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Availability and significance of data for the development of a geodatabase on the water physicochemical quality: the example of the Moroccan groundwaters

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ABSTRACT
Water resources are relatively limited in Morocco, as well as in other South-Mediterranean countries, mainly because of the aridity of their climate, marked by recurrent droughts. On the other hand, the water needs are continuously growing and the main solutions adopted during the last 60 years to cover these needs were damming and groundwater pumping, and it is recently that the public departments resorted to the use of treated wastewaters. This water scarcity was progressively amplified by pollutions that reduce the availability of good quality waters. Indeed, the population increase led to an exponential and concomitant expansion of urban, industrial and agricultural activities, which pollute both surface and underground waters, making their use as a big challenge for public sectors. Therefore, both surface and underground waters need, today more than ever, to be sustainably managed. In this context, new diagnostics and syntheses are necessary, but the best way to tackle this challenge should be long-term surveys of the water quality. That means a crucial need to performant information system on this topic, covering the whole country and designed in the context of a decision-making mechanism, both strategic and operational. This work aims to verify the feasibility of such information system, using the example of the groundwater physicochemical parameters. A database has been designed and filled with a high proportion of available physicochemical data, proving that this database is technically feasible. The first synthesis attempts of these data with classical models revealed that they are relatively well adapted to the database structure. However, different obstacles prevent getting significant results. They are mainly due to imprecision and heterogeneity of the data format and the methods used. These obstacles were partly lifted by transforming and completing information, but many existing data will remain unexploited or with weak significance, particularly in spatiotemporal analyses. In addition, this study aims to suggest some standard methods for developing a monitoring that could be qualified as national.

Keywords: Groundwater, Morocco, Physicochemical parameters, Water quality database.

INTRODUCTION
As a South-Mediterranean country, Morocco has a relatively arid climate, with hot and dry summer and high rate of evaporation (Sinan 2001; Sinan & Jalil 2004). Despite this aridity, this country is known as a big reservoir of aquatic biodiversity (Dakki *et al.* 1997). Indeed, Half of its area is occupied by high mountains, which generate adense hydrographic network, besides high plateaus and vast lowland plains (Michard 1976), which have given

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rise to numerous and diverse lacustrine ecosystems (Dakki & Al Agbani 1995). The long coastline (3,500 km), both on Mediterranean Sea and Atlantic Ocean, increases significantly the wetland diversity of the country: 6 lagoons, 300 estuaries and hundreds of sea beaches and cliffs (Dakki *et al.* 2015). On another hand, underground waters play a major role in maintaining these aquatic ecosystems, while they occupy also a prior place in human development. Indeed, Morocco has built his development mainly on water-dependent activities (agriculture, industry, tourism …) (Bzioui 2004). These led to a rapid increased water consumption, concomitantly with an exponential growth of the population and polluting activities (Agoumi & Debbarh 2006; Bader *et al.* 2015). Consequently, the degradation of both surface and groundwaters quality already exceeded the tolerable thresholds in several areas (El Haiba 1991; El Atmani 1991; Nejmeddine & Yatribi 1997; Bouguenouch *et al.* 2012). This makes the sustainability of water management among the highest strategic priorities of the country (Jellali 1997; Dakki *et al.* 2015) targeting both people and nature, as well as acting on multiple fronts to implement preventive and curative solutions. Any of these solutions should be based on a serious national monitoring of the water quality and its determinant factors that requires a performing database. Some public departments declare having their own water quality databases, but for internal use only and not published. In parallel, many scientific studies are undertaken, and frequently limited to diagnostics of local cases, with rare comparisons with national situations. This article, produced as a result of the feasibility study of a national database on the water quality, is dedicated to the specific case of groundwater. It is also focused on the challenge of significance of the available data in developing a geodatabase.

MATERIAL AND METHODS

Data sources

This study is based on a quasi-exhaustive sample of existing data on physicochemical characteristics of Moroccan groundwater. These data were essentially extracted from published articles, available at the Scientific Institute of Rabat, and from end-of-study memories of PhD and MSc. dissertations, but some of them are in unpublished reports of the Public Water Department. A great effort was made to obtain the university memories, in the sense that some of them were borrowed directly from their own authors or from different universities and high schools, but many doctoral dissertations were found in the national documentary database of the IMIST (Moroccan Institute of Scientific and Technical Information).

This work do certainly not cover all existing data sources, but we estimate that more than 80% of the available documents have been exploited, providing sufficient data to assess the feasibility of an information system on the groundwater quality.

Data organization: designing the water quality database

The database is designed in a way to produce significant outputs on the spatiotemporal variation of the water quality in a defined area. Indeed, the basic information needed for these outputs is the *'value of a physicochemical parameter measured in a waterpoint at a given date/hour'*. These values, stored in a special table, named *'Results'*, are well defined, using several attributes (Fig. 1):

(1) ***Parameter***, precisely defined in a reference table where they all parameters are classified according to a significant scheme, which corresponds in our case to the classification proposed by Rodier (2009);

(2) ***Value*** of the parameter, measured by one or more ***operator***(s), using a given ***method*** (including a standard measuring ***unit***); as these methods (as presented with the results) can vary, even for the same parameter, they were inventoried in a table named 'Methods', which is linked to a standard methods' table;

(3) ***Site*** (waterpoint), defined as a fixed point, with precise coordinates (expressed in the same projection system), type of water, borrowed from a general typology of waters, and depth if the this type is 'underground waters'; other useful attributes can be added (code, name, altitude, location text, description text, etc.); this spatial data allows to qualify the database as geodatabase;

(4) ***Date*** (including hour) of the measure, crucially needed in monitoring programs and in temporal (and spatio-temporal) analyses.

Two other attributes are necessary to ensure credibility and high quality syntheses:

(5) ***Sample***, defined by the couple waterpoint and date, generally; indeed, different parameters can be measured in the same water sample, and if their results are linked by this attribute, they can allow very significant syntheses, mainly spatiotemporal correlations between different parameters.

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(6) ***Data*** source (documents and databases), which is necessary for verifying the data credibility; this attribute means that a special bibliographic database is created and linked to the physicochemical geodatabase.

RESULTS AND DISCUSSION

Technical feasibility of the geodatabase

The present study is limited to the underground waters; the data were extracted from a sample of 198 data sources (documents), considering that these references represent only a part of the studies made on these waters in Morocco. A total of 59 parameters were measured for groundwater in more than 4,361 different sites, through some 8,134 samples (Fig. 2).

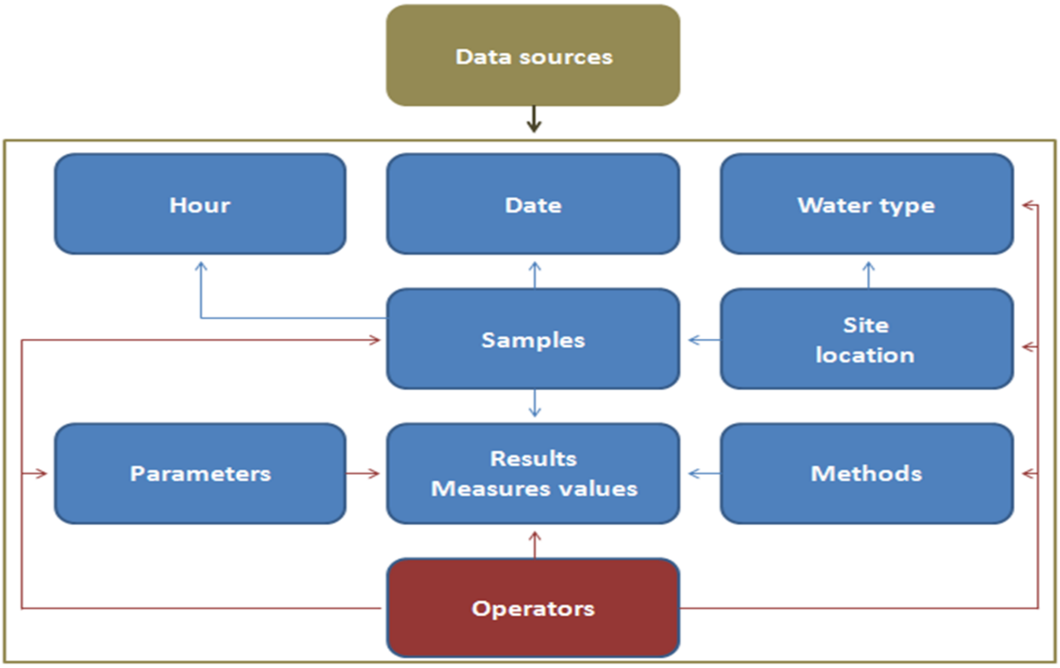

Fig. 1. General structure of the geodatabase on water physicochemical data.

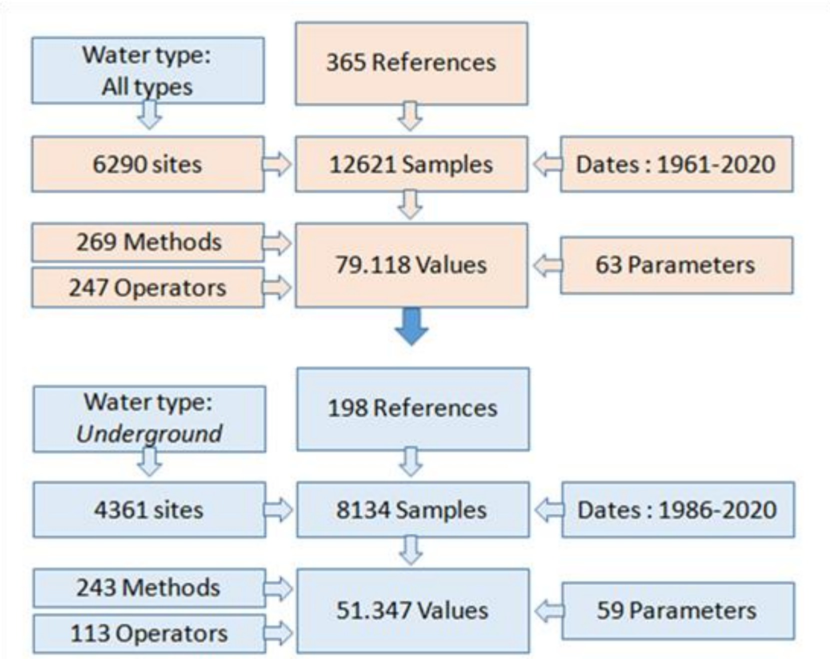

Fig. 2. Flowchart illustrating the extraction of groundwater data from the global database.

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Fig. 2. It was possible to insert the high majority of the existing data into the designed system. Therefore, the geodatabase is technically feasible, in the sense that most of the data are in a format that can be directly used or slightly adapted to the database structure. However, some data are not adapted to the designed attributes, as data with ambiguous date (e.g. data in average format, covering different dates or samples) site location (use of unknown locality name or imprecise coordinates). Therefore, these gaps, which will be more discussed below, do not prevent the establishment of this database. Nevertheless, we should admit that the lack of some significant information in the database will play against expected significant syntheses, as spatiotemporal.

Data efficiency: brief analysis through major examples

Space and time location of water samples

Site location frequently imprecise

Given the rapid spatial variability of the physicochemical characteristics of the groundwater, the location should be highly precise in a geodatabase. Unfortunately, the site coordinates are frequently approximate or absent, making the site location partly usable in spatial analyses and its related data as lost (Fig. 3). Indeed, in old studies, most of the coordinates are in 'degree-minutes' (DM), corresponding to a large area that can cover different underground units. Some authors provide the site location as polygons or points drawn on low scale maps, while in other studies, the site is identified by a vague name, with eventual location related to a large space unit, as agglomeration (city, village) or toponym or water table, making it difficult or doubtful its exact positioning on a map.

A great effort has been invested to find the exact site coordinates, sometimes using our personal field knowledge or by asking the authors themselves. Despite this effort, about the third (1984 water point) of the location data remains unusable in high precision spatial analyses. However, the data related to these cases are kept in the database for other kind of syntheses.

The coordinates' format adopted in the database is Decimal Degree (DD), generally confirmed using available satellite images, in Google Earth as well as in ESRI base maps. Thus, all coordinates provided in other formats, mainly Lambert or 'degrees-minutes-seconds' (DMN), are transformed (thanks to different tools) to DD format (Fig. 3).

On another hand, in many studies of groundwater, the sampling depth is not mentioned; this gap is important, because it's very rare to find throughout the country an area with one only water table.

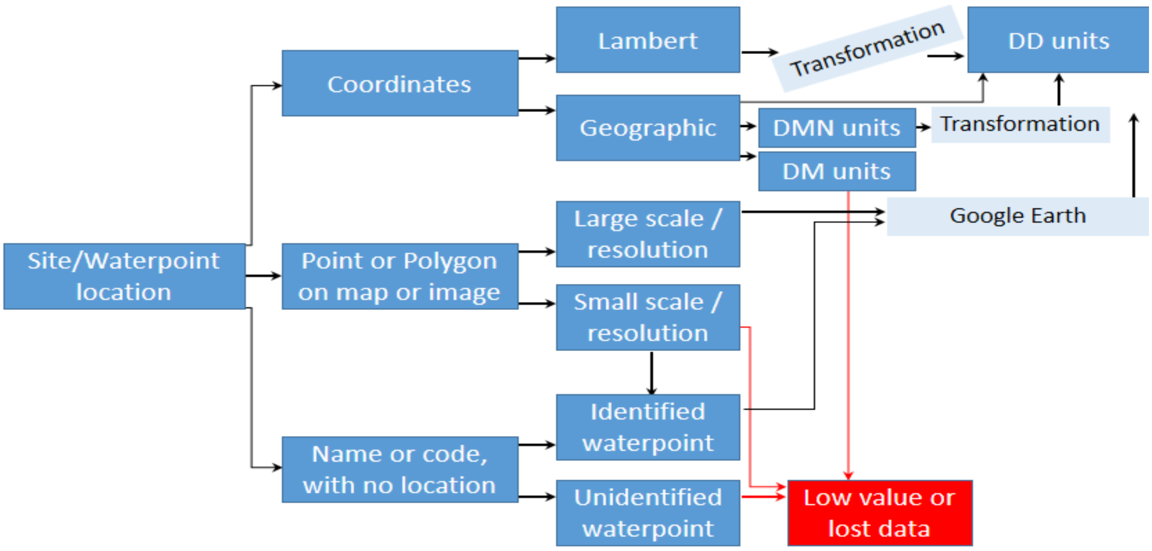

Fig. 3. Different methods used for sites location.

Lack of sampling dates

The sampling date is considered as a structuring data in the information system, mainly for spatiotemporal syntheses, knowing that depollution and restoration initiatives are becoming numerous throughout the country. Nevertheless, some studies provide results with imprecise sample's date (e.g. Month and Year) and even without date in rare cases. This makes all the results related to such sample unusable in chronological analyses. We admit, but in limited cases, that the physicochemical characteristics of deep-water tables undergo relatively low

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seasonal variation, compared to the surface waters; however, the sampling date remains crucial for long time trend analyses of pollution or climate change effects.

Space and time variability hided by averaging

In several studies, the authors decide that in a same site they measure parameters in several samples, e.g. in different places and/or at different times (even different dates), but they provide only average values of the results. This averaging approach could hide important intra-site variability in large heterogeneous and low depth water tables, mainly when this variability concern some structuring hydrogeological factors. However this approach remains acceptable for small sites, as wells, springs and river underflow, but it should be carefully used for long time series measurements.

Data redundancy

In some documents, the results are borrowed from former published studies; when this redundancy is detected, we include only original data, which are identified using the sampling date. All further studies are included in the database without recording their redundant results, but they may contain useful commentaries about the results.

Measurement values hidden in graphs

To be authentic, the result of a measurement should be provided in numeric format. However, in some studies, the authors give only graphs, from which it is often difficult to deduce precise values. Other studies (e.g. in preliminary water quality diagnostics or in ecological macro-distribution studies) adopt voluntarily a low precision level in the measurements; they generally use light field equipment that allows rapid measurement, but their data should be used with caution, mainly in drinking water assessment.

Lack of information on measurement methods

Methods of sampling and measuring parameters permit to assess the credibility of the data. Nevertheless, only 43% of studies indicate all the methods used, while 28.1% mentioned only a part of the parameters, and 28.5% (both in scientific works and in unpublished reports) give no indication on the methods.

However, when provided, the methods are referred to some standards, generally AFNOR (Fawzi *et al.* 2001), Moroccan standards (Benabbi *et al.* 2016). But more frequently the authors refer to analytical catalogs: Rodier (Mehanned *et al.* 2014), Aminot *&* Chaussepied (Chafik *et al.* 2001), and provide sometimes more precisions on the techniques and equipment used.

The problem that arises when there is no precision of the measurement method and that it is only a standard such as Rodier or AFNOR is mensionné is that for the measurement of a single parameter, we can have several methods, for example in the case of measuring nitrates on Rodier 2009 we find four methods that are; molecular absorption spectrometry method, cadmium reduction method, continuous flow method (CFA method) and ion chromatography method.

Parameters disproportionally studied

The occurrence frequency of the parameters measurements is highly variable, meaning that their representability in the database cannot reflect their real distribution at the national level. Indeed, this frequency is closely dependent on the choices made by authors, and also generally dependent on the specific objectives of the studies and on the availability of sampling or measuring materials (Fig. 4).

CONCLUSION

The need of a database can be justified by its objectives and by the pertinence of its expected results and services. Indeed, this water quality geodatabase was designed with two main objectives: (1) making available the existing data on the water physicochemical components, which could be extracted using specific filters (parameter, site, date, etc) and exploited for diverse purposes (water assessment, water use, research, etc); (2) allowing syntheses that can reveal significant models or pertinent maps and factors that can help in interpreting the groundwater quality (space, time, combination of parameters, etc).

The expected results could be useful in different domains (urban water supply, water use in agriculture or industry, pollution assessment, water treatment, etc.). Some public sectors (as Environment and Water

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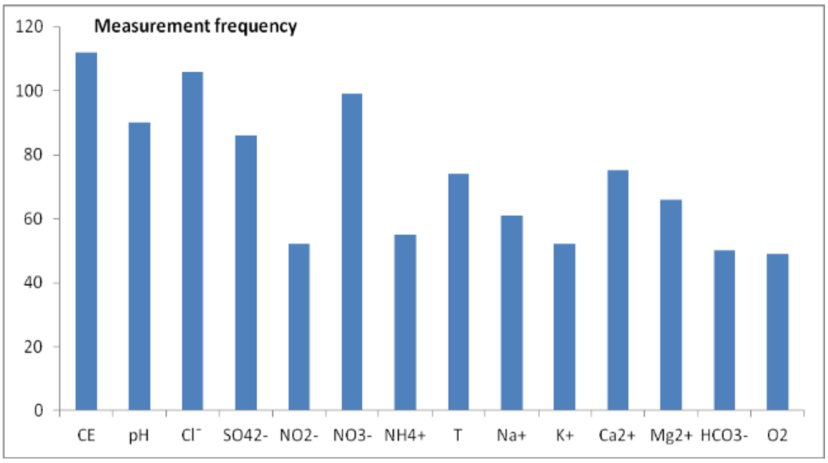
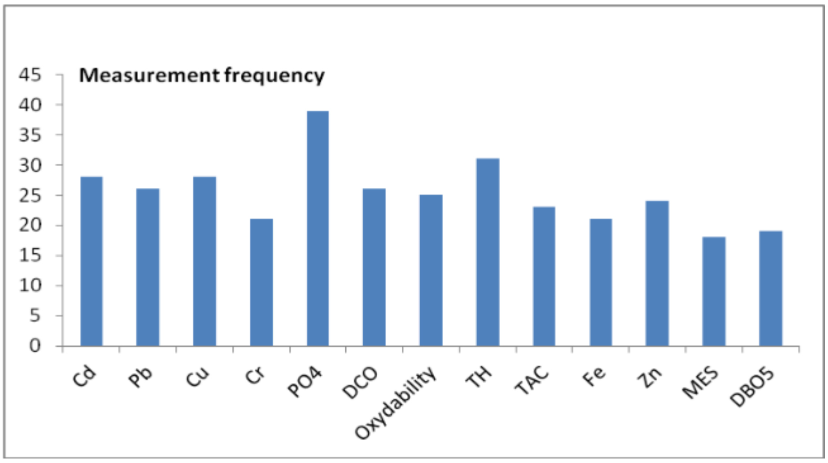
departments) have their own internal databases, and their data are not generally available to researchers and sometimes even to other departments. This is why the Scientific Institute of Rabat suggests creating an open access national geodatabase on the water quality.

(1)



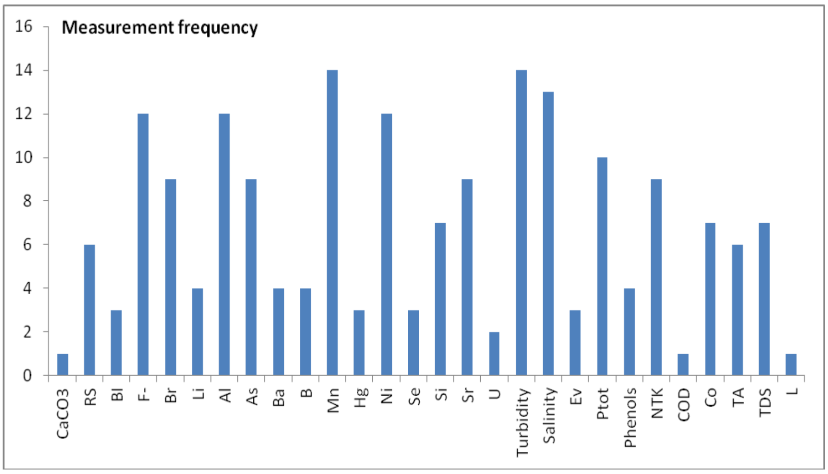
High frequency

(2)



Moderate frequency

(3)



Low frequency

Fig. 4. Relative representability of the parameters in the results: (1) high frequency; (2) moderate frequency; (3) low frequency.

The present study indicated that such database is fully feasible for the ground waters quality. Even this study do not cover all existing data sources, it was possible to identify the main limits of this database and difficulties to

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establish it. These limits are mainly linked to the high proportion of imprecise or lacking data, some of them being obligatory attributes (as coordinates, dates, methods, etc), in the sense that they are very useful in syntheses. The difficulties generally consist in searching complementary information on data with the objective to adapt them to the database structure and to improve their significance in the expected spatiotemporal analyses. Both difficulties and gaps could be reduced by providing national guidelines for measuring the water quality in different natural conditions. In addition to these guidelines, we expect that different spatial, chronological and thematic analyses will facilitate establishing new priorities in water quality studies and standard methods.

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قابلیت دستیابی و اهمیت دیتا برای توسعه پایگاه دادههای زمین شناختی در خصوص کیفیت فیزیکوشیمیایی آب: مثالی از آبهای زیرزمینی مراکش

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چکیده

منابع آب در مراکش و همچنین در دیگر کشورهای اطراف مدیترانه محدود است و علت این امر هم خشکی اقلیم است که شاخصه آن را میتوان، خشکسالیهای دورهای (برگشتپذیر) به حساب آورد. این مشکل فقط به مقدار آب محدود نمیشود، بلکه به کیفیت آب نیز مربوط میشود که امروزه بیش از هر زمان دیگری باید به خوبی مدیریت شود. با وجود این، نیاز به آب به طور مداوم رو به افزایش است و عمدهترین راههای حل این مشکل در خلال ۶۰ سال گذشته برای پوشش دادن این نیاز سد سازی و پمپاژ آبهای زیر زمینی بوده است. اما اخیراً دپارتمانهای ملی به مسئله تصفیه آبهای زیر زمینی روی آوردهاند. افزایش سریع جمعیت منجر به رشد انفجارگونه فعالیتهای شهری، صنعتی و کشاورزی شده که آبهای سطحی و زیرزمینی را آلوده کرده و استفاده از آن را به صورت چالشی بزرگ برای دولت در آورده است. قطعاً روشهای تشخیصی و سنتزهای جدید مورد نیاز است. این امر به معنی نیاز مبرم به سیستم اطلاعاتی اجرایی در باره کیفیت آب است که کل کشور را پوشش دهد و در بستری از تصمیمسازی، هم از بعد راهبردی و هم عملی طراحی شود. هدف این طرح تایید امکان سنجی این نوع سیستم اطلاعاتی با استفاده از مثالی از فراسنجههای فیزیکوشیمیایی آب زیرزمینی بوده است. ساختار پایگاه دادهای فراهم شد و با تقریبا همه دادهای فیزیکوشیمیایی موجود و در دسترس تکمیل شد تا تایید شود که این پایگاه از نظر فنی قابل انجام است. اولین تلاشها در باره این دادهها با مدلهای کلاسیک آشکار کرد که آنها با این ساختار پایگاه سازگار هستند. با وجود این، موانع مختلف از رسیدن به نتایج معنیدار جلوگیری کرد. علت این امر عمدتاً عدم دقت و ناهمگونی فرمت دادهها و روشهای مورد استفاده بود. این موانع تا حدی با تبدیل و تکمیل اطلاعات برطرف شد اما بسیاری از دادههای موجود غیر قابل استحصال یا با معانی ضعیف باقی خواهند ماند. علاوه بر این، هدف این مطالعه پیشنهاد روشهای استاندارد برای توسعه پایگاه دادهای است که بتواند در سطح ملی شایستگی لازم را داشته باشد.

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