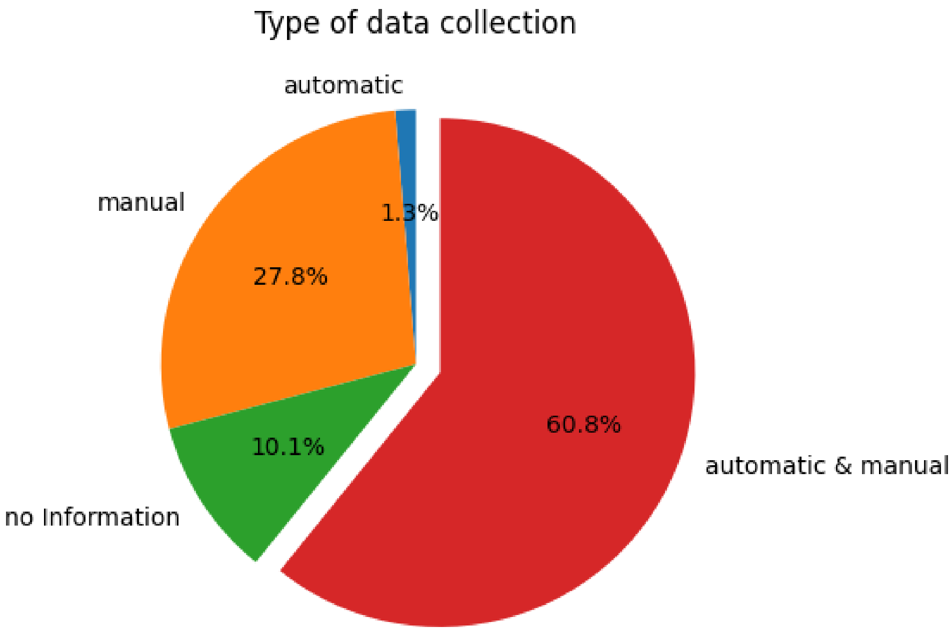

Figure 5. Type of data collection

Similar comments received by the respondents stating their opinion on groundwater monitoring network in their country are summarized into overarching statements:

"A groundwater monitoring program was initiated, involving various data collection methods such as field investigations, water sampling, quality testing, surveys, and borehole constructions. The program identified issues and recommended extending the network to critical areas, including aquifers and river basins. The effectiveness of monitoring varies due to different water table levels at different places. Data is collected and regulated locally, but the distribution of monitoring is uneven."

"India has a groundwater monitoring network based on geological formations and rock types, with measurements taken periodically. The data collected is not widely accessible, and there's a need to increase monitoring stations. In some cases, data is only used for research purposes. There is a Central Groundwater Board (CGWB) in India responsible for groundwater monitoring."

"Japan monitors lakes, rivers, and mountainous groundwater but faces challenges with incomplete data, especially in mountainous regions. Monitoring is not comprehensive due to resource limitations."

"Monitoring in different regions is regulated by the EU Water Framework Directive and Groundwater Directive. Hydrological surveys are sometimes conducted by unskilled personnel, affecting data quality."

"Groundwater monitoring in Somaliland is based on manual and old data collection and relies on community-based data collection. There are no clear guidelines or laws for groundwater management."

"Nigeria has a national groundwater monitoring program, but some monitoring points are out of use. The existing guidelines are not very efficient, and there is limited concern for groundwater protection or conservation."

"Germany has two national networks for data collection on nitrate and for EU reports, along with state-level networks."

Table 1. Summary of comments about groundwater monitoring network per country

Guatemala	No water law or regulation, poor data quality.
Lebanon	Limited data collection; unclear laws.
India	Local scale monitoring is lacking.
Libya	Not all data types are collected.
Morocco	Irregular and disrupted monitoring.
Nigeria	Basic water monitoring
Tanzania	Poor network with few boreholes; inadequate data.
Gambia	Old monitoring network
Uganda	Upgraded from manual to telemetric systems
Ethiopia	Not all data types are collected.
Sri Lanka	Community-based groundwater monitoring.
Egypt	Established monitoring network for Nile Delta Aquifer
Turkey	Multiple official institutes
Kenya	Data collected at the county level.
Jamaica	Manual monitoring; limited water quality monitoring.
United States	State-level monitoring
Brazil	Limited data collection
Japan	Not all data types collected.
Portugal	Old monitoring network, incomplete data.
DRC	Government ministries involved in groundwater monitoring.
Senegal	Outdated data.
Indonesia	Not all data types are collected.
Sudan	Pollution due to lack of separation between surface and groundwater.
Austria	Nationwide data collection
Korea	Thorough nationwide monitoring network.
Pakistan	No monitoring network
Bangladesh	Not all data types collected.
Chad	Large number of monitoring stations
Mongolia	Not all data types collected
Hungary	Abandoned monitoring wells

Figure 6. shows respondents' opinions on the most important groundwater variables that need to be collected in their country. It can be seen that groundwater quality and level are considered the most important information that needs to be collected, as well as the information on natural and artificial recharge.

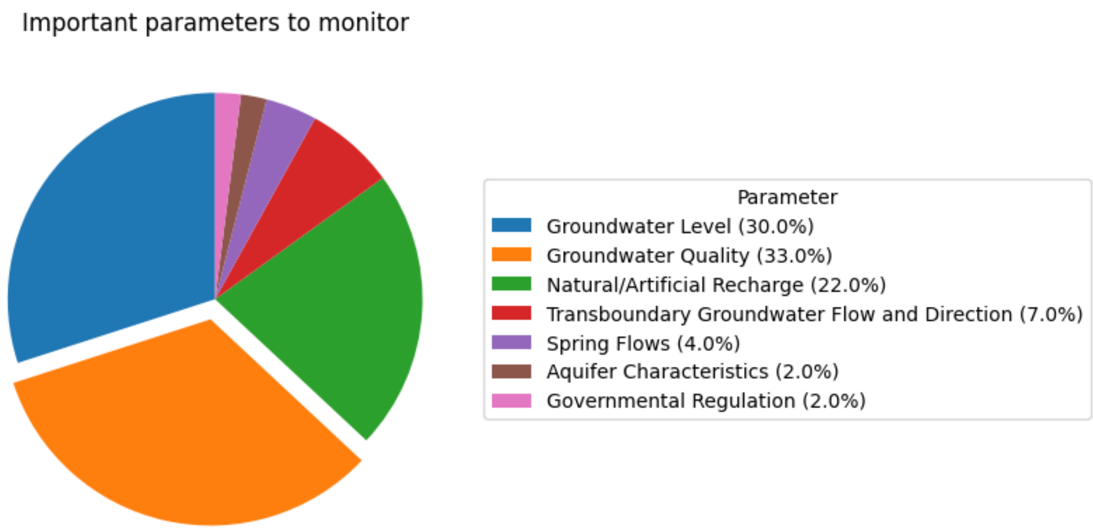

Figure 6. Respondents' opinions on the most important variable that needs to be included in the monitoring.

Information about knowledge of the young population about groundwater-related issues in their country is shown in Figure 7. Groundwater contamination (pollution) is considered the main problem alongside groundwater level decline, decrease in groundwater recharge, as well as seawater intrusion.

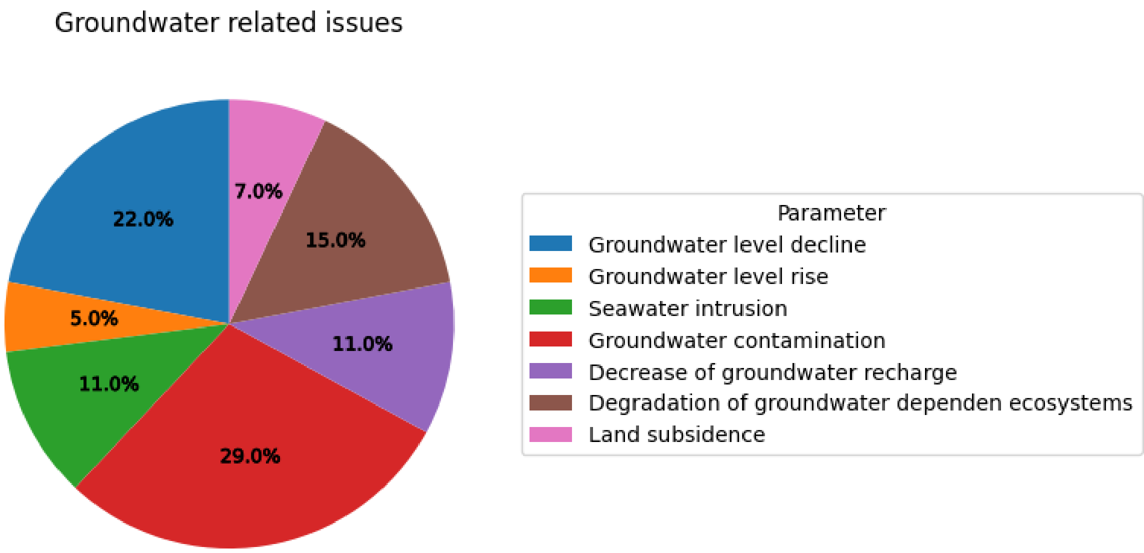

Figure 7. Groundwater-related issues by respondents' opinion in their country.

Due to the most significant concern on groundwater contamination (pollution), respondents answered that groundwater quality-related issues are the biggest concern in their countries. In Figure 8. can be seen that organic contaminants (pesticides, pharmaceuticals, etc.) and emerging pollutants (like microplastics) are the main problems in 55 % of respondents' countries as well as Nitrate contamination (17 %), Arsenic contamination (13 %) and Fluoride contamination (11 %).

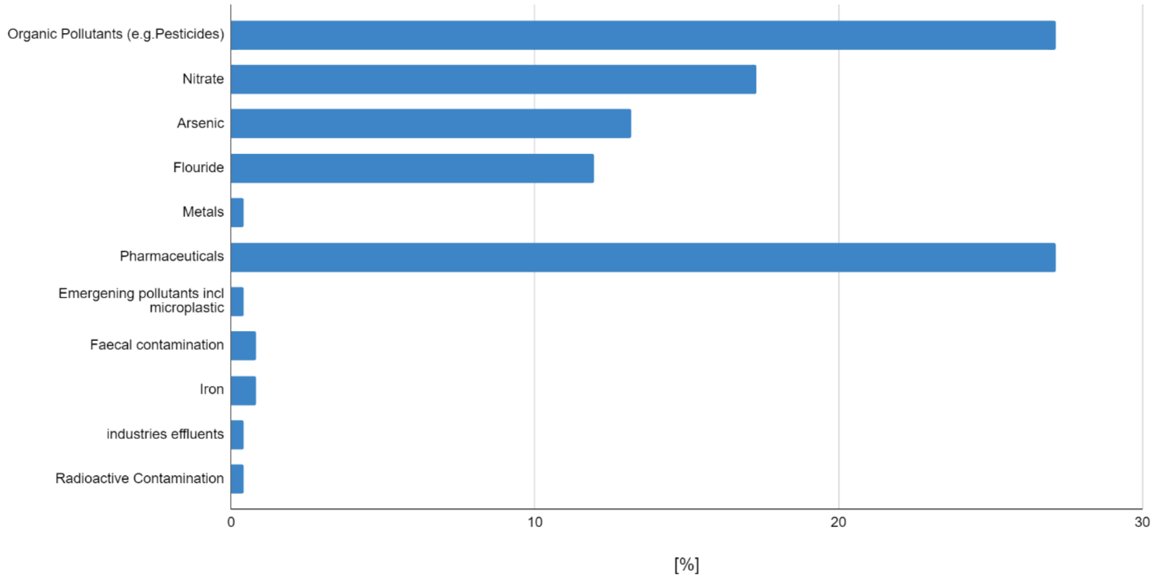

Figure 8. Opinion on most serious quality groundwater-related issues that require monitoring in respondents' countries.

These contaminants originate from different sources: pharmaceuticals are either released from private households or hospitals, pesticides stem from agricultural activities (Lapworth, 2012). Nitrate can be released into the groundwater by either natural source, as nitrate is naturally occurring in soil and groundwater. Nitrogen in the Earth's atmosphere can be assimilated by certain microorganisms, while geological deposits of nitrate salts contribute to natural nitrate sources. Human activities are also a significant contributor to nitrate contamination. Major sources include Agricultural Practices, where nitrate contamination often results from the use of nitrogen-based fertilizers in agriculture, especially in irrigated and heavily fertilized crops like corn, vegetables, and horticultural crops. The disposal of animal waste, particularly from concentrated animal feeding operations (CAFOs), contributes to nitrate contamination when not properly managed. Domestic wastewater disposal using septic tanks can lead to nitrate leaching into groundwater when effluent is inadequately treated. Industrial and food processing operations may release nitrate-containing effluents into the environment. Nitrogen compounds, including nitrate, can enter the soil and groundwater through atmospheric deposition from sources like power plants and combustion processes (Dermont et al., 1992).

Arsenic is naturally present in geological formations, including arsenic-bearing rocks and minerals. It can exist in various forms, such as elemental arsenic, sulfides, arsenides, oxides, arsenates, and arsenates. Geothermal activities, biogeochemical processes, and geohydrological interactions can release arsenic compounds from sources like arsenopyrite, a mineral containing arsenic. Microbial processes can lead to the formation of orpiment, another arsenic-bearing compound.

Human activities contribute significantly to arsenic contamination. These sources include: Processing of ores that are already contaminated with arsenic. Use of arsenic-containing ingredients in pesticides.

Hazardous waste sites that may leach arsenic into the environment. Burning coal contaminated with arsenic, which can release the element into the atmosphere. Geothermal waste, mining operations, and industrial discharges that can pollute rivers, often important sources of drinking water.

Fluoride contamination in groundwater has both geogenic (natural) and anthropogenic (human-induced) sources: The primary geogenic source of fluoride in groundwater is fluoride-bearing rocks. Weathering or leaching from these rocks can lead to the contamination of groundwater reserves. Fluoride is naturally found as calcium fluoride (CaF_2) and is a key component in minerals like topaz, fluorite, fluorapatite, cryolite, and phosphorite. Different geological formations can contain varying levels of fluoride. For example, granite typically has five times more fluoride than basalt rocks. Shale tends to have a higher fluoride concentration compared to sandstone and limestone. Alkaline rocks often contain higher concentrations of fluoride (ranging from 1200 to 8500 mg kg^{-1}). Groundwater with low calcium and high bicarbonate alkalinity is more likely to have high fluoride concentrations. Fluoride-contaminated water is typically soft, has a high pH, and contains a significant amount of silica. Groundwater fluoride concentrations can vary widely, ranging from less than 1.0 mg L^{-1} to more than 35.0 mg L^{-1}, depending on various factors.

Human activities contribute to fluoride contamination in groundwater. These sources include: Run-off and infiltration from agricultural fields, especially due to the use of fertilizers containing high fluoride concentrations. Discharges from septic and sewage treatment systems can introduce fluoride into the groundwater. Seepage from industrial waste and potentially other industrial activities release fluoride into the environment. Both natural geological processes and human activities can impact the fluoride levels in groundwater (Bibi et al., 2017).

Other groundwater variables that are surveyed in the respondents' countries are:

- Organic pollutants within the Argentine Food Code (which is outdated considering the pesticides that are most used in agriculture, such as Glyphosate, are not included);
- pesticides, metabolites of pesticides are not monitored in each groundwater body (GWB);
- screening for a wide range of organic contaminants is carried out by the regulator using GC-MS techniques. Water companies also sample and analyze groundwater quality to ensure drinking water quality. The suite of parameters measured is often dependent on a risk assessment of whether specific contaminants may be present.
- parameters that are regulated within EU WFD, 1. and 2. Watch list (CIS (2019)).

- all major ions, trace metals, and biogenic elements. Some selected pesticides, and emerging contaminants.
- organic contamination, arsenic contamination, and crude oil contamination.

Figure 9. shows on a scale of 1 to 5 (5 being highest rate of danger) respondents' opinions on how dangerous organic contamination in groundwater is.

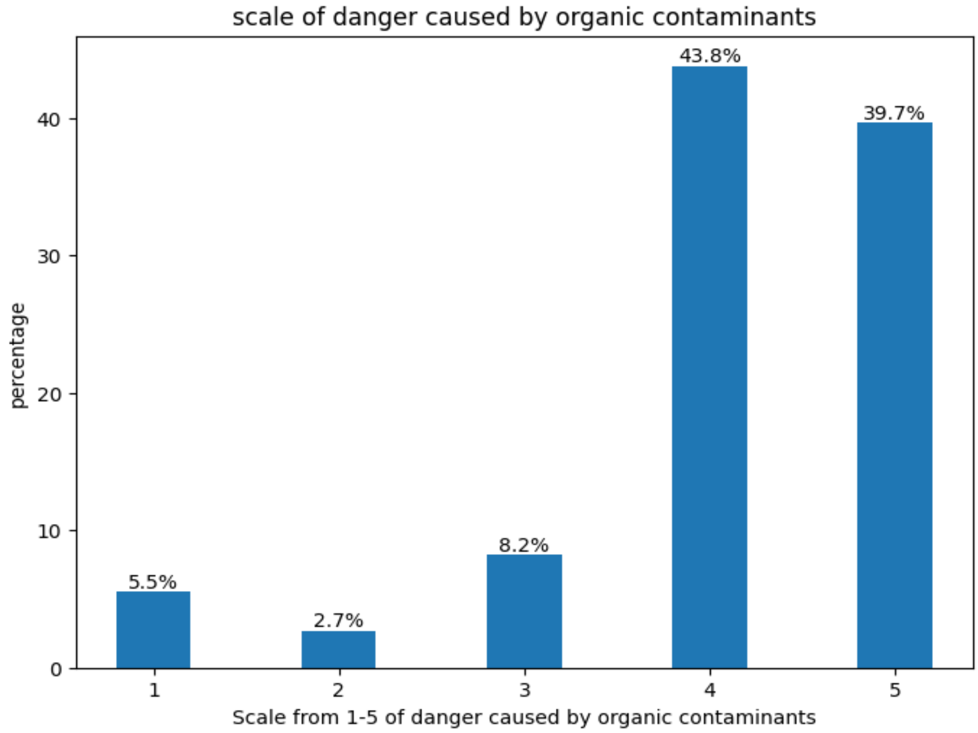

Figure 9. Scale from 1 to 5 about the danger of organic contamination in groundwater

It can be seen that the youth perceive organic contamination in groundwater as highly dangerous. This has prompted the question of regulations on maximum allowed concentrations (MAC) of organic pollutants in waters, especially groundwater. 46.6 % of respondents answered that in their country there are some regulations on groundwater quality monitoring of organic pollutants and established MAC values, while 31.5 % do not have any regulations and others don't know the current state of regulations or MAC values.

Figure 10. shows the countries in question have regulated vulnerability assessment for groundwater protection.

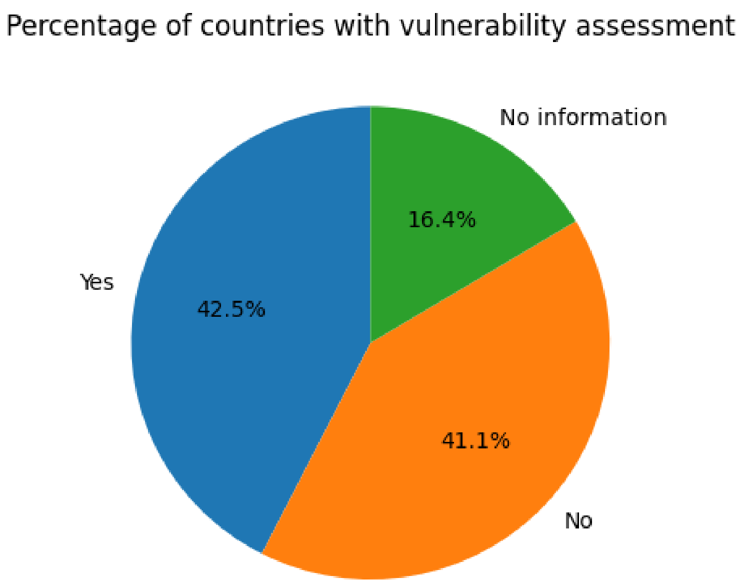

Figure 10. Vulnerability assessment for groundwater protection

As expected, the number of countries with a regulation equals the number of countries without a regulation on vulnerability assessment for groundwater.

Figure 11. shows if the youth are directly involved in groundwater monitoring in countries that are listed in Table 1.

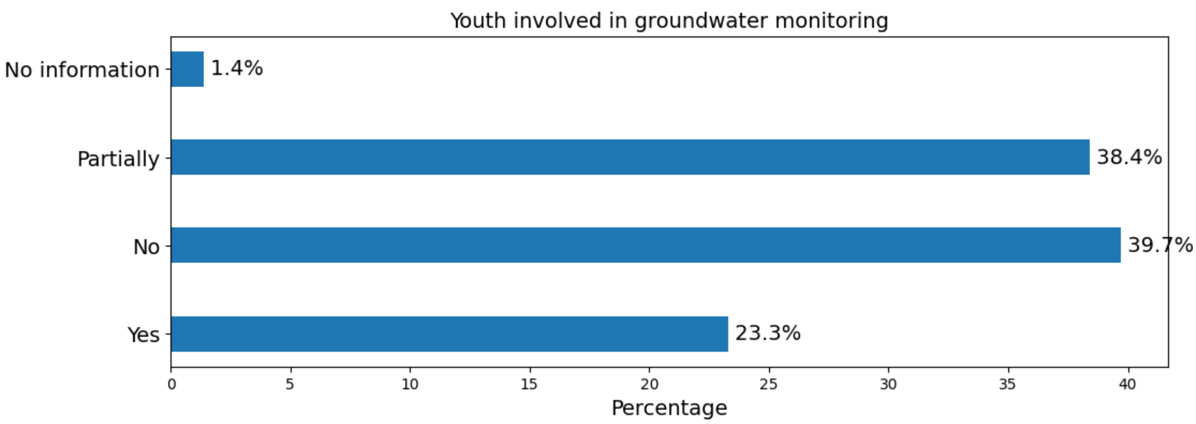

Figure 11. Presentence of youth involved in groundwater monitoring.

As can be seen, youth are mostly not involved in groundwater monitoring. A young perspective on monitoring groundwater quality and quantity is important to give a new point of view to the government in order to better understand and protect this valuable resource for the next generation.

3. Regulations in EU countries implementing WFD

3.1. Water Framework Directive (WFD)

The Water Framework Directive (2000/60/EC) (WFD, 2000) is a comprehensive piece of legislation that sets out, inter alia, “good status” objectives for all waters in Europe. The Directive provides for sustainable and integrated management of river basins including binding objectives, clear deadlines, and a comprehensive program of measures based on scientific, technical, and economic analysis including public information and consultation. Soon after its adoption, it became clear that the successful implementation of the directive will be equally as challenging and ambitious for all countries, institutions, and stakeholders involved.

3.2. The Common Implementation Strategy (CIS) of the WFD

In order to address the challenges in a cooperative and coordinated way, the Member States, Norway, and the Commission agreed on a Common Implementation Strategy (CIS, 2001) for the Water Framework Directive only five months after the implementation of the directive. Furthermore, the water directors stressed the necessity to involve stakeholders, NGOs, and the research community in this joint process as well as to enable the participation of candidate countries in order to facilitate their cohesion process.

3.2.1. CIS: Guidance Document No. 15_Guidance on Groundwater Monitoring (CIS, 2007)

This document provides guidance on establishing groundwater monitoring programs to meet the requirements of the WFD and the new Groundwater Directive (GWD). These programs include both quantitative and chemical (quality) monitoring for status and trend assessment, monitoring to support (ground) water body characterization, and drinking water protected area objectives. The establishment of high-quality long-term monitoring programs is essential when the implementation of the WFD and the daughter GWD shall be effective. It is recognized that monitoring can be very expensive and so the guidance presented here aims to establish cost-effective, risk-based, and targeted groundwater monitoring across Europe that enables WFD objectives to be met. However, inadequate investment in monitoring, including network infrastructure and data quality and management will result in a significant risk of failure to meet the WFD’s environmental objectives.

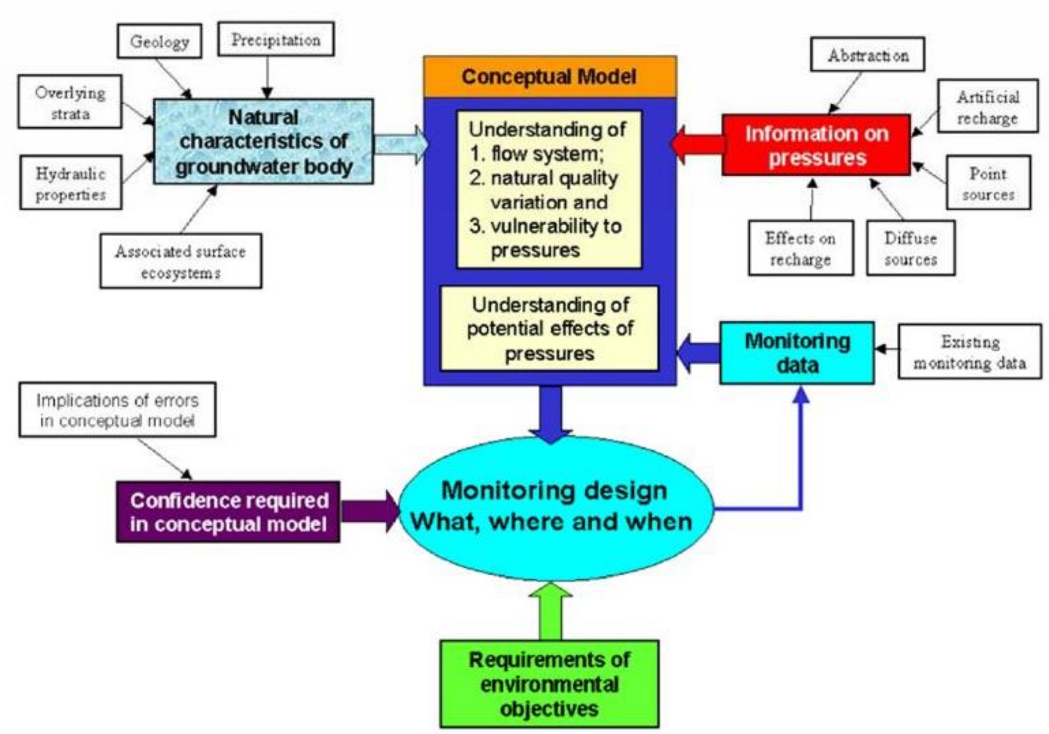

Figure 12. Proposed monitoring frequencies for surveillance monitoring (where understanding of aquifer systems is inadequate) (CIS, 2017)

3.2.2. CIS: Guidance Document No. 18_Guidance on Groundwater Status and Trend Assessment (CIS, 2010)

This mandate required the development of practical guidance and technical specifications for the derivation of threshold values, the assessment of status (both quantitative and chemical), and the assessment of groundwater trends and trend reversal.

Assessment of the chemical status

The GWD establishes a requirement for Member States to derive threshold values for pollutants (or groups of pollutants) that are related to the pressures identified as putting GWB at risk. These threshold values and standards are then to be used to assess groundwater chemical status, as defined in the WFD. In addition to assessing the impacts of pollutants, the WFD also requires consideration of the impacts of groundwater abstraction on GWB, dependent surface water bodies, and ecosystems, and an assessment of quantitative status.

This document provides practical guidance on meeting each of the requirements described above. It:

- sets out a methodology for deriving threshold values;
- establishes frameworks for assessing both chemical and quantitative status;
- identifies a method for identifying environmentally significant trends;
- outlines the reporting requirements;

• provides case study examples to illustrate the application of the guidance in different Member States

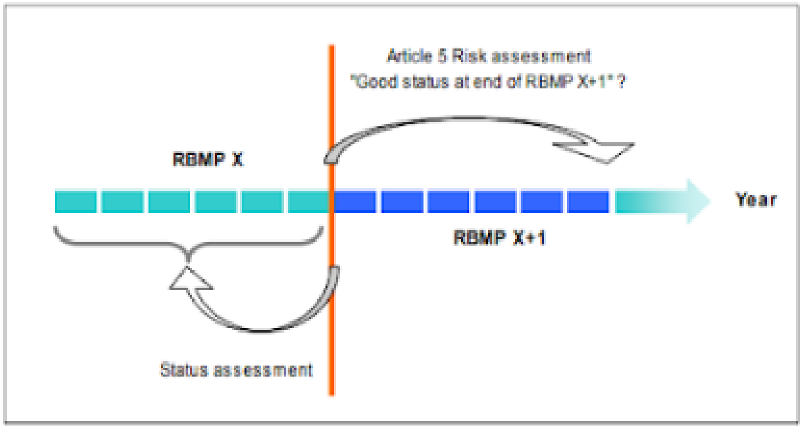

Figure 13. Risk assessment looks into the future whereas status assessment looks back on the performance (CIS, 2010)

4. Case studies

4.1. Croatia

Croatian Waters is the national agency for water management, implementing the Croatian Water Act and the regulations on Water Quality Standards. The Legislation for water management is based on EU Commission WFD and GWD (GWD, 2006) and are supplemented by CIS documents.

Groundwater directive (GWD, 2006):

- establishes a regime that sets quality standards for groundwater and introduces measures to prevent or limit it introduction of pollutants into groundwater.
- establishes quality criteria that considers local characteristics and enables further improvements that would be made on the basis of surveillance data and new scientific data cognitions.
- represents a scientific response to the requirements of the Framework the Water Directive (WFD), as it relates to assessing chemical status of groundwater and the identification and termination of significant and permanent upward trends in concentrations of pollutants.

The state of water is determined at the level of water bodies, which represent the basic units for analysis and management of the water state. Determining water bodies begins with the analysis of the natural characteristics of water, based on which the totality of water in an area is divided into clearly defined, naturally approximately homogeneous elements. Hydraulic demarcation and demarcation based on the natural chemical composition of groundwater are used to separate GWB (if necessary, groundwater typification according to natural geochemical features).

GWB are made for the purpose of assessing the risk of not achieving the goals in three dimensions (width, length, and height). It has to be singled out in a way that it belongs to some water area. In Croatia, there are two basins: Adriatic and the Black Sea basin.

Vulnerability and risk assessments are carried out after grouping the water bodies, which is followed by proposals for operational and supervisory monitoring.

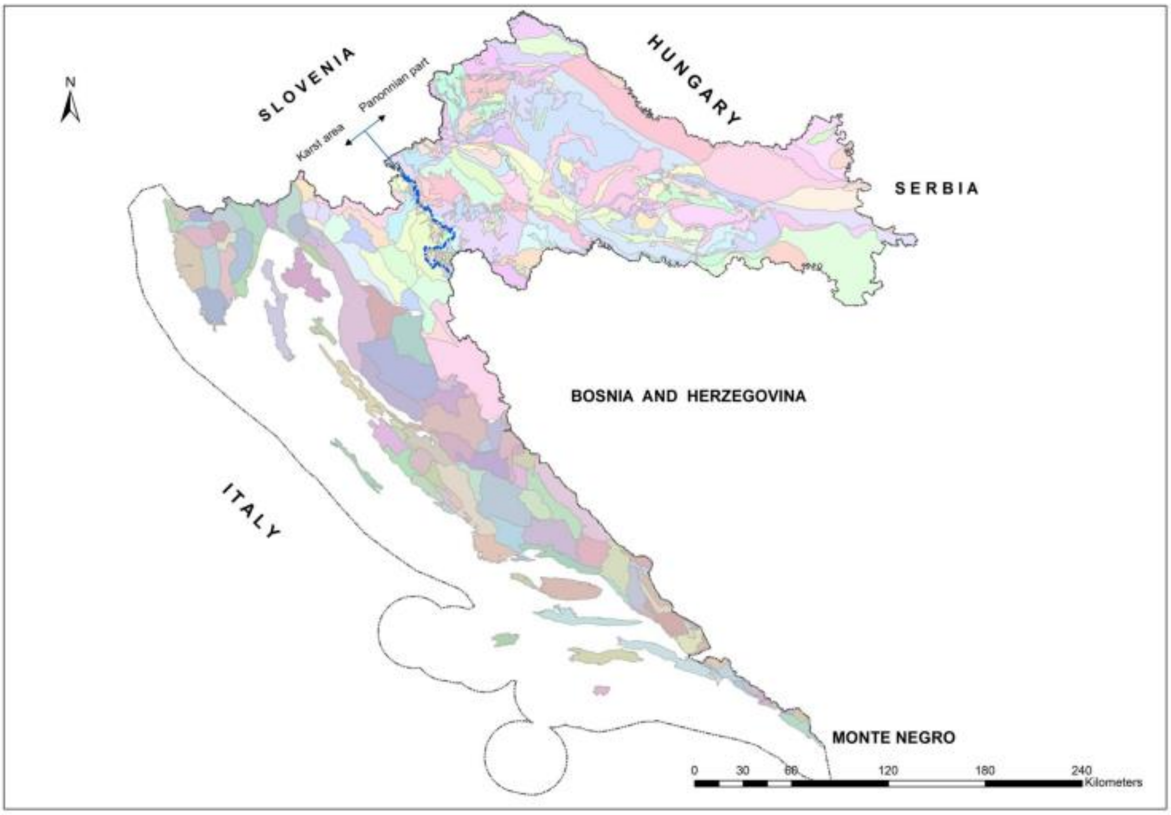

Figure 14. GWB in Croatia (Brkić & Larva, 2011)

The spatial scale of the groundwater monitoring network in Croatia is national and is carried out for the assessment of groundwater quantity (groundwater levels in aquifers with intergranular porosity) and discharge of main springs (in karstic areas), as well as groundwater quality for the assessment of the status of GWB for the preparation of river basin management plans.

Data is collected both manually and automatically (using a data logger and automatic transmission). Automatic stations (data loggers) measure levels every day, and manual stations provide readings twice per week. The groundwater quantity monitoring network has 528 stations. The objective of the national groundwater monitoring network of Croatia is to provide data to estimate the long-term state and trends of groundwater in the country and provide input for the national water policy planning, regulatory agencies, and the public. Data is used to perform time series analysis, statistical analysis, and modeling. The groundwater observations are available for governmental institutions and upon request. Additionally, all data are reported to the Water Information System Europe (WISE). (IGRAC, 2020)

Based on young professionals' perspective groundwater contamination is not monitored sufficiently. As it can be seen in Table 3 and Figure 13, the EU Commission Voluntary

Groundwater Watch List (CIS, 2019) is based on voluntary research of the member states and analysis of only a few (less than 30) substances in groundwater, but from the youth perspective should be obligatory due to the risk posed by emerging contaminants. Emerging contaminants as well as organic contaminants are dangerous for the environment and human health, so they need to be under monitoring and the maximum allowed concentrations need to be defined.

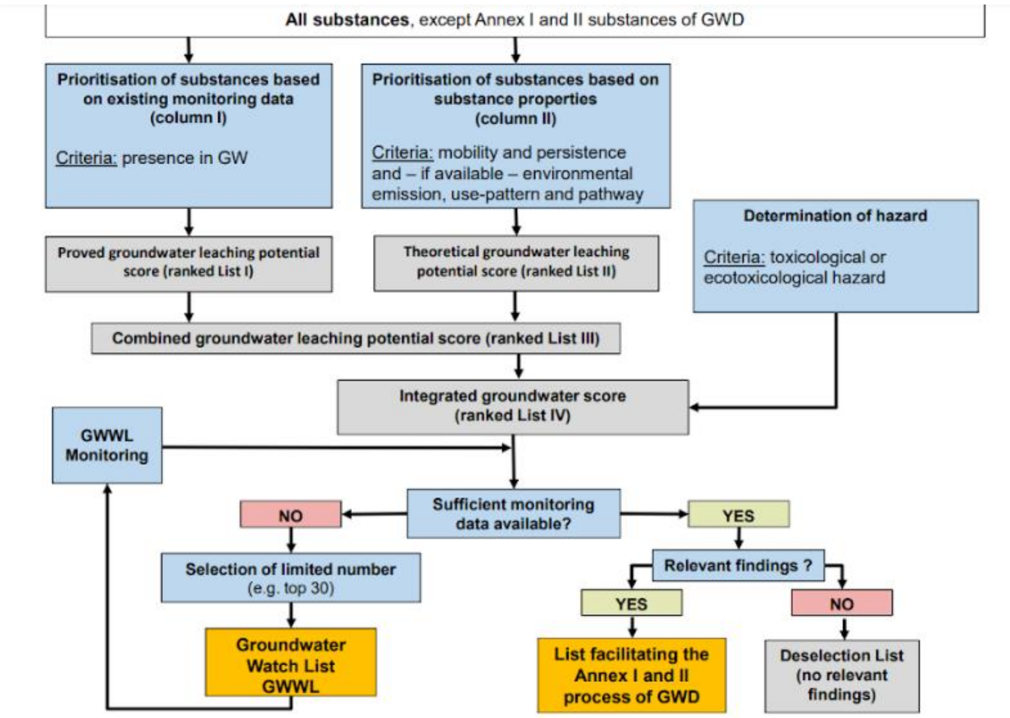

Figure 15. Watch List Concept (EU) (CIS, 2019)

Table 2. Examples of substances listed in the Groundwater watch list (CIS, 2019) (non-exhaustive)

Substance Name	CAS[1] #
Perfluorododecanoic Acid (L)	307-55-1
Perfluoroundecanoic Acid (L)	2058-94-8
Clopidol	2971-90-6
Crotamiton	483-63-6
Amidotrizoic Acid	117-96-4
Sulfadiazin	68-35-9
Primidone	125-33-7
Sotalol	3930-20-9
Ibuprofen	15687-27-1
Erythromycin	114-07-8
Clarithromycin	81103-11-9

[1] CAS Number is a unique identifier for a specific substance that allows clear communication and, with the help of CAS scientists, links together all available data and research about that substance. Governmental agencies rely on CAS Registry Numbers for substance identification in regulatory applications because they are unique, easy validated, and internationally recognized (https://www.cas.org).

4.2. Germany

In Germany, federal states are responsible for the monitoring of groundwater. The best practice example is given in the current IGRAC report from the federal state of Bavaria. Here, a compilation of three networks is built, containing a basic network, a compaction network, and a regional network. In the basic network, regular water level monitoring is conducted with level loggers, which usually transfer data remotely and measure groundwater levels regularly. The remaining two networks cover monitoring only in limited time periods. A low water information service was established in Bavaria, which provides water level information for selected sites to the public. This information covers daily groundwater classification for shallow and deeper aquifers (IGRAC, 2020). No information is given on how the amount of groundwater recharge is determined. An example from the federal state Bavaria is shown in Table 3.

Table 3. Some information on groundwater monitoring in Germany

Groundwater Monitoring	State geological surveys
Best practice example -> prepare against dry periods	LfU Bavaria
Basic network	620 sites (remote data transmission) many loggers (continuous recording)
Compaction NW	341 sites (completes basic NW, limited period)
Regional NW	2063 sites (limited period) NW for 110 springs
Data availability	only for water level
Classification of wells	low, very low, etc.

Besides the individual monitoring networks of the federal states, federal states also operate two national networks for monitoring nitrate and for delivering data for the report for the European Environment Agency (EEA). This network covers around 800 sites. States provide the results to the German environment agency to EEA to display an overview of the groundwater status in the EU. The network for Nitrate includes 180 sites where the concentration of nitrate is measured 2-4 times per year. Germany provided data from 13270 monitoring sites to the EU commission which delivers information on groundwater quantity. In a report from 2007, only 5 % of GWB in Germany are classified as endangered regarding their quantity. In a current report it is stated that 4.8 % of GWB are classified as "bad condition" (see figure), which constitutes a deterioration from the percentage of 4.3 % reported in 2015. The reasons for bad conditions are mainly caused by seawater intrusion and water table drawdown for mining, as explained in both 2015 and 2021 (UBA, 2015 and 2021). A GWB is classified as in “good condition” regarding the quantity when the extracted amount of groundwater does not surmount the natural groundwater recharge. However, groundwater recharge is estimated based on different methods in Germany. In Germany, the amount of groundwater recharge is determined through water balance on a nationwide basis, in smaller areas other approaches are applied like empirical methods or models.

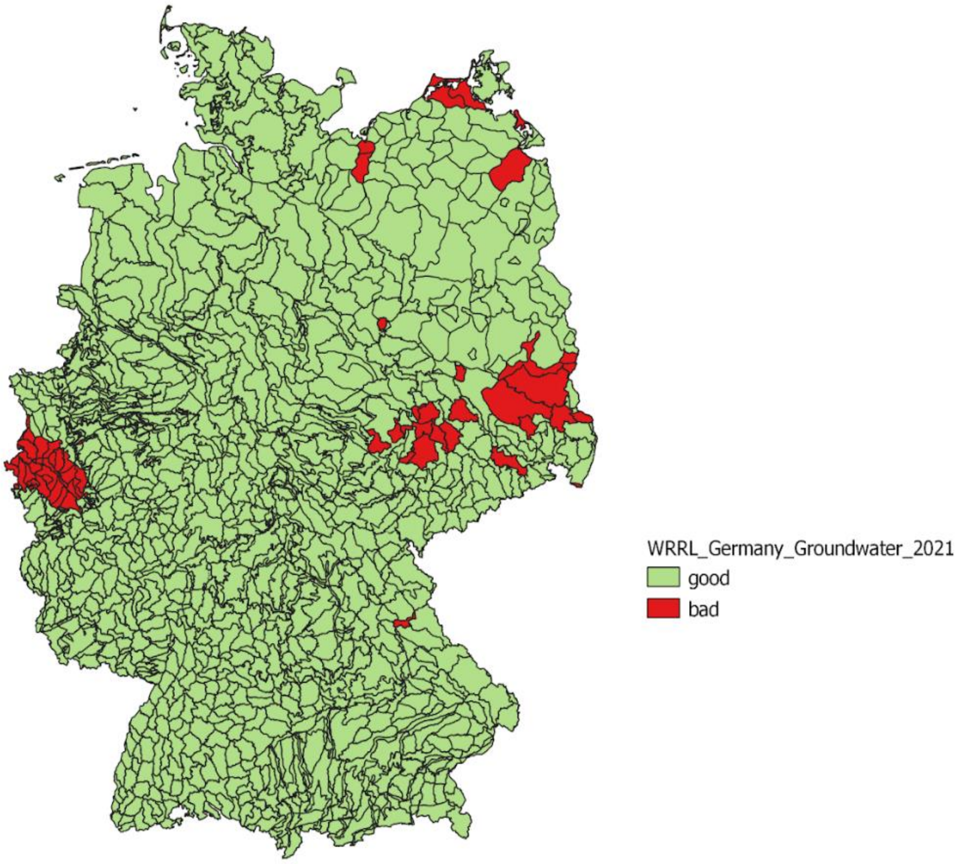

Figure 16. Map showing the status of groundwater in Germany regarding quantity (WasserBlIcK BfG, 2022)

Regarding the chemical condition of groundwater, German legal requirements are based on the EU directive (GWD and WFD), which means the Environmental quality norms for nitrate and pesticides are monitored. Furthermore, a list including minimal thresholds for arsenic, cadmium, lead, mercury, ammonium chloride, nitrite, ortho-phosphate, sulfate, the sum of tri-and tetrachloroethene also based on EU law is established. In addition to the EU law, a working group of German federal states developed a list of 'significance thresholds' of pollutants. The thresholds define a concentration, at which no relevant ecotoxicological effect will occur, even if the amount of the substance increases, and the requirements as a source for drinking water can be met. This is to guarantee that groundwater can be used as drinking water and provides a safe ecosystem. The determination of the threshold is based on human- and ecotoxicological data. The list includes inorganic and organic parameters, pesticides, and biocides along with their degradation products, tin organic compounds, and explosive material compounds.

4.3. Italy

Italy, as a European Union member, complies with the Water Framework Directive (2000/60/EC) and to the subsequent GFD (2006/118/EC). They were transposed in 2006 (Decreto Legislativo 3 April 2006, n. 152) and 2009 (Decreto Legislativo 30/2009), respectively.

The GFD institutes specific measures to prevent pollution and quantitative degradation of groundwater resources. Its goals are to reach a "good" state for all groundwater basins, both qualitative and quantitative, to define water quality standards and threshold values for pollutants, and to define the monitoring programs of both quantitative and qualitative conditions. Italy also introduced a cognitive phase in which the "hydrogeological model" of the water body must be reconstructed, considering possible intercommunication between the different aquifers, surface waters, and ground waters (Decreto Ministeriale n. 260/2010).

Following the EU's Water Framework Directive, Italy is divided into seven River Basin Districts (RBD), *Distretti Idrografic*i in Italian, which gather several hydrological basins and their respective groundwater basins and coastal water. Each district writes its own management plan, with instructions on monitoring and other issues, relative to their respective area of management. So, there is no national-level plan for monitoring. There are, however, national guidelines to perform the monitoring.

Figure 17. River Bodies District division in Italy (ISPRA, 2017)

ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale), the national environmental authority, produced in 2017 an extensive guideline (Percopo et al, 2017) containing technical criteria on monitoring and analysis of GWB. The goal was to standardize the methodologies, analysis criteria, and monitoring network design across the country, as each Italian region has a regional authority monitoring groundwater among other environmental sectors (Agenzia Regionale per la Protezione Ambientale or ARPA) (ARPA, 2021). Each of these has its own groundwater monitoring network in its own region. For example, ARPA Lombardy has 421 monitoring points across the region monitoring groundwater quantity and 500 monitoring different parameters for groundwater quality. Usually, these authorities are the ones performing the monitoring activities for the River Basin Districts, if they don't have their own monitoring network. Data collection is still mainly performed manually, with frequency ranging from monthly to twice a year. Few continuous data collectors are operative relative to the complete set of monitoring points. Each regional authority provides the data to ISPRA which collects them and produces national reports and analyses. In 2019, ISPRA's national report on groundwater quality status in the country was performed thanks to roughly 3800 monitoring stations. Other authorities may possess a complementary groundwater monitoring network, such as irrigation consortia, and public or public-private companies which manage water distribution. Individual municipalities may have their own monitoring networks as well.

Data availability for the public is the main issue. Public authorities rarely share their raw or cleaned data with the public. Reports are not disseminated regularly but only annually and usually at the national level, lacking more detailed information. There is a lack of communication between "same level" authorities (e.g., ARPA of different regions, irrigation consortia, and ARPA). Data is hardly shared and joint planning on interregional groundwater basins is largely non-existent. Data on water extraction from privates is not reliable. Sometimes a database collecting this information does not exist. Non-uniformity in the collection of quality parameters. Not all quality parameters are collected in all the regions and collection of quantity parameters are non-uniform. Monitoring frequencies and database structures also vary across authorities.

4.4. Slovenia

Slovenia is an EU member, so it has to follow the Water Framework Directive (WFD) guidelines (WFD, 2000) and CIS guides. Implementation of WFD resonated in the Waters Act (WA) which defines rules for the management of waters (both surface and subsurface) for the protection of waters, sustainable use of waters, good management of water use facilities, and other water-related questions. With WA there are defined measures within the Program of Measures that are formulated every 6 years by the government. Also, there is the Decree on groundwater status and the Decree on the protection of waters against pollution caused by nitrates from agricultural sources. The decree on groundwater status was transposed from the EU Groundwater Directive with the aim to define procedures for determining groundwater quality, standards of quality, and corresponding threshold values, but also other demands concerning the preparation of groundwater protection action plans, etc. For any given GWB, an investigation of pollution was executed, and bodies with good chemical status were determined. Bodies that were not recognized as such are considered vulnerable,a program of measures has to be formed with an aim to prevent further pollution and restore the body to a good chemical state. Rules on determining groundwater bodies define a water body based on aquifer location, groundwater movement, groundwater quality, and human activity above the water body (Curk & Glavan, 2019).

In Slovenia groundwater is the largest source of drinking water (98% of drinking water comes from groundwater), so EU drinking water directive values apply to all groundwater, that are still under threat., mainly in shallow-soil alluvial plains, risk of nitrate pollution due to the agricultural activities is high (Curk & Glavan, 2019).

Regulation on operational monitoring of groundwater status, based on the provisions of the Slovenian Environmental Protection Act, in order to determine the impact of landfilling in accordance with Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, and to determine the impact of the operation of installations in accordance with Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), sets rules and indications on operational monitoring of groundwater status, including related methodology of sampling, measurement, and analysis of samples, evaluation of analyzes and impact, the content of indicated program and report, method and form of recording and reporting data on operational monitoring of groundwater status. This text further determines all technical conditions that must be met by the operator of groundwater monitoring for obtaining authorization for operational monitoring of groundwater, and more detailed reasons for revoking the authorization for operational monitoring of groundwater. The Annex is part of this publication (containing the basis for determining the program of operational monitoring of groundwater status).

Slovenian Environment Agency performs expert, analytical, regulatory, and administrative tasks related to the environment at the national level. The Environment Agency is a body of the Ministry of Environment and Spatial Planning. Its mission is to monitor, analyze and forecast natural phenomena and processes in the environment, and to reduce natural threats to people and property. The following tasks are performed by the national services for meteorology, hydrology, and seismology:

- preserving natural resources, biodiversity, and sustainable development;
- observing, analyzing, and forecasting natural phenomena and processes in the environment;
- reducing the impact of natural hazards;
- ensuring legal protection and professional assistance to participants in environmental encroachment procedures;
- funding change of national and personal values system in relation to the environment as well as influencing the value criteria for environmental encroachments;
- ensuring high-quality environmental data for all target groups;
- raising the awareness of people and institutions about the environment and environmental issues.

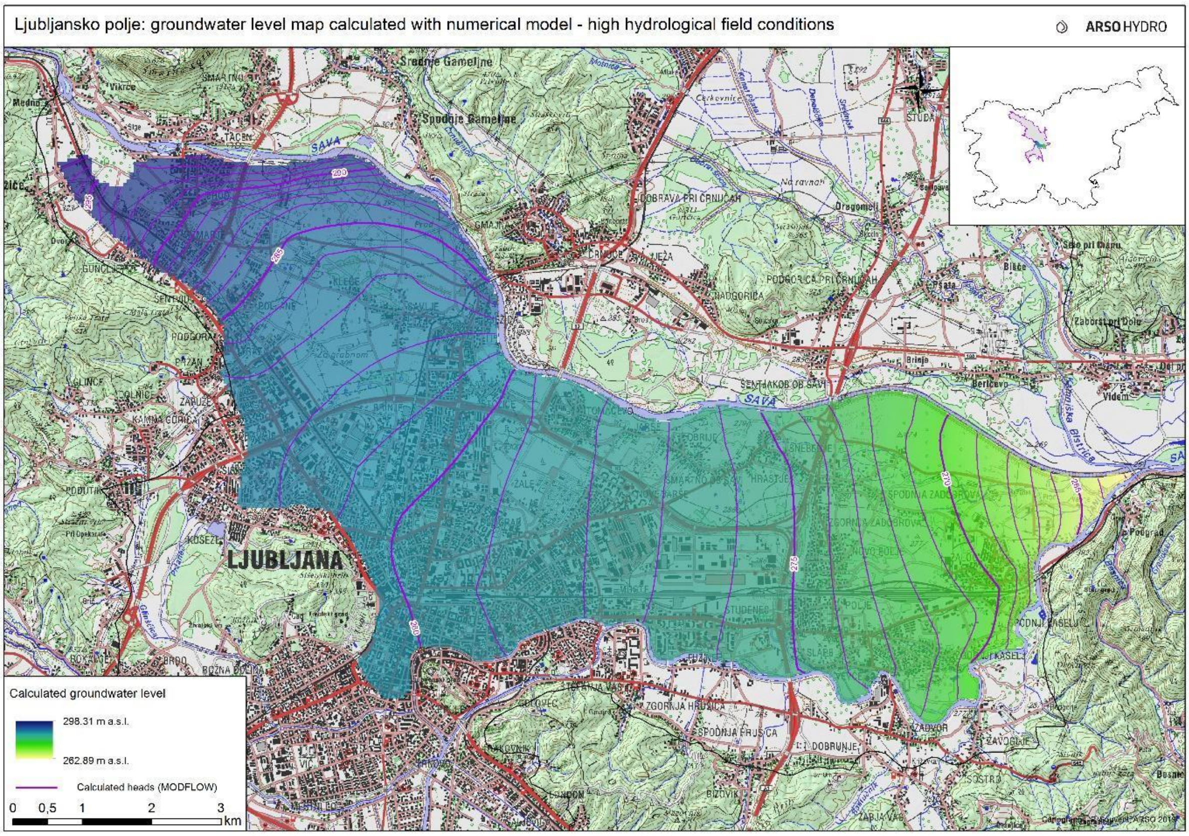

Figure 18. Groundwater level map (METEO SI, 2023)

4.5. Spain

Spain is an EU member state and has to implement EU regulations, i.e., the Water Framework Directive (WFD, approved in 2000; EU, 2000). Following the WFD requirements, the new River Basin Management Plan (RBMP) states that at the end of the last planning cycle (2027) about 80% of the Spanish GWB will meet the objective of good status, while less stringent objectives have been set in 4% of the GWBs (De Stefano et al., 2015). In the remaining GWBs available data are insufficient to predict their status by 2027. Pollution, mainly by nitrates, is the main cause of non-compliance with good status objectives and the establishment of less stringent objectives (De Stefano et al., 2015).

Groundwater use in Spain has significant socio-economic importance, both as a factor of production in agriculture and industry and as a source of drinking water for over 12 million people (almost one-third of the total population).

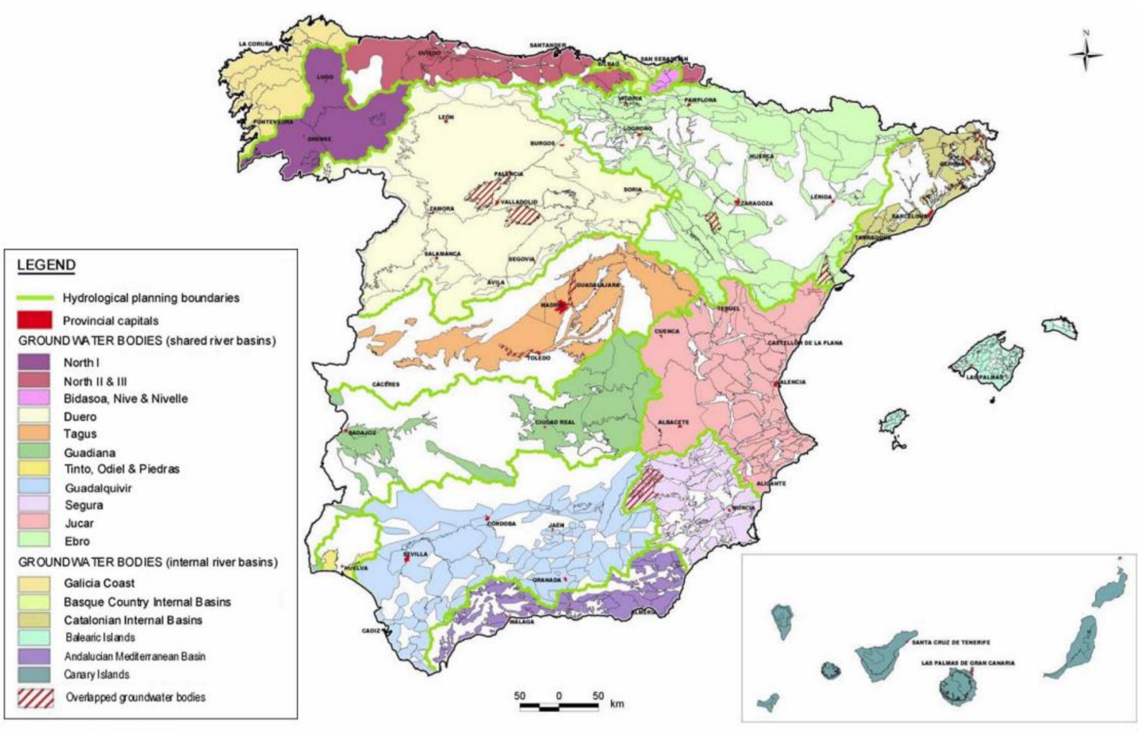

Figure 19. GWB in Spain (EASAC, 2015)

Spain has implemented a national information system called SINAC, which collects information on the quality of water for human consumption and information on the characteristics of the infrastructures of the supply areas. The data collected in this system offer information on drinking water corresponding to 84.2 % of the population registered in Spain. Data is collected not only for the urban areas (over 5,000 inhabitants) but also about the quality of drinking water in the rural population (less than 5,000 inhabitants) SINAC have currently more than 78 million data.

Approximately 75 % of groundwater abstracted in Spain is used for irrigation. Groundwater irrigates around one million hectares, about 30 % of the total irrigated area, although frequently both surface and groundwater sources are used conjunctively to irrigate crops. The Ministry for Ecological Transition and Demographic Challenge is in charge of groundwater monitoring in Spain.

4.6. India

India is a federation with a parliamentary system, which consists of 29 states, which are subdivided into districts and blocks, and 8 Union territories (UT). Since India is one of the major users of groundwater in the world, India has country-level and state-level groundwater governing bodies.

At the country level, the central government is the Ministry of Jal Shakti, the main wing that is responsible for groundwater management. The Ministry of Jal Shakti includes the Department of Water Resources, River Development and Ganga Rejuvenation, Department of Drinking Water and Sanitation. National Mission for Clean Ganga (NMCG), Central Water Commission (CWC), Central Groundwater Board (CGWB), National Water Development Agency (NWDA), National River Conservation Directorate (NRCD), and Brahmaputra Board are some of the attached subordinates under Department of Water Resources, River development, and Ganga Rejuvenation. Of these, Central Groundwater Board (CGWB) is solely for sustainable development and management of groundwater resources of the country.

The CGWB is in charge with the task of contributing scientific understanding to the management, exploration, monitoring, assessment, augmentation, and regulation of the nation's groundwater resources. Blockwide groundwater resource assessment data (2020), dynamic groundwater resources of India (2022), water quantity and quality maps (Figure 17), and water quality reports were constructed from the data obtained.

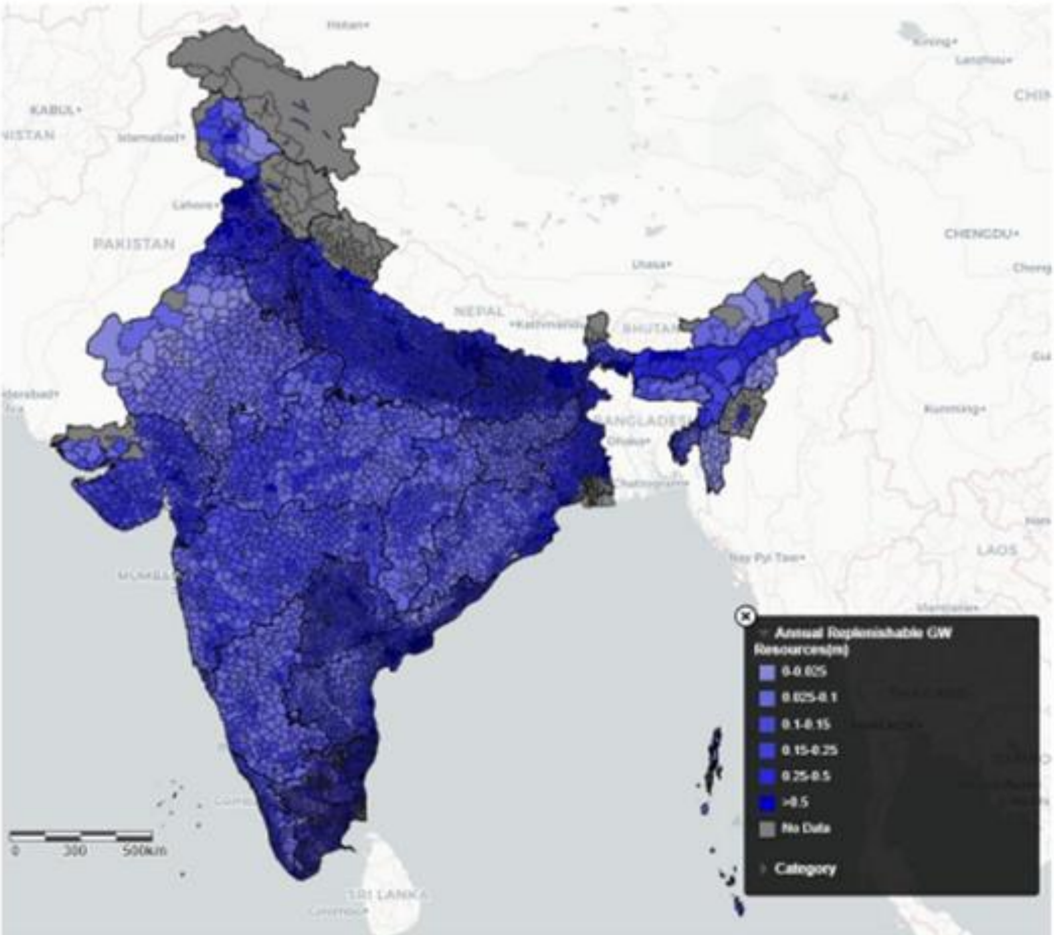

Figure 20. Spatial variation in annual groundwater recharge (CGWB, 2022)

Not only at the country level, but the state government also has its own departments to work on groundwater management. These state/UT groundwater departments have close cooperation with the corresponding CGWB field offices. A database was created to put together the entire datum available, a web-enabled water resource information system called India-WRIS funded by Central Water Commission (CWC). They have yearly and monthly based rainfall and groundwater level data, groundwater quality data in the form of maps and graphs. The data and information gathered help to assist the Indian government in developing policies and prioritizing areas for management interventions.

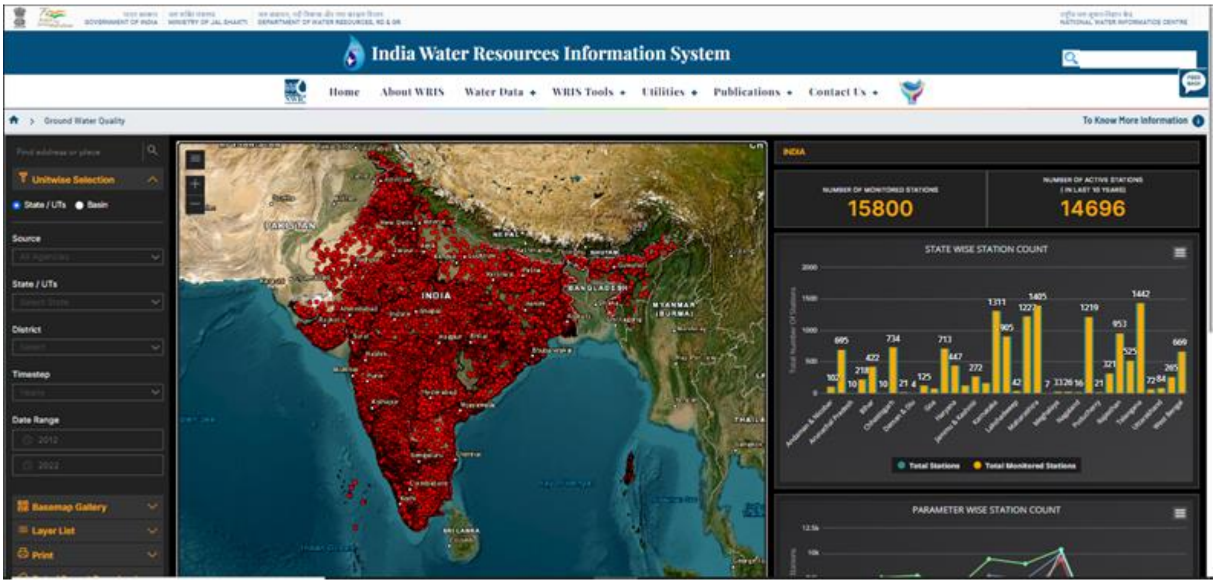

Figure 21. Database of water quality monitoring data in India (INDIA WRIS, 2023)

4.7. Jordan

The Ministry of Water and Irrigation (MWI) is in charge of the national groundwater monitoring network objective of the network: provide data on the long-term state and trends of groundwater. In Jordan, there are 252 monitoring wells: groundwater levels, groundwater quality parameters (EC, pH, temperature), and data collection with manual and automatic methods (data loggers, automatic transmission) (IGRAC, 2020).

Project to check the amount of groundwater available, monitoring and managing of groundwater resources through the Ministry of Water and Irrigation. The increasing water need in Jordan is mainly covered by groundwater resources (70 %). The increase is caused by higher irrigation and a higher population. Most of the used groundwater is fossil-based, hence the recharge rate is shallow.

Also, groundwater quality is decreasing due to higher application of fertilizers caused by intensified agriculture, excessive extraction, insufficient treatment of industrial and agricultural waste, and insufficient domestic wastewater treatment.

Due to these trends, the goal is to improve the monitoring in general and conduct more regular monitoring of groundwater. Cooperation between the Ministry of Water and Irrigation (MWI) and water suppliers shall lead to joint monitoring of the groundwater resources. In the future, water suppliers will assess the power of wells and the protection of water resources. In the long term, MWI and the water authority of Jordan pursue the goal of countrywide, systematic monitoring of groundwater quality to guarantee high groundwater quality. Laboratories are included in the planning and conducting of quality monitoring.

5. Conclusion

Monitoring of groundwater quality and quantity is essential in order to keep good condition of this valuable resource and its related ecosystems. Research on the current state of groundwater monitoring regulations and practices all over the world shows the urge for better protection of drinking water sources due to contamination with non-organic and organic pollutants.

Key to a better future in every aspect of environmental management is teaching the youth about problems and possible solutions, and in frame of the water management such practice is necessary for preserving groundwater in good quality and quantity. Due to technological progress young professionals in various countries are more connected throughout the world which can affect faster knowledge and experience sharing. This also can foster a faster decision-making approach, as well as faster reaction to implement decision into actions. Still, it should be considered, that many countries lack of internet connection and energy supplies, which creates a larger drawback for them. Solutions for this must also be part of the developing process in the water sector.

This report showed the youths' point of views on groundwater monitoring in multiple countries and their suggestions for better implementation of monitoring and/or regulations as detailed in Annex 1.

This report's results show that youth are not involved enough in groundwater monitoring-related issues. This presents an incentive to promote networks such as GWYN with the aim of involving more young professionals in groundwater management and, ultimately, in creating and implementing groundwater monitoring regulations.

Annex A

List of countries of respondents

COUNTRY
1. Algeria
2. Argentina
3. Australia
4. Bangladesh
5. Benin
6. Cameroon
7. Canada
8. Colombia
9. Croatia
10. Democratic Republic of Congo
11. Ethiopia
12. France
13. Germany
14. Guatemala
15. India
16. Italy
17. Japan
18. Jordan
19. Kenya
20. Latvia
21. Liberia
22. Mexico
23. Montenegro
24. Nepal
25. Nigeria
26. Pakistan
27. Sierra Leone
28. Somalia
29. Spain
30. Sri Lanka
31. Tunisia
32. Uganda
33. United Kingdom
34. Vietnam
35. Zimbabwe

Annex B

YOUTH SUGGESTIONS TO IMPROVE GROUNDWATER MONITORING IN THEIR COUNTRY

Summary of Similar Ideas:

1. There is a need for more comprehensive and accessible groundwater data, including better data sharing and data availability in various countries.

2. Groundwater quality and recharge should be prioritized for sustainable management.

3. Improved data collection and processing techniques are essential for both quantity and quality monitoring.

4. Increased youth involvement and capacity development are crucial for groundwater monitoring.

5. There is a call for integrated management of groundwater and surface water features.

6. Community-based, participatory groundwater management is seen as a valuable approach.

7. Raising awareness about the importance of groundwater and its sustainable use is essential.

8. The importance of implementing policies and regulations for groundwater protection and management is emphasized.

9. Stronger government support, funding, and a well-structured monitoring network are needed.

10. A shift from centralized to localized monitoring and open-access databases is suggested.

11. Suggestions for regular, village-based, and real-time groundwater monitoring systems.

12. Collaboration between governments, experts, and young people to improve water monitoring.

13. Involvement of hydrogeologists and regulators in groundwater monitoring programs.

14. The implementation of integrated water resources management (IWRM) to minimize conflicts and enhance coordination.

15. Addressing the issue of water abstraction and discharge permits, including the adoption of real-time monitoring systems.

16. Preservation and efficient use of water resources in the face of climate change and limited resources.

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