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Assessment of Vulnerability and Risk Mapping at Marsaba – Feshcha Catchment

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Abstract:

Groundwater resources are the main fresh water supply for Palestinians especially from karst aquifers. Human utilization of water resources for several uses has increased that make a water stress on the resources.

This study focuses on Marsaba-Feshcha Basin as one of the most important basins in the West Bank that connected to the Dead Sea have been studied and water budget, vulnerability and risk maps were constructed due of its location in eastern aquifer and karstic formation. Lithological data of well bores was drawn using the "Win Log" and "Win Fence" software in order to have a more detailed insight of the strata around the area of Daraja Catchment that locates in the lower part of the basin in the east.

Water budgets provide a means for evaluating availability and sustainability of a water supply. A water budget simply states that the rate of change in water stored in an area, such as a watershed, is balanced by the rate at which water flows into and out of the area. The water budget has been calculated by using Guttman model 2000 through period of 2010-2013. This model depends on the precipitation, evapotranspiration, surface runoff, water import, spring discharge, well abstraction and groundwater recharge of the basin to have the remaining lateral outflow. Depending on these estimates, Out of calculations the groundwater recharge was about 124.9mm/yr corresponding to the value of 80 MCM/a with a remaining lateral outflow of 89.2 MCM/a.

Population growth is a major contributor to water scarcity. Growth in populations means increasing demand and competition for water for domestic and agricultural uses. By using geometry method for projection, the growth rate of the study area ranges between 2.63% and 2.66%. It shows that population in year of 2040 will be doubled as it in 2015 which means increases around 51%.

The water quantity that supplied to household is an important indicator that measures the

adequacy of domestic water supply. The average rate of water supply slightly increased through projected years.

By using Geometric method in statistics calculation, the population has been projected through the period from 2007 to 2040 in addition to water supply, demand, consumption and wastewater production. The population starts to be increased in 2015 until it will be doubled in 2040. The water demand for domestic and agricultural uses in 2040 will increase 68% of 2007 uses, water supply in 2040 will increase with 77% of 2007 supply, the water consumptions in 2040 increased with 31.47% while wastewater production volume in 2040 increased with 31.45%. With the increasing of population, this mean an increasing gap between availability and expected demand which will reach 0.425 MCM/yr with population of 200921 in 2040.

Protection of groundwater starts with the evaluation of the sensitivity of its environment. For M-F basin a groundwater vulnerability map have been demonstrated which shows the areas with potential for groundwater contamination on the basis of hydro-geological conditions. The research uses a GIS-based approach called the PI method, which takes into consideration the nature of karst aquifers. Inherent geological, hydrological, hydrogeological, climatological and vegetation data, in terms of thematic layers, were collected and used in the creation of the groundwater vulnerability map of the Study area. The results obtained from this study indicate that majority of the study area is under moderate to low groundwater vulnerability for contamination.

Also, the risk map has been constructed in this research by using ArcGIS and myObservatory software based PI map. The risk appears in both methods shows low risk in the majority of the study area.

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Table of Contents

Chapter 1

1. Introduction

Water is considered to be one of the graces that God has bestowed upon mankind on Earth and one of life's essentials as it known to be a main ingredient in most of agricultural, industrial, and domestic activities (AlYaqoubi, 2007). Moreover, the availability of water indicates the independency of a country over another as it allows its citizens to have their needs fulfilled. However, there are many water crisis found in the world and specifically in the Middle-East region. One of the examples is the scarcity of water resources in Palestine which makes it suffer from several conflicting effects and challenges (AlYaqoubi, 2007). This issue is resulted mainly due to unstable political situation in West Bank and Gaza which deprives both regions from normal economic development, average living standard and guaranteed environmental sustainability (Isaac,2009).

In fact, West Bank has fresh groundwater resources that are approximately 669 MCM/yr and runoff water of about 215 MCM/yr; this makes it a water-rich region (PWA, 2010). However, Israel has been retaining control of water resources since its occupation of the West Bank in 1967 which has limited Palestinians' share to 11%, while 89% is used by Israelis who also use 87% of the annual safe yield from the West Bank's Aquifer systems to meet 25% of their water need (Isaac,2009). According to the world health organization (WHO), the average consumption of water is 100 L/capita.day for healthy life which indicates that Palestinians are below this standard as they consume around 60 L/c/d and 65 L/c/d (PWA, 2010), whereas Israelis consume about 280 L/c/d (NAD-PLO,2011) and 350 L/c/d (PHG, 2008/09).

In 2009, Israel abstracted 94 MCM of which 50 MCM are used to irrigate around 90,000 dunum of land and 44 MCM are used in industrial and domestic activities (Isaac, 2009).

Another amount of water, 54 MCM, was purchased out of which a significant amount is discharged from wells belong to Mekorot company in the West Bank. Thus, Palestinians consume 148 MCM and lose a rate of 35% which makes the real net amount of consumption about 98 MCM (PHG, 2008/09).

1.2 Study Area

The target area of the study is Marsaba-Feshcha that is located in the West Bank to the west of the Dead Sea and the Lower Jordan Valley and differentiated from most regions as it has accessible to a limited amount of ground water. However, the area is in the risk of having this source of water as the only available one due to the inaccessibility of national water resources which makes it in constant lack of freshwater (Shoqeir., J., 2014). Most of Marsaba-Feshcha population is found in the following major cities: Ramallah, Jerusalem and Bethlehem that are all located in the western part of the Eastern Basin. On the other hand, fewer people are living in the Lower Jordan Valley (LJRV) (Bensabat., J. et. al., 2010).

"The replenishment and the outcrops of the water bearing layers of Lower Cenomanian-Turonian are located in the western part of the basin. There, the average rainfall is approximately 600-700 mm/year. To the east (the LJRV and the Dead Sea), the aquifer becomes confined and rainfall reduces sharply with precipitations of 50 to 150 mm/year and potential evaporation of up to 2,600 mm/year" (Bensabat., J. et. al., 2010).

Marsaba anticline is known to be what distinguishes the area as it constitutes the eastern boundary of a large freshwater body that shapes the flow of the groundwater and the outlet. Additionally, the area of Marsaba-Feshcha has two regional aquifers of fresh water, the upper and the lower. The salinity of the lower Aquifer is high and total salinity of Feshcha springs is between 1500-6000 mg/l CL^- and the total discharge 60-65 MCM/yr. (Shoqeir., J., 2014)

The study area is located in the Eastern Aquifer Basin (EAB). EAB is considered as a water resource in Palestine that covers an area of 3100 km^2 in the eastern side of the West Bank and extends from the north to the south of the West Bank borders (Abusaada, 2011). The average rainfall of EAB is about 281(mm) and its recharge volume is about 153 MCM (PWA, 2011). The annual yield of this basin varies from 145 to 185 MCM. However, according to official estimations, the Israelis exploit the aquifer at a rate of 50 MCM/Y from wells in addition to 100 MCM/y from Dead Sea Springs that are controlled by Israel; while the Palestinians utilized about 42 MCM/y from groundwater wells and springs in 2011(PWA, 2011).

The EAB is consisted of a mostly-unconfined upper sub-aquifer that goes back to the upper Cenomanian to Turonian ages, and of a mostly-confined lower sub-aquifer that belongs to the lower Cenomanian age. Both of these layers are separated by a less permeable layer known as Yatta formation (CH2MHILL, 2001). Both of these upper and lower sub-aquifers are considered to be the main fresh water sources in the eastern side of the West Bank (Abusaada, 2011).

The gravity leads to an inflow towards the Dead Sea and the Jordan River which makes the recharge mixes with saline water and emerges thereafter through the Dead Sea springs (Abusaada, 2011).

The water level is 450 m above sea level on the western side and decreases to the level of the Dead Sea and Jordan River on the eastern side (CH2MHILL, 2001).

The outflow of the Basin is divided into three types: groundwater wells, springs and seepage. However, groundwater is considered to be the primary source of water for the Palestinians in the West Bank from which good water can be abstracted on a sustainably rate (SUSMAQ, 2001). In addition, ground water has been used mainly in domestic activities that have been increasing due to the natural increase of populations in West Bank and Israeli's settlements there (SUSMAQ, 2001).

Wadi Al-Nar is considered an open area for pollution sources because of its karstic formation. The pollution resources in this area are cesspit tanks, dumping sites and gas station.

Due to the inaccessibility of groundwater to some regions in the West Bank, citizens of such areas tend to use simple tools to generate water as cisterns, used to collect water from houses' roofs, and other agricultural ponds (Isaac and Sabbah, 1998).

Through this study the reasons of the water scarcity in the West Bank is vary from water pollution, Israeli control, mistreatment of wastewater and misdistribution among population. Also, the population of the study area depends on rainwater stored in cisterns and additional amounts of water from springs.

1.3Problem Statement

MF Basin is considered as one of the most future resource to be developed for the Palestinians in the EAB therefore risk maps and vulnerability maps should help in identifying the point and none point pollution sources.

1.4Justifications

This study focus on pollution risk that may be caused by wastewater from cesspits in the rural areas and Israeli settlements, solid waste dumping sites, gas station, olive mills, quarries, urban storm water, industrial activities, and agricultural activities.

The construction of aquifer vulnerability mapping in this study in order to develop risk maps is an efficient tool forecasting, planning and management option to be used by Palestinian Water Authority to identify action priority.

1.5Objectives

The overall objectives of this study are:

- To delineate boundary conditions of the study area based on surface and groundwater hydrology.
- To evaluate the potential, loss, demand and availability of water resources in the study area to estimate water budget for Marsaba – Feshcha Basin.
- To determine and rank the pollution source in the study area, and to construct vulnerability and risk map for the study area using PI – GIS based model and risk map by using myObservatory.

1.6 Limitations

The available hydrogeological data is insufficient as the historical data is neither detailed nor precise which makes the assessment difficult.

Assessment of Vulnerability and Risk Mapping at Marsaba – Feshcha Catchment

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الملخص :

تعتبر المياه الجوفية المزود الرئيسي للمياه العذبة للفلسطينيين خاصة في الخزانات الجوفية الكارستية. حيث ان استهلاك الانسان لمصادر المياه لعدة استخدامات آخذ بالزيادة مما يسبب بالضغط على تلك المصادر.

ان هذه الدراسة تركز على الحوض المائي مارسابا–فشخة باعتباره كواحد من اهم الاحواض المائية في الضفة الغربية المتصلة بالبحر الميت والتي تم دراسة الموازنة المائية له وانشاء الخرائط التي تظهر مدى الحساسية والخطورة فيها ولموقعها في الحوض المائي الشرقي والتكوين الكارستي

إن التكوينات الصخرية لتجويف الابار تم رسمها باستخدام برنامج "Win Log" من أجل الحصول على نظرة أكثر تفصيلاً للطبقات حول منطقة التغذية Daraja والتي تقع في الجزء السفلي من الحوض في الشرق.

توفر الموازنات المائية وسيلة لتقييم توافر واستدامة إمدادات المياه حيث تنص ببساطة أن معدل التغير في المياه المخزنة في المنطقة مثل منطقة تجمع مياه الامطار متوازن بالمعدل الذي يتدفق الماء فيه إلى داخل وخارج المنطقة. وقد تم احتساب الموازنة المائية باستخدام نموذج غوتمان 2000 خلال الفترة من 2010–2013. يعتمد هذا النموذج على كميات الأمطار، والتبخر، الجريان السطحي، واستيراد المياه، وتصريف الينابيع، والضخ من الابار وكذلك تغذية المياه الجوفية من الحوض لحساب التدفق الجانبي المتبقي. واعتماداً على هذه التقديرات فإن الناتج منها بالنسبة إلى تغذية المياه الجوفية قدرت بحوالي 124.9 مم/ سنوياً والتي تعادل 80 م.م^3 /موسمياً أما بالنسبة للتدفق الجانبي المتبقي فقد

قدر بحوالي 89.2 م.م^3/موسمياً.

يعتبر النمو السكاني هو المساهم الرئيسي في ندرة المياه حيث ان نمو السكان يعني زيادة الطلب والتنافس على المياه للاستخدامات المنزلية والزراعية. وباستخدام الطريقة الهندسة في الإسقاط فإن معدل النمو في منطقة الدراسة تتراوح بين 2.63٪ و 2.66٪. والي يدل على أن عدد السكان في عام 2040 سيتضاعف مما يعني زيادة في عدد السكان بمقدار 51% من عدد السكان في عام 2015.

ان كمية المياه التي تزود بها الأسرة هي مؤشر هام والذي يقيس مدى كفاية إمدادات المياه للأغراض المنزلية حيث ان متوسط معدل تزويد المياه ارتفاع قليلا خلال السنوات المتوقعة.

باستخدام الطريقة الهندسية في الحسابات الإحصائية، تم تقدير عدد السكان خلال الفترة 2007-2040 بالإضافة إلى كميات المياه المزودة والطلب والاستهلاك والكميات المنتجة من مياه الصرف الصحي. بدأت أعداد السكان بالزيادة في عام 2015 والتي ستتضاعف في عام 2040. حيث سيكون الطلب على المياه للاستخدامات المنزلية والزراعية في عام 2040 بزيادة مقدارها 68٪ بالنسبة إلى عام 2007، وإمدادات المياه في 2040 ستزداد بنسبة 77٪ بالنسبة إلى عام 2007، واستهلاك المياه في سنة 2040 سيزداد بنسبة 31.47٪ في حين سيرتفع حجم إنتاج مياه الصرف الصحي في 2040 بنسبة 31.45٪. مع زيادة عدد السكان، وهذا يعني وجود فجوة متزايدة بين العرض والطلب المتوقعة على المياه التي سوف تصل إلى 0.425 مليون متر مكعب / سنة مع ازدياد عدد السكان الذي سيصل إلى 200921 في عام 2040.

إن حماية المياه الجوفية تبدأ بتقييم حساسية بيئتها حيث ان خارطة حساسية المياه الجوفية للحوض المائي مارسابا-فشخة أظهرت المناطق التي لها احتمالية تلوث المياه الجوفية على أساس العوامل الهيدروجيولوجية.

يستخدم البحث النهج القائم على برنامج نظم المعلومات الجغرافية طريقة PI، والتي تأخذ بعين الاعتبار طبيعة المياه

الجوفية الكارستية. ان المعلومات الجيولوجية الكامنة والهيدرولوجية والهيدروجيولوجية والبيانات المناخية والغطاء النباتي تم جمعها واستخدامها في إنشاء خارطة تعرض حساسية المياه الجوفية للتلوث في منطقة الدراسة. ان النتائج التي تم الحصول عليها من هذه الدراسة تشير إلى أن أغلبية منطقة الدراسة هي معتدلة إلى منخفضة من حيث تعرض المياه الجوفية للتلوث.

وأيضا قد تم انشاء خارطة المخاطر الموجودة في منطقة الدراسة في هذا البحث باستخدام برنامج ArcGIS وبرنامج myObservatory بناء على خارطة PI. وان الخطر الي ظهر باستخدام الطريقتين يظهر كخطر منخفض التأثير في معظم منطقة الدراسة.

Chapter 6

Conclusion and Recommendations

6.1 Conclusions

This study focused on using PI method GIS based for assessment the vulnerability in M-F Basin using ArcGIS and the risk map using ArcGIS and myObservatory software. Office and field investigation method were used to collect data that is needed for this study.

Several Geological Cross Sections have been studied and are very significant in developing an overview of the hydro-stratigraphy related to Daraja Catchment which is the lower part in Marsaba-Feshcha basin. These cross-sections are essential to evaluate the characteristics of the groundwater movement and aquifer recharge.

By using Geometric method in statistics calculation, the population has been projected through the period from 2007 to 2040 in addition to water supply, demand, consumption and wastewater production. The population starts to be increased in 2015 until it will be doubled in 2040. The water demand for domestic and agricultural uses in 2040 will increase 68% of 2007 uses, water supply in 2040 will increase with 77% of 2007 supply, the water consumptions in 2040 increased with 31.47% while wastewater production volume in 2040 increased with 31.45%. With the increasing of population, this mean an increasing gap between availability and expected demand which will reach 0.425 MCM/yr with population of 200921 in 2040.

Water budget estimation for Marsaba – Feshcha sub basin have been calculated for the period 2010-2013 by using Guttman et al., model (1995 and 2000). Long-term climatic and hydrological data have been used for this study. The spring's discharge for Feshcha springs group is 53 MCM/a (AQU Lab), while the well's abstraction that are located in the study area is 12 MCM/a (PWA,2012).

The precipitation map shows rainfall gradient, with values higher than 450 mm/yr in the western mountain area and to values approximately of 50 mm/yr near the Jordan Valley. While the groundwater recharge map shows that the recharge has the same gradient of precipitation. The groundwater recharge has values higher than 135 mm/yr in the western mountain and less than 30 mm/yr in the Jordan Valley. The average annual runoff has been estimated of 31.5 mm/yr which corresponds to about 7 % of the average annual rainfall. Evapotranspiration have been estimated as 40 % of the precipitation of 180 mm/yr.

Depending on these estimates, Out of calculations the groundwater recharge was about 124.9mm/yr corresponding to the value of 80 MCM/a with a remaining lateral outflow of 89.2 MCM/a.

The vulnerability map by using PI method shows the intrinsic vulnerability and the natural protection of the uppermost aquifer. Most of the study area ranges with moderate to very low groundwater vulnerability.

The conducted analysis in this research was identified as well as classified the Hazards and its source, the high vulnerable areas to contamination and the high risks areas regarding to groundwater contamination. According to the analysis, the sensitive risks resulted from the wastewater generated from the urban and agricultural areas.

The risk assessment scheme used for risk map of M-F basin is based on the intrinsic vulnerability map constructed using the PI method and the hazard map and focuses on risk assessment for the groundwater resource. The first part used ArcGIS and Risk Map of the study area that can be classified as low or very low, the second part used myObservatory and it shows Risk Map of the study area that can be classified as low or very low risk.

6.2 Recommendations

The following recommendations can be drawn out of this research:

- Vulnerability assessment is recommended to be applied on other basins and areas with high potential for specific contamination.

- Decision makers in planning process have to take the issue of groundwater protection into consideration when deciding about locations and conditions for the establishment of facilities and activities which are possibly hazardous to groundwater
- Reducing the risk resulting from the wastewater generated from the urban and industrial sectors.
- Control the quantities of fertilizers and pesticides used in the agricultural sector.
- Minimizing the number of pollution point sources especially the solid waste disposal points by establishing a main isolated dumping site in the study area.
- Finally, it is recommended to conduct a regular monitoring program for all domestic wells (e. g. on a monthly basis) in the study area to make sure that no contaminants reach the aquifer.