Water Resources Management by Aquifer storage and Recovery in Jordan

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Abstract: ***Water resources in Jordan are very inadequate which is why its name is counted among the countries that have the lowest level of water per capita in the world. The demand for water at this time surpasses the available resources of renewable water which have been overexploited in order to eliminate the gap. However, it is also predicted that in all the sectors of water, this gap is potential of widening in the future. To overcome the situation of water scarcity, there is a need for endangering sustainable development thus Jordan is required to adopt a strategy for planning and storing water crucially. The proposed method or approach in this project is focused on managing demand and developing non- conventional resources of water. This paper has provided the strategy of Aquifer storage and recovery for coping with the current water situation in Jordan along with water development and planning components.***

Keywords : water resource management, aquifer storage and recovery, Jordan groundwater

I. INTRODUCTION

Due to the overexploitation of groundwater resources globally, the problem of aquifer depletion is emerging gradually (Wada et al., 2010). Furthermore, the effect of climate change is also imposing negatively in some of the areas around the globe which include increasing temperature and lowered rainfall amounts. The world is currently facing two of the major physical impacts caused by the change in climate and overexploitation of groundwater resources which includes degradation of groundwater quality (Murad, Aldahan, and Hussein, 2018) and aquifer depletion (Griebler, Avramov, and Hose, 2019). Impact of these two major issues bringing the severe adverse implications for the supplies and deprivation of available resources. It is found in many of the research papers that if adequate measure would not be taken to resolve the issue of degradation and depletion of groundwater, it will become imperative to new resources of water in order to overcome the increasing demand as well as to prevent the shortages of water supply (Tsakiris et al., 2015; Kummu et al., 2016). In addition to that, it is also found that harm to groundwater causes negative impacts on the supplies of water to be used in households, industries, and agriculture. Besides, there are many harmful effects on the economy of the country as well since a decrease in the quantities of irrigation water and deteriorating quality of water causes low-income level for farmers, increase poverty, increase unemployment, and diminish food security which illustrated as social time bombs. In addition to that, the research papers have also emphasized on the aspect that dearth of water supply or degraded quality of water supply for either domestic use or commercial use can cause severe health risks and children become vulnerable to poor health (Black, 2016)

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II. LITERATURE REVIEW

Jordan's Water Footprint

The table given below provides the national water footprint of Jordan with respect to different sectors. According to the study of Hoekstra, (2016), concept of water footprint is the measure of total volume of groundwater utilized in producing goods consumed by a person, industries or a nation along with the volume of groundwater that is required to assimilate the surpluses generated by the same person, industries or a nation (Hoekstra and Hung, 2005 cited in Sun et al., 2016). Though it is found in the studies that water footprints are based on two of the parts i.e. internal water footprint and external water footprint (Al-Saidi et al., 2016). In the book, internal water footprint is defined as the volume of domestic water resources in the national econosubtracted from the total annual volume of water based on the annual simulated flow of water to other countries in terms of traded products (Distefano and Kelly, 2017). Whereas, the external footprint of water concept is defined as the annual volume of resource of water that is utilized in other countries in terms of producing products and services that is consumed by the locales of the concerned country. In the article of Namrouqa, (2018), it was found that annual per capita footprint of water in Jordan has dropped by 16% implies that domestic, internal agricultural and business footprints of Jordan is lower than the global average.

Aquifer Storage and Recovery (ASR)

A tool for water resource management that helps in opening up the world of opportunities with respect to water access is known as aquifer storage and recovery (ASR) (Pyne, 2017). Using this tool or approach in projects for managing water, depletion of water can be eliminated. If the country has an appropriate setting of water available, this approach can help in storing the water for a long time until it is needed such as in the times of drought years. Many of the research studies have used different terms in order to address the approach of Aquifer Storage and Recovery (ASR) such as some of the papers have defined it as artificial recharge (Page et al., 2017), some of the studies have used the term managed aquifer recharge (MAR) (Pade et al., 2018), or rainwater harvesting (Clark et al., 2015) which is an option to acclimatize to the change in climate; more specifically in such conditions where these changes are prone to impose a negative effect on the accessibility of water in arid and semi-arid regions.

According to studies conducted on the topic of aquifer storage and recovery, it is regarded as the approach to store water that is collected from evaporation and from the affluence to which bodiesof surface water are open to (Mazareva. Druschel, and Pichler, 2015; Pyne, 2017). It is also found that most of the treated wastewater in winter is not used for the reason that there are no facilities provided to store it generally. In this way. ASR can also potentially use it for recharge. According to the studies of Wurtsbaugh et al., (2017) the level of Dead Sea is also declining from the number of years along with the levels of groundwater and stocks within its catchment. By the help of ASR, alleviation in its impact and their implications to supplies of water can be facilitated along with the implication in terms of politics, economics, and social. In the research of Ringleb, Sallwey, and Stefan, (2016) is found that aquifer storage and recovery system or approach is man-made for intentionally enhancing the recharge of groundwater in specific areas regardless of the methods that are used to increase its amount. It can be said that this tool is used in order to avoid the negative impacts of climate change and over-exploitation of groundwater resources that would decrease the high demand of water by providing a high supply of water. Besides Jordan, there are many other examples of managing groundwater artificial recharge projects and the projects for river bank infiltration and storage are also found all over the world by specifically in Europe (Dillon et al., 2019; Salameh, Adfallat, and van der Valk, 2019). However, the utilization of approached to artificially recharge, store, and treat the issues of water waste is sufficiently stated in the literature (Page et al., 2017; Johnston and Nelson, 2018; Page et al., 2018). It can be said that nowadays, the management of water resources by an approach such as aquifer storage and recovery has become a major necessity within the integrated concepts of water management. The research studies have defined that regions that are arid or semi-arid are benefited by the storage of water underground as compared to surface storage based on the reason that it minimizes the evaporation losses on underground level rather than the surface storage, it also helps in preventing the water from direct pollution and accidents of pollution, it isalso effective in avoidance of eutrophication, it is also relatively economical mode for storing water, and it is also helpful in improving the quality of groundwater in many areas.

Projects and their evaluation

There have been many projects for artificially recharging groundwater either planned or not intended but projects have proved to be resourceful in generating artificial water recharge. In the research of Pyne, (2017), it is found that successful water resources management by aquifer storage and recovery should mainly serve the objectives of the project that is was planned for. In the light of the above statement, all the projects that have been devised in Jordan based on aquifer storage and recovery must serve the purpose of increasing the freshwater resources and enhancing its quality. Besides this, there are certain conditions and guidelines were also set in regions like Europe, USA, and many others that can be used to assess the situation of appropriateness for Jordan. The techniques that are used in the projects for water management by Aquifer storage and recovery in Jorden uses dams, pools, excess irrigation, weirs, and well to enhance the quality of water as well as its climate and topography (El-Rawy et al., 2016). Sites such as WadiWala, WadiKarak, WadiShueib, WadiKafrain, Rajil Dam, WadiMadonnah and WadiButum, and Muwaqqar Area, WadiMugheir are some of the sites where recharge water projects are being deployed (Salameh, Abdallat, and Van der Valk, 2019).

A summary has been provided regarding the preceding and current projects related to aquifer recharge in Jordan in the funded project of United States Agency for International Development (USAID) named as Acceleration of Aquifer Storage and Recovery in the MENA Region (Arab Water Council). It is found that all of the projects do not fulfil the initial intents, but, in some of the cases, dams and their related reservoirs have involuntarily recharged aquifers which were intended for irrigation and providing water for drinking. In some of the other cases, it was also found that few projects in Jordan that was started as the groundwater recharge projects had converted into the projects for drinking water and irrigation because of the lack of infiltration.

Problem Statement

According to the report, Jordan is counted among one of those 10 countries which faced water stress in the world (Schyns et al., 2015). Based on the predictions, it is projected that there will be only 90 cubic meter water in Jordan by the year 2025 (Halalsheh and Kassab, 2018). On the other hand, as the population is increasing continuously, the demand for quality water is surging. Besides these issues, water scarcity is also complemented by the low rainfall i.e. approximately 91% of the areas in Jordan receives less than 200mm rainfall on average annually (Hussein, 2018). Considering these factors which include a shortage of groundwater combined with the increase in the demand of water have put immense pressure on non-renewable aquifers in Jordan and have deepened its dependency on shared sources of water with its neighbouring regions. Therefore, this papers aims to research of the technique of Aquifer storage and recovery (ASR) in order to manage water resources in Jordan so as to combat the issue of depletion and degradation of groundwater resources which is intensifying by the passage of each day. In addition these problems, it is also found that the evaporation ratio is very high annually is consider as 85-90 as Per USAID Reports for Jordan Water Studies and the Critical situation of the surrounding countries and the Risk of Contamination for the Open Dams Due to the Clash and Fighting's which may make very bad contamination of chemicals for the Dams.

4 Objectives of the Study

This research study Endeavour to find the answer for the question given below:

What are the Critical factors in the designing and implementing of the Aquifer storage and recovery (ASR) program?

Reducing the Evaporation from the open dams??.

To analyse the water footprint in Jordan

To analyse different artificial groundwater recharge projects in Jordan
To discover the Potential for Artificial Recharge of Groundwater in Jordan

III. METHODOLOGY

The section of methodology in any research study holds great significant for the entire research as it is considered as the working principle of the entire study (Flick, 2015). It reflects upon the adopted strategy to conduct the research and helps in understanding the underpinning design of the research. Furthermore, it reflects upon the tools that are used in the study to gather data and assisted in formulating findings of the study. It is found in the studies that an ambiguous research methodology is potential to lead towards the inappropriate conclusion of the study as well as incorrect result (Bell, 2014).

IV. RESEARCH DESIGN

The design of this research is qualitative in nature as it is mainly based on reports and research papers that were published in the past years. Basically, the results and findings of this study are solely based on secondary data. In this regard, secondary data consist of research papers from the past that has discussed the case or project for improving the water resources in Jordan, reports that have highlighted the issues and future prediction regarding consumption of groundwater resources and some of the research papers that have provided the key point regarding global water resource management.
To this end, different keywords are being entered to retrieved research papers and case studies such as water resource management in Jordan or Aquifer storage and recovery in Jordan. To make sure that only recent studies are incorporated into the study, research papers that are published within the time frame of the past ten years. In this was the secondary data has been taken from the past ten years scholarly articles available on the well-known platforms of the research articles such as Jstor or Google Scholar which are written on the topic of water resource management in Jordan. Thus, the approach of formulating results on the basis of data is qualitative methods since it entails data from qualitative methods.

Research Instrument

Since this research is exclusively based on the analysis of past studies, the research instrument used in this research is the literature review. There were more than 30 research studies that were analysed in this research in order to build its results and findings. This research instrument offered the vast range of information on the research subject and helped the author to build and support the further discussion in the study.

Ethical Consideration, Reliability, and Validity

To carry out the research in an ethical manner, the research has been restrained from including any bias or unauthentic statements in the research. In addition to that, the ideas, arguments, and taken from the research studies and reports are not left uncited. For the reliability of the research, it is to state that research papers, cases, statistics, and reports are gathered from the credible sources and no information form general web has been included into the review of the literature. Data from the country's website, published research papers, and statistics published by bodies such as the United Nations are utilized. As long as the validity of the research is concerned, it can be said as most validated research since no outdated data has been used in the study; only recent data is used to reflect upon the situation.

Results and Findings

In this section, the research papers and literature review is analysed in accordance with the objectives. To provide the answer for Critical factors in the designing and implementation of the Aquifer storage and recovery (ASR) program and analysed the potentials for artificial recharge of groundwater as per discussed and identified in the research papers. Critical factors in the designing and implementation of the Aquifer storage and recovery (ASR) program As per found in the studies, there were several categories were found to define the critical factors in the designing and implementation of the Aquifer storage and recovery (ASR) program. The first category is found in the research study of Missimer et al., (2015) which is considering the purpose of enriched recharge. This critical factor entails the key points such as storing the water from times of plenty to times of necessity that is one of the major key points under the consideration of the purpose of enriched recharge of water resources (Keats and Tu, 2015). The next point can include the augmentation or building of reserves or use recharge as a way of treating additional water. The purpose of enhanced recharge may include avoidance of salt water encroachments and intrusions (Pyne, 2017), or improving the quality of water by mixing. In theresearch, another purpose of enriched recharge of water resources was found i.e. prevention of aquifer compaction. The next category of the critical factor for consideration found in the studies is ease of use of appropriate water for restore. It entails the key points of considering the time of supply and the quantity of supply. Water quality is also the key consideration that needs to be taken care while analysing the ease of use of appropriate water for restore (Megdal, Dillon, and Seasholes, 2014). The research of Niazi et al., (2014) has also highlighted that distance from the area of water use and differences in elevation should also be considered.
Third category found regarding critical factors in designing and implementation of the Aquifer storage and recovery (ASR) program is conditions in the obtaining aquifer which include the highlighted points of availability of land in sites that do not have the potential of high ASR and the quality of recharge water (Sun et al., 2016). Whereas, the research of Al Saidi et al., (2016) has also suggested that easiness in abstracting or recharging the recharge water is key point under the consideration of conditions in the obtaining aquifer critical factor.
Condition of the site is also the critical factor that needs to be considered while designing and implementing the Aquifer storage and recovery (ASR) program in Jordan as found in the research study. Under this critical factor, the key points such as distance from the end use of water are entailed. Furthermore, it also contains the consideration of the availability of communication, electricity, and roads and the ability of

institutes to control site (Page et al., 2018).

The category of methods of abstraction and recharge is also found as the category of critical factors which consists of key points such as requirements for pre-charge treatments (sediment removal, filtration, or chemical conditioning), methods for recharge (channels, recharge pools, surface spreading, or wells), methods for extraction (spring, flow to stream, galleries, and wells), and requirements for the treatments of post-extraction (Page et al., 2017).

The last category as found in the research studies regarding critical factors is economic, institutional, and cultural conditions that entail water acceptance by the end user and economic conditions. In the research study. It was also found that availability of supplies from alternative sources or treatment of storage options also comes under the consideration of the critical factor of economic, institutional, and cultural conditions (El Rawy et al., 2016). The capacity of institutions to design, build, and maintain the projects of ASR is also the critical factor to consider.

Potential for Artificial Recharge of Groundwater in Jordan

As found in the studies, surface water has seven of the final destinations in Jordan namely Red Sea, the Jordan Rift Valley, Azraq Oasus, Infiltration to groundwater, Sirhan Depression, Jafr depression, and small playas that accommodates up to a few thousand of cubic meters of water (Salameh, Abdallat, and van Valk, 2019). Some of these destinations that are mentioned above are endorheic basins that are dealt with collectively for the reason that these destinations have similar conditions with respect to the recharge of groundwater. These locations have the similarity of ending up in pools or desert playas. In addition to that, flood water can be used for recharge is usually originated a few tens of kilometres from the base level or discharge level site.

Such as flood occur in Azraq partially originated about 100 to 120 kilometres away in Syria. In general, the process of infiltration and recharge of groundwater take place along the course of the wadi that is sheltered by clastic sediments mostly with high rates of infiltration. Ackowledgment This Work was supported by the Deanship of Scientific Research, Jerash University using their Laboratories and premises, our thanks to reviewers for their valuable suggestions to enhance the quality of our article

V. CONCLUSION

Since Jordan is a semi-arid country, the projects and schemes of Aquifer storage and recovery are becoming one of the imperative measures for saving water and manage water resources. It is also considered as the way to evade from the harsh impacts of change in climate on the stocks of resources of groundwater. The main reason behind this includes high rates of evaporation of water that is stored in dames, increase in pollution accidents as compared to the storage of water underground, and processes of eutrophication. In addition to that, research studies has defined that flood water is lost for the reason that there is lack of facilities for storage and it is not possible to construct dams all over the country specifically in the smaller inter-catchments exists between major wadis which is a major call for aquifer storage and recovery to manage water resources in Jordan. The research papers have even highlighted that flood and base flow along with the treated wastewater has no use or facility of storage in the time when it is raining or there is no need for irrigation. This measure for managing water has many promising and potential advantages which can solve the sever issue of low water resources in Jordan significantly. Furthermore, there were certain projects that have been initiated in order to combat the scarcity of water in the region and evade the challenges of low groundwater level and natural water resources. The research has mentioned seven critical factors that need to be considered while designing and implementing the projects of aquifer storage and recovery in order to manage water resources in Jordan.

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