International Journal of Mechanical Engineering and Technology (IJMET)
Volume 10, Issue 02, February 2019, pp. 511–519, Article ID: IJMET_10_02_052
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=02
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

ENVIRONMENTAL PECULIARITIES OF TRANSBOUNDARY GROUNDWATER MANAGEMENT

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ABSTRACT

Groundwater is a unique kind of mineral resources, relation to which should be special in our modern world. Geology of the earth's surface is arranged in such a way that boundaries of groundwater aquifers and complexes distribution do not coincide with the boundaries of states, and therefore extraction of this priceless resource must be regulated at the international level. Aquifer exploitation occurs in all the countries at all the continents in accordance with local legislative norms. Many international conflicts can be prevented if one approaches the problems of subsoil use on the basis of a general agreement. The aim of the research is development of an international conceptual model for groundwater production management through regulation of specification systems, monitoring, licensing, control of groundwater extraction. Features of groundwater extraction from transboundary aquifers are considered, international experience of conflict regulation in this sphere is reviewed, environmental measures are offered, recommendations and prerequisites for development of an international system for groundwater extraction management are given.

Key words: transboundary aquifers, groundwater extraction management, UNESCO, environment, natural resource, license, sustainable.

Cite this Article: Ekaterina Golovina, Environmental Peculiarities of Transboundary Groundwater Management, International Journal of Mechanical Engineering and Technology, 10(02), 2019, pp. 511–519
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=10&IType=02

1. INTRODUCTION

Water is humanity's most important natural resource. The availability of, and access to, fresh water is high on the agenda of planers, politicians and executives [1]. Most of all freshwater is found in aquifers, many of them Trans boundary. In recent decades groundwater has become a source of wealth and well-being for a society that shows an increasing need for water. Because of this any effort made to protect and wisely use aquifers will contribute greatly towards the improvement of human life and the preservation of groundwater dependent ecosystems. To define

the characteristics of the world's groundwater resources, the world map (WHYMAP) was prepared (Figure 1) within the framework of the sixth phase of the UNESCO International Hydrological Programme (IHP) 2002-2007.

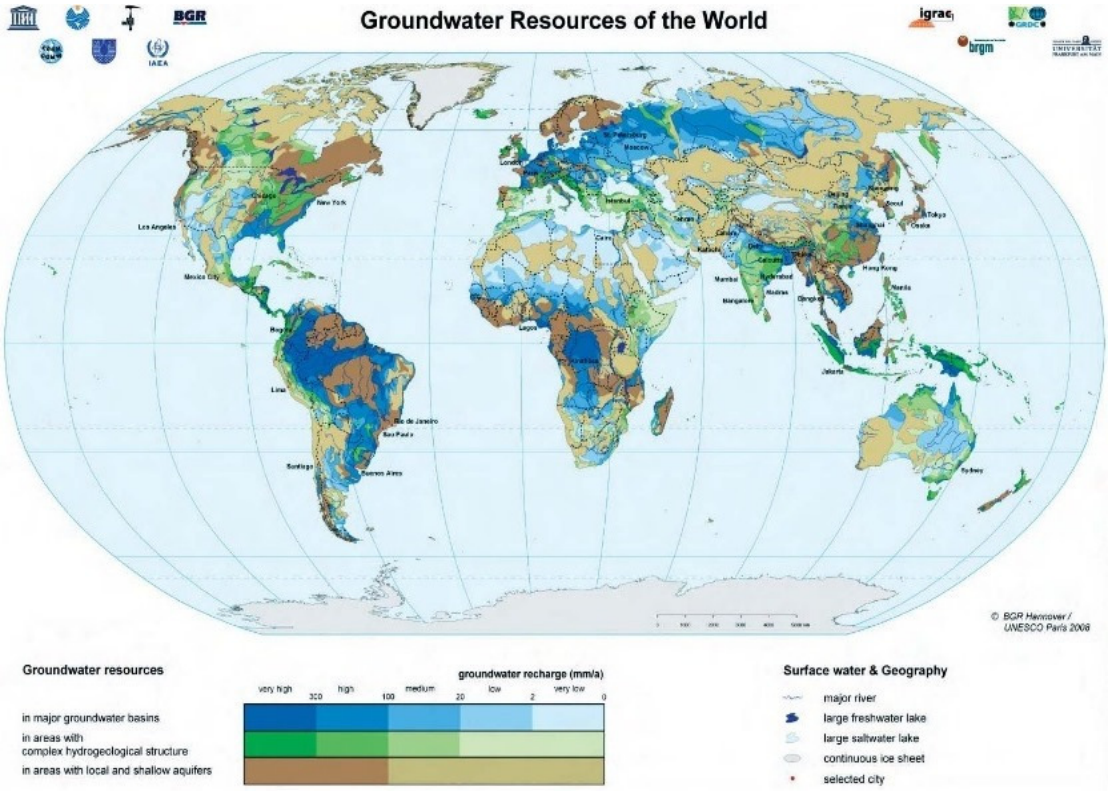

Figure 1 Groundwater resources of the world (WHYMAP, 2008) [1]

First of all, groundwater is a commonly used, widespread and shared mineral resource. Groundwaters are extracted from aquifers and used for drinking and household purposes, in agriculture and production [2, 3]. Groundwaters belong to the category of strategic minerals, along with hydrocarbon resources, so the supply of drinking water will be one of the pressing problems of modern society. According to UN experts, by 2030, about half of the world's population will suffer from a shortage of fresh water, and this can lead to future military actions and conflicts [4].

In this connection, extraction of such valuable minerals as groundwater must be managed rationally. On a combination of a reasonable selection of groundwater with observing the norms of their quality, the concept of "rational use of them" is based. That is, under the rational use of groundwater it is recommended to understand their economically feasible operation, which provides protection from pollution and depletion of operational (mineable) reserves and allows to maintain groundwater resources and environmental conditions at a given level [5]. Chemical composition change is also possible in the case of irrational extraction. Some environmental problems in the extraction of groundwater can be caused by penetration of various substances, such as gases, petroleum products and acids into aquifers. The formation of highly soluble gases along with organic acids increases the corrosive aggressiveness of groundwater, whereas the accumulation of poorly soluble gases in its turn leads to a significant decomposition of dispersive soils [6]. All these factors influence groundwater production.

Over-limited extraction of groundwater and, at the same time, inefficient use cause a rapid depletion of groundwater resources in many countries [7]. In addition, both natural processes and human activities can have a significant impact on groundwater quality and future constraints as a source of water supply. In view of such natural and anthropogenic reasons as population growth,

unplanned urbanization, economic development, the amount of groundwater continues to decrease. Therefore, strategies for sustainable management of groundwater production are required. In turn, development of a proper groundwater management strategy requires the study of aquifers characteristics, spatial and temporal groundwater monitoring [8].

2. LITERATURE OVERVIEW

Worldwide, about 60% of all freshwater runs within cross-border basins; only an estimated 40% of those basins, however, are governed by some sort of basin agreement [9]. In an increasingly water-stressed world, shared water resources are becoming an instrument of power, fostering competition within and between countries. The struggle for water is heightening political tensions and exacerbating impacts on ecosystems [10, 11].

In a complicated modern political situation issues connected with mineral resources extraction at transboundary territories have not only political meaning but also ecological ones. If one country uses groundwater resources irrationally, it inevitably influences economy and environment of the neighboring country. Evaluation to objects of natural resources usage is largely determined by the characteristics of the legal framework [12].

Characteristics of the aquifers are different from those of surface water bodies. An aquifer can be defined as a permeable water-bearing geological formation underlain by a less permeable layer and the water contained in the saturated zone of the formation. An aquifer system consists of a series of two or more aquifers that are hydraulically connected. A transboundary aquifer or transboundary aquifer system is an aquifer or aquifer system, parts of which are situated in different states. An aquifer state is a state in whose territory any part of a transboundary aquifer or aquifer system is situated. As geological formations and aquifers know no political borders, international boundaries are often crossed by groundwater flow [1]. The main features of transboundary aquifers are such factors as feeding and discharge areas, extensive distribution, interconnection with other aquifers and open water bodies.

By its nature, beneficial and rational use of groundwater depends more on socio-economic, institutional, legal, cultural, ethical and political considerations than surface water. Their national development is hampered by weak social and institutional capacity, as well as by weak legal and policy frameworks. In a transboundary context, this can be further strengthened due to contrasting levels of knowledge, opportunities and institutional frameworks on both sides of many international borders [13].

Despite their significance, physical interactions between surface and groundwater have largely been ignored in international water law. While surface water has been given considerable attention as a transboundary natural resource, groundwater has not received the same recognition. International legal doctrines regarding water, such as the 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, only recognize done aspect of groundwater, excluding confined aquifers. While the issue of transboundary groundwater in international treaties is becoming increasingly relevant as disputes over groundwater resources come to the fore, it is usually only indirectly mentioned in treaties. Groundwater and surface water should be considered together as part of the hydrological cycle and reflected as such in the legal body. The uncertainty of physical properties is not an excuse for the delay of a concrete framework. An Interactive Coordinated Approach (ICA) is recommended as a guideline for future implementation of transboundary groundwater management [14, 15]. The purpose of this research is to demonstrate the need to develop comprehensive transboundary groundwater management conceptual model taking into account environmental issues of groundwater extraction.

Aquifer resources management, aiming at the responsible exploitation and adequate protection of the groundwater resources, is therefore of key importance and has to be based on

sound hydrological, environmental, economic and social principles. In order to accomplish groundwater resources management goals in the case of transboundary aquifers, a balanced joint strategy is needed [16].

3. MATERIALS AND METHODS

Many of the world's existing groundwater systems (or "aquifers" - so called usable groundwater reservoirs) are transboundary, that is, they lie on the territory of two or more administrative units within the country or two or more countries (Figure 2). Obviously, in the second case, administrative and operational management of groundwater resources is facing additional challenges and requires harmonization of rules and transboundary cooperation between various bodies involved in groundwater mining, based on mutual trust and transparency. There are still not many examples of such cooperation in the world.

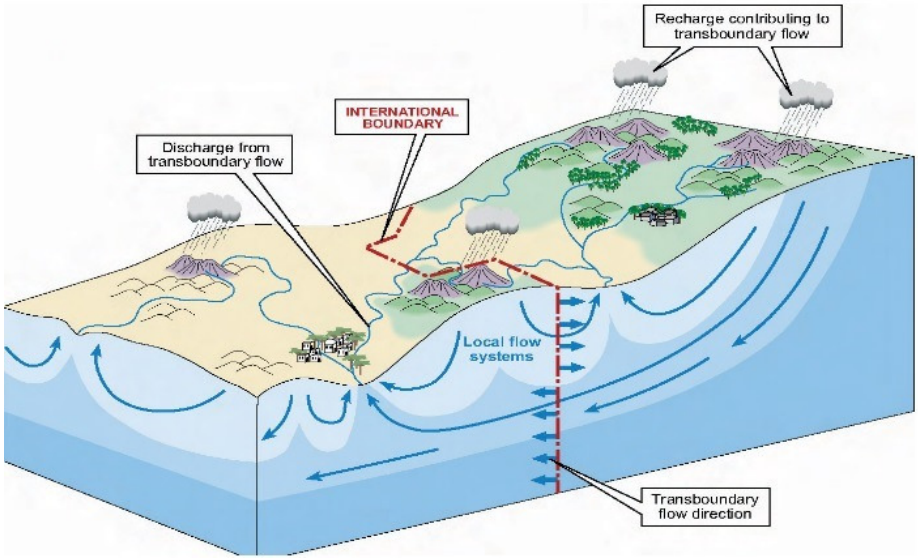

Figure 2 Schematic diagram of a transboundary aquifer system [1]

In many cases, aquifer may have a catchment area in the territory of one state, and the water discharge area is located in the territory of other border states. Such schemes are common, as a rule, in submontane and foothill-flat areas. This is typical, for example, for Austria - the Czech Republic, Germany - Poland, Switzerland - France.

The UN International Law Commission (ILC) embarked on the codification of the law of transboundary aquifers in 2002 in order to provide legal regime for the proper management of aquifers in view of the critically important freshwater resources. UNESCO and IHP (International hydrogeological programme) played a central role in providing the valuable assistances and support to the ILC by mobilizing hydrogeologists, aquifer administrators and water lawyers.

At its 14th Session, in June 2000, the Inter-governmental Council of IHP adopted a resolution to promote studies on transboundary aquifers (considered an important source of freshwater, particularly under arid and semi-arid climatic conditions) and launched the International Shared Aquifer Resources Management Project (ISARM). The aim of the project is to improve existing scientific knowledge and to contribute to the multifaceted efforts involved in global cooperation. The Project has identified five key focus areas for the sound development of transboundary aquifers. These include scientific, hydrogeological, legal, socio-economic, institutional and environmental components.

As the problem of aquifers is indeed an urgent global matter, it would be most desirable if the UN General Assembly would decide to transform the draft articles into a legally binding frame-work convention. Unfortunately, this issue is not solved yet.

Very few international borders correspond to natural physical features, and water resources can cross them without hindrance. To effectively manage and equitably distribute these resources, scientists assess the resources that cross these boundaries. In hydrogeological terms, these crossing resources can only be estimated by observing and measuring individual hydraulic parameters, similar to the process of assessing other transboundary resources.

There are marked differences in the status of the recognition for transboundary surface water and groundwater. Consequently, transboundary groundwater directives have been omitted from overall water management regulations. The two primary reasons for this absence are also points of contention in transboundary groundwater management. First, groundwater characteristics vary in each aquifer. Groundwater is often deep or unevenly distributed geographically. These uncertainties make groundwater seemingly impossible to regulate, as well as ill defined. The other reason is the transboundary element. Dealing with transboundary issues has been intensively studied in surface water; as a result, the difficulties as well as the necessity for management structures are understood. By contrast, in terms of transboundary groundwater, even the delineations of an aquifer are a challenge. Under the best use of monitoring and modeling techniques to identify groundwater characteristics, the definition of an aquifer cannot provide concrete conclusions about groundwater ownership. Therefore, the establishment of an apparent management framework is critical [15].

Surface waterways, such as rivers and lakes, are regulated by the European Water Framework Directive. All kinds of activities are clearly regulated by international laws. But, extraction and use of groundwater, due to a certain specificity and diverse legislative base, often do not have a single universal management model.

In any legal agreements that should be drawn up for the management of transboundary resources, the initial stage should be the correct definition of the flow and movement of water with subsequent quantification. Institutional weakness and political pressure may not solve all relevant issues, which can lead to serious consequences for the environment and unsustainable development.

Current growing problems with respect to the quality of groundwater resources and sustainability of groundwater abstraction levels acquire a special political connotation when groundwater flows across the international border of states and, as a result, becomes a "common" resource. Sensitivity to sovereignty, diversity of legal and socio-political systems and various national programs cause certain difficulties. This is exacerbated by the fact that none of the internal "water" laws of neighboring countries can provide acceptable universal management rules. Consequently, such rules must be found elsewhere, that is, in treaties and agreements between interested sovereign states, or in case of non-observance of such treaties and agreements, in the consistent practice of the states themselves [13].

The problem is the following: nowadays there are very few treaties and agreements that provide unified international rules for managing groundwater extraction, as well as protection of common groundwater resources. Particularly acute this problem affects states with a shortage of water resources (countries in Africa, Central Asia, the Middle East, some countries in Europe and North America).

4. RESULTS AND DISCUSSION

The environmental issues that affect Tran’s boundary aquifers are wide ranging and can be viewed both from a local and a global perspective. Thus, sustainable development of Tran’s boundary aquifer resources should be analyzed.

If the conventional definition of sustainable development, i.e. “development that meets the needs of the present without compromising the ability of future generations to meet their own

needs" can be applied to aquifers within a nation, then there is no reason why the same can`t be applied to transboundary aquifers.

In sustainable management of transboundary aquifers, problems such as groundwater overdraft will often emerge gradually. If they are identified and actions initiated to address them early, joint action may cause little social disruption. If, on the other hand, joint responses are delayed until major problems arise, massive social disruption may be unavoidable. In a scenario where to return groundwater use to sustainable levels, extraction needs to be drastically reduced, the resulting social disruption will be politically difficult and socially unacceptable.

Sustainable development of transboundary aquifers requires making predictive analyses involving the use of computer modelling techniques, to define the life of the resources. A holistic conceptual understanding of the groundwater system is the basis for the proper construction of a computer model. Real and relevant hydrologic features of the groundwater system must be correctly incorporated into the model. Furthermore, all models need to be calibrated using real and consistent data. The results of the monitoring program provide this validation check. The more sophisticated tools and methods of analysis that can indicate sustainability are built on a foundation of conceptual understanding and monitoring [13].

Determining the sustainability of a transboundary aquifer with any degree of confidence can only be conducted in a resource planning context having detailed information and under-standing. Ultimately, though, resource development policy involves tradeoffs. Most aquifer systems have ecosystems, landscape elements, or pre-existing water users that are dependent on current discharge or recharge patterns. Further development may require trading off these dependencies in favor of new plans or policy. If dependencies are not well understood or considered, management changes may have major unanticipated impacts. The best approach to minimize negative outcomes is to follow the progression of investigation outlined above.

Thus, at present legal issues regarding quantitative factors of groundwater extraction from transboundary aquifers and systems are not fully resolved. There is a huge number of countries that have encountered problems regulating the use of transboundary groundwater resources. Some of them are listed below.

For example, the extraction of groundwater from the aquifer of Trifinio - by the name of the region where the borders of the three countries: Guatemala, Honduras and Salvador meet. The most serious problem related to water management in the region is pollution. According to the estimations of the experts of the project GRGTA (Groundwater Resources Governance in Transboundary Aquifers), in the absence of effective monitoring, the level of groundwater pollution here of time will only increase [17].

The lack of monitoring data (climate, as well as data on groundwater abstraction, water levels and quality) makes it very difficult to conduct systematic diagnostic analysis. Such a problem has arisen in the Stamprietta system of transboundary aquifers, located in a vast arid region in Central Namibia, Western Botswana and the Northern Cape of South Africa [17].

The Pritashkent transboundary aquifer (PTTA), located on the territory of Kazakhstan and Uzbekistan, causes the following problems: inevitable depletion of groundwater resources as a result of their selection. In the long term, groundwater level may drop below a level that is minimally necessary for exploitation from a technical or economic point of view. Another major problem is potential deterioration of groundwater quality. The gradual lowering of water level in the transboundary aquifer may lead to the infiltration of brackish and saline groundwater from the overlying aquifers. Finally, contamination of the upper aquifers can lead to the abandonment of their use and transition to water intake from PTTA [17].

Of the twelve million people who live within 100 km of the US-Mexico border, 90 percent are clustered in transboundary sister cities that share common water sources and pollution problems. Diversity and geographic dispersion of water conflicts presupposes the possibility of applying an interrelated approach to water negotiations between the United States and Mexico. Back in 1973, Mexico and the United States reached an agreement on specific volume restrictions on the annual production of groundwater in the territories of both countries, within eight kilometers from the international boundary of Arizona-Sonora. In addition, the agreement requires that two countries consult each other before any new development or substantial modification of both surface and groundwater resources on their territory in the border zone, which could adversely affect another country [18].

The alluvial aquifer system is shared by the Czech Republic and Poland in catchments draining northward to the Baltic Sea that belongs to the Odra River basin. The area represents one of the most attractive and valuable natural reserves of both countries. However, it is also characterized by the impacts of quite inappropriate human interventions into the hydrogeological regime. Wide deforestation and intensive agriculture and industry on the Czech side of the locality is causing erosion and consequently an increase of surface runoff, especially to the Polish lowland area and creating potential floods. Groundwater flow direction is from SW to NE, i.e. from the Czech to the Polish side. Contamination of the ground and surface water has serious risks for the wells drawing on the aquifer in the Polish side. But the majority of the potable water for the Polish side is from the aquifer. In case that contamination of groundwater occurs, the Polish water supply sources would be irrecoverably damaged and a completely new system will have to be established, which would require a large amount of finances [13].

The absence of a common reciprocal management system for groundwater extraction from transboundary aquifers and complexes leads to numerous conflicts, including military actions in the territory of Israel, Palestine and Jordan.

This is not a complete list of examples of the lack of cooperation between states that exploit "common" groundwater resources and resulting disagreements. There are other agreements, in particular in Europe that cover groundwater resources within a broader framework for cooperation in the management and protection of bordering rivers or in their development. However, groundwater plays an insignificant role in these agreements.

Thus, problems of groundwater production from transboundary aquifers and complexes are:

1) Absence of a unified international system for managing the extraction of groundwater as a particularly valuable type of minerals.

2) Attempt of local, as a rule short-term, laws and by-laws regulating the system of groundwater extraction management from transboundary aquifers. In this case, directives and framework agreements are adopted in each specific situation.

3) Scale of the problem, which lies in the field of its operation. The problem concerns any border subsoil use, in contrast to surface water bodies and streams, which are regulated by the European, Asian and other water directives [19, 20].

After identifying these problems, it is proposed to use the existing experience of managing groundwater production in Russia, Germany, France and other developed countries to create a unified international concept for managing groundwater production from transboundary aquifers and complexes.

The international management model implies development of a mechanism based on:

- Uniformity of the licensing procedure for groundwater extraction (mining permits for individuals and legal entities);
- Compatibility of the monitoring system based on uniform standards and reporting on the extraction of groundwater with identification of the main relevant parameters (factors such as

dynamic parameters of heads when groundwater reserves are developed, periodic reporting of chemical and bacteriological analyzes);

- Access to subsurface resources for all categories of water users with common subsoil use rules for transboundary aquifers;
- unification of the system for planning the development of groundwater deposits, including domestic, drinking, technical, medical and energy purposes based on modern numerical models, allowing complex, real-time analytical calculations (for example, as in Germany);
- System for financing the above systems by optimizing the taxation system (a tax on the extraction of minerals, as an effective way of managing the development of a groundwater deposit) and at the expense of state budget sources;
- planning geological exploration for both existing and poorly studied groundwater deposits, including the creation of a network of observation wells and facilities included in the network of a unified monitoring system using modern remote observation technologies;
- Calculation of the limits of influence on transboundary aquifers, the level of critical aquifer operation;
- Opportunities for supporting poor countries to provide access for specialists to build observing systems, to identify opportunities for restrictions on groundwater production volume;
- Control over the target consumption of groundwater resources, which is especially important for aquifers with difficult water exchange or for unique deposits of medicinal mineral waters.

The main proposal is to prove the necessity of organizing special ecological monitoring stations, situated on the territories of the state's borders (double-sided system). These stations need to be made both for main and for unexploited wells. This observation system should include periodical water sampling for biological, chemical and radiological analysis, monitoring of groundwater levels during a calendar year. Location and frequency of these stations depend on hydrogeological characteristics of aquifers and groundwater extraction volumes. Methods of equiping these monitoring stations must be chosen by leading hydrogeologists from different countries.

5. CONCLUSION

To sum up, yet international law has paid only marginal attention to the management and protection of transboundary aquifers and only recently these resources have become a subject of international law in their own right.

However, practice has shown that management of groundwater resources and their protection is a very difficult task. Groundwaters interact with other components of natural environment and are exposed to them. Often, there is only the most limited knowledge of local groundwater systems and their behavior; In addition, each groundwater system usually unites a multitude of consumers and other parties that often compete or conflict with each other. Adequate administrative measures for information systems, institutions, policies and various forms of support are required for effective measures to manage the extraction of groundwater resources.

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