International Seminar On Non-Conventional Energy Sources for Sustainable Development of Rural Areas,
IJAERD- International Journal of Advance Engineering & Research Development
e-ISSN: 2348-4470, p-ISSN:2348-6406
Impact Factor: 4.72, DOI:10.21090/ijaerd

Beneficial impacts of rain water harvesting in Chhattisgarh

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Abstract - *Although rain water harvesting has been practiced for ages in India, it has gained momentum among the Central and State Governmental officials, water resources managers, decision makers, practicing engineers, researchers and scientists, Non-Governmental-Organization (NGOs), social workers, and the media personnel alike from the last three –four decades. Some of the advantages of rain water harvesting normally cited are making water available for various purposes when needed, economic prosperity, drought proofing, and sustainable development etc. Any method or technology has its advantages and disadvantages and hence, both must be looked at and evaluated carefully with a view of long- term and short- term benefits and costs alike. This paper highlights some of the issues related to the possible impacts of the rain water harvesting practiced in Chhattisgarh that need to be understood and evaluated carefully before implementing large scale rain-water harvesting projects in catchments of prevailing water bodies viz. Rivers, ponds, streams and waterfalls etc. Some of the considerations that need attention are hydrological, environmental, climatic, geo-technical, and seismic considerations. The detailed hydrologic studies capable of evaluating the impacts of large scale rain water harvesting practiced over long periods of time on the hydrological balance of a region, and determining optimum strategies of catchment development and management are needed.*

Keywords *-Rainwater harvesting, hydrology, catchment management, water resources, sustainable development.*

I. INTRODUCTION

Water is essential to all kinds of lives on our planet. The total quantity of available water is estimated to be about 1386million cubic kilometers (MKm^3). Out of all this water, only 10.6 MKm^3 is available as fresh water on land , and the rest is contained either in the oceans (97%), or in the form of frozen ice on mountain tops and glaciers . The fresh liquid water useful for human-beings is available in rivers ,lakes, ponds, streams, fountains and reservoirs as surface water or groundwater in aquifers-confined, unconfined and pearched. The total fresh liquid water available has remained constant over the years but the needs of water are increasing day by day owing to the population growth, economic development, urbanization, industrialization and other developmental factors. The United Nations predictions indicate that the global water demand will exceed the available water approximately by the year 2050. If the available water resources are not utilized efficiently on a sustainable basis, the water demand will exceed the available water supply sooner rather than later. The policy makers all over the World have realized the gravity of the of the situation and several apex organizations like World Water Council (WWC), Global Water Partnership (GWP) and World Water Forum (WWF) have been set up with an objective to promote research and technological advancement in efficient use of the available water.

The water –crisis scenario in India is worse than that at the global level due to the higher population growth, increasing water demands and the limited water availability in India .The spatial and temporal distribution of the available water in India is highly uneven that makes the problem of handling the water–crisis a more challenging task. The major source of water for irrigation is monsoon rains in most of the territory of the Country. The spatial distribution of the available water in India is highly uneven causing floods in one part and droughts in the other at the same time. Also, most of the rainfall occurs during the monsoon spells (June-September) at any given place making water availability throughout the year very limited. Such an uneven distribution of water leads to the wastage of valuable water resources and calls for appropriate approaches to utilize the available water efficiently. The solutions of water crisis in India are related to the reason of the of the water-crisis itself i.e. the highly uneven spatio-temporal distribution of the water availability in the country. The first solution lies in minimizing the spatial variability in water availability and the second one lies in minimizing the temporal variability in water distribution at one place. Spatial variations can be minimized by making water available in part of country facing water-shortage from the part of country having surplus water at the same time. This can be achieved through inter-basin transfer of water from water surplus zones to water deficit zones of the country. Interlinking of rivers is being considered by the Government of India; however, it is an ambitious project involving huge expenditures. Its technical feasibility & economic viability have been questioned by experts & scientists. Moreover, the implementation of a project of the magnitude such as the interlinking of rivers would be an extremely challenging task for the agencies involved. Another solution of water crisis lies in the manner of handling the temporal variations in water availability. This can be achieved through rainwater harvesting.

II. RAINWATER HARVESTING

The rainwater harvesting is the simple technique of intercepting the water where it falls. Rainwater harvesting, in the simplest of terms, can be defined as the method of capturing the rainwater where it falls, storing it for longer

duration and utilization it as and when needed for various purposes e.g. agriculture, industry, drinking and recharge of ground water etc. Rain water harvesting was prevalent in Europe in early parts of the nineteenth century and in the United States near the end of the nineteenth century. Since then, many studies have been reported in literature on using the concept of rain water harvesting for artificial recharge of ground water throughout the world.

The rain water harvesting has become popular recently due to its apparent advantages e.g. bringing water for all, economic prosperity, drought proofing, capability of providing sustainable water systems in light of the limited water resources and increasing water demands due to population growth and economic developments. This paper makes an attempt to highlight some of the issues related to the possible impact of the rain water harvesting that need to be understood and evaluated carefully before implementing large scale rain water harvesting projects in major catchments.

III. POSSIBLE IMPACTS OF RAIN WATER HARVESTING

Some of the considerations that need deep insights and evaluation relating to the possible impacts of large scale rain water harvesting in a catchment include its impacts on the hydrological cycle in region, environment and water quality considerations, climate considerations, geotechnical considerations, seismic considerations and its impacts on infrastructure including buildings, bridges, roads, railway networks etc. There are many questions that need evaluation before large scale rain water harvesting projects can be taken up in catchment for continued long durations. Some of the important questions that arise are: What impacts the rain water harvesting can have on the hydrological balance of a watershed? Should rain water harvesting be practiced as a short- term or a long- term solution to the water crisis? Is rain water harvesting the only solution in an area; if yes, then to what extent it should be taken up? Is there an optimum level of area of a catchment that should be rainwater harvested? What can be the possible impacts of the rain water harvesting on the surface and ground water quality? Are the impacts to the environment, the hydrologic cycle, and water quality, if any temporary or permanent in nature? Are geo technical considerations important while developing large scale plans for the rainwater harvesting in a catchment? What about its impacts on the infrastructure, the storm-water and sewerage system, transportation sector etc? Should the rain water harvesting be taken up in high seismic zone? What can be the possible impacts of rainwater harvesting on the infrastructure in a high seismic activity zone? This paper attempts to offer deep insight on to the technicalities involved with some of these aspects in an attempt to answer some of these questions. Obviously, a lot of work needs to be carried out in order to answer some of these questions; however, an attempt has been made to offer some of the possible scenarios that may lead to the answer to some of these questions.

IV. HYDROLOGICAL CONSIDERATION

The water balance in a region is a part of the overall hydrologic-cycle. A hydrologic cycle is the natural engine driven by the forces of gravity and the heat energy provided by the Sun, which is responsible for the occurrence, moment and distribution of water available on the earth. The hydrologic cycle is a closed physical system that starts with the evaporation of water from oceans, movement of water vapor through wind action over the land masses, and precipitation of water on the land-masses in various forms such as rain, snow and hail etc. However, we need to restrict our attention to rainfall only, as it is the most common form of precipitation in India and also important from rainwater harvesting point of view. The rain falling on the earth goes through various component of the hydrological cycle e.g. interception and depression, infiltration , surface and sub surface runoff evapo-transpiration , deep percolation, ground water flow into streams etc. The understanding of the hydrology of a particular catchment is extremely important from the viewpoint of modeling and forecasting various components of hydrological system of the catchment and planning, design, operation and management of the available water resources in the catchment. The major hydraulic structures in a catchment, such as bridges and dams, are designed based on the current climatic and hydrological condition of the catchment. If due to certain reasons, the hydrological condition of the catchment change, such hydraulic structures may either become useless or unsafe depending upon the extent of the possible impact of human interventions on the hydrological cycle through various anthropological activities. Therefore, it must be kept in mind that the natural balance is of prime importance and it should be related to environment, ecology and hydrology of a region. The hydrological considerations for the impact of rain water harvesting have been dealt in two sections: surface water and groundwater.

V.1. HYDROLOGICAL CONSIDERATION FOR SURFACE WATER

Rain water harvesting essentially increases the time of storage of water in the watershed in different storage components viz. surface storage, subsurface storage, ground water storage etc. Storage of rain water in the catchment for longer duration may have possible impacts on the hydrological cycle that need to be properly managed. Increase of storage time will no doubt change the hydrological characteristics of the catchment. The immediate impact of storage of rain water in surface and sub surface component would be to reduce the runoff in a river at a downstream location. The practices of large scale rain water harvesting in upstream regions of catchment leads to the reduced surface water availability at downstream location in the catchment. This is because the surface water that used to contribute to runoff in a river would decrease due to its storage in rainwater harvested structure, limiting the surface water availability in the downstream portions of the catchment. The methods included a catchment monitoring network hydrological

modeling, and application of remote sensing technique, the Surface Energy Balance Algorithm for Land (SEBAL), for spatially estimating the total evaporation in the region covering the entire catchment of the watershed. The preliminary results indicated that the practices of rainwater harvesting have influenced the partitioning the rainfall, significantly reduced the surface runoff, and resulted in increased infiltration and deeper percolation in to the sub-soil. The impacts of rain water harvesting on the ecology and hydrology of a catchment need to be given due importance while making large scale rainwater harvesting plans in a catchment. There is a strong need to carry out research to understand the impacts of rainwater harvesting on catchment hydrology.

In the context of Chhattisgarh state which is the 10^{th} largest state in India with the topographical area of 1,35,194 KM^2 , rainwater harvesting will prove extremely beneficial since its 44% of the total topographical area of the state is covered with forests. Owing to adequate average rainfall of 1292 MM in Chhattisgarh and the prevailing larger forest areas, infiltration and percolation of rainwater in to subsoil will be more; on the same time surface accumulation of rainwater in to various water bodies prevailing in Chhattisgarh viz. ponds, rivers and reservoirs will also be more and in turn it will enhance water storage in to them to a significant extent and thereby enabling the surface water hydrology of Chhattisgarh quite sustainable. The growth of trees and vegetations in larger forest area of Chhattisgarh will give higher Potential evapotranspiration (PET) and hence adequate circulation of hydrological cycle.

IV.2. HYDROLOGICAL CONSIDERATIONS FOR GROUNDWATER

As discussed earlier, the effect of rainwater harvesting essentially is to increase the time of storage of water in the catchment. The harvested water resides in the surface, sub-surface, or groundwater storage components of the catchment. The storage of water in surface and sub-surface components of the catchment for long durations would mean the catchments being closer to saturation for longer durations throughout the year. A few more spells of rain, in such moist conditions, would obviously result in less infiltration and higher runoff. The higher soil moisture conditions would causes increased activity of water movement in the sub-surface zone. This may result into increased interflow component in overall stream flow at the outlet of the catchment. On the other hand, higher moisture in root zone will also mean high permeability that would cause increased infiltration. It is a well known fact that the hydraulic conductivity increases with the moisture content of the soil (Chow et al., 1988). Increased hydraulic conductivity of sub-surface zones would lead to more deep percolation, increased groundwater table, and increased base flow. Higher surface runoff, interflow, and base flow would mean increases in overall flow in streams and rivers. Raju et al. (2006) reported on the sub-surface dams to harvests rainwater in Swarnmukhi River Basin in South India. They analyzed the hydrographs of piezometer of four sub-surface water harvesting structures, monitored during October 2001-December 2002, and it was revealed that there was an average rise in the groundwater table of approximately 1.44 M in post-monsoon period and 1.80 M in the pre-monsoon period of the following year. This study clearly suggests that rainwater harvesting efforts lead to increases in groundwater tables in the region. Further, it is possible that the sustained rainwater harvesting efforts in the catchment over a long period of time (say a decade as in the case of rivers in Rajasthan) may lead to more surface flow in rivers and the rivers becoming perennial. The increased groundwater table and increased surface flow in a region can increased agricultural production and enhance the economy in an area. However, there is an optimum level of such activities as significant increase in groundwater table and surface flow may not be desirable as it may causes water-logging and flooding problems. These aspects need to be studied by hydrologists and researchers to ascertain the impacts of sustained rainwater harvesting efforts on the groundwater hydrology of a catchment.

The rainwater harvesting can be potentially harmful if not exercised with care regarding the water quality. Rainwater harvesting is normally exercised by storing surface runoff into ponds that contribute to groundwater by infiltration and deep percolation. The quality of the surface conditions would dictate the quality of the water being harvested. The existence of various contaminants on the residential and agricultural areas would find their ways into the rainwater harvesting structures. The infiltration and deep percolation of the contaminated water into the groundwater aquifers can cause the aquifers to be polluted making then unfit for drinking and other use full purpose. For example, most of the urban areas in India have waste disposal lands that are not properly maintained. The existence of harmful contaminants from industries is also high in urban areas. Many fertilizers are used for agriculture in rural areas that can find their way into the rainwater harvested ponds and then into the groundwater aquifers through infiltration and deep percolation. The leakages from septic system and sewerage networks will be able to find their way into the groundwater aquifers more easily and rapidly due to increased activity of water movement in the sub-surface zone. Many states (including Delhi and utter Pradesh) have passed legislation that every building must have rainwater harvesting structures to increased artificial recharge of groundwater. However, one has to be cautious about putting the water harvested from rooftops of buildings due to its quality. Recently, Meera and Ahammed (2006) reported on the water quality of rooftop rain water harvesting systems in India their study indicated that the quality of harvested water from roof catchments often does not meet the drinking water guideline values. The harvested water was found to be heavily contaminated microbiologically by a variety of indicators and pathogenic organism unless special care is taken during collection and storage of rainwater. It is to be noted that the damage to the groundwater aquifers may be permanent rendering them

unfit for water consumption of any kind or huge costs in remediation measures may be involved.

It is clear from the above discussion that any human intervention with the natural balance may have possible implications that may not be desirable. The practice of rainwater harvesting is gaining momentum in the Chhattisgarh and the entire country with the government and non government organizations alike. The center and state organizations responsible for water resources development are undertaking the practice of rainwater harvesting without considering its possible long term implications. The extent of changes in the hydrologic characteristics of a catchment would depend upon the extent of rainwater harvesting and the storm characteristics of the catchment. Since the characteristic of the catchment are unique in terms of its size, slope, land-use, soil type, storage and climate, it is clear that each catchment will have an optimum level of rainwater harvesting. The amount and duration of rainwater harvesting other than the optimum level may either result in adverse impacts and/or reduced benefits in order to assess the impacts of rainwater harvesting on the hydrology of a catchment and determined the possible optimum level of rainwater harvesting that should be adopted, the detailed hydrologic budget studies are necessary.

Other considerations

The large-scale rainwater harvesting over long period of time may affect the climate of a region. The climatic conditions of regions are characterized by the minimum and maximum air temperature, pressure, humidity, wind speed and direction, and intensity of solar insolation etc. The hydrology and climate of an area are often inter-related since the physical factors affecting the hydrologic and climatic characteristics of a region are common. For example, increased moisture in a catchment would cause increased evaporation that would in turn cause increased humidity and increased cloud covers. The presence of many large rainwater harvesting structures in an area over several years would tend to change the overall atmospheric moisture conditions of the area. Therefore, the dry conditions of an arid area will get affected overtime due to the increased humidity, cloud covers and a reduction in the sunshine hours. Such conditions would lead to modified evapotranspiration characteristics of the catchment that may affect the irrigation patterns and agricultural activities in the area. Further, the presence of aerosols and moisture in the atmosphere can form heavy fogs due to condensation during winters that can be hazardous to road, railroad, and air-traffic. Therefore, the changes in the climatic conditions also need to be given due consideration while planning large scale rainwater harvesting in watersheds.

The discussions above focused on the large scale rainwater harvesting or the community based rainwater harvesting. The rainwater harvesting can be exercised at an individual house or building complex level in urban areas that mat have some implications from geotechnical and seismic point of view. The load bearing capacity of a saturated soil is less than that of the unsaturated soil. The increased moisture condition due to rainwater harvesting may cause the load bearing capacity of the soils to decrease to an extend that the foundations of the existing buildings would compromised the "factor of safety" use for design. Liquefaction of soil can take place under extreme conditions leading to the failure of the foundation and the structures. Another problem of rainwater harvesting at individual housing level is the non uniform moisture condition in the sub-surface zone that may be created due to the existence of harvested rainwater on one side and a dry soil on the other side of a house or a large building. Such an even moisture conditions around a building may cause differential settlement of the building and failure of foundation in extreme conditions. The occurrence of earthquakes is not very uncommon in India. The seismic activity causes horizontal forces in the earth that travel up to long distance, which need to be resisted by the soil-foundation framework. It is known that the shearing capacity of the soil also reduces with an increase in its moisture content. It may be possible that the reduction in shearing capacity in soil may cause failure of foundations during earthquakes in rainwater harvested areas, which otherwise may have withstood the earthquakes of minor and moderate magnitudes. Therefore, rainwater harvesting should be exercised with caution giving due consideration to seismic activity in high risk zone, especially the urban areas. The transportation infrastructure in a catchment consists of roads, railroads, bridges, and tunnels. As mentioned earlier, increased soil moisture conditions in a watershed may lead to more stream flow and flooding problems. The existing transportation infrastructures are designed for the peak discharges computed for the current hydraulic conditions. In the hydrologic conditions modified due to rainwater harvesting, the factor of safety of the transportation facilities may be compromised and such structures may fail in extreme conditions. In a rare eventuality, if flooding and earthquake occur simultaneously, that can cause large-scale damages due to the "factor of safety" being compromised. The increase water vapor contents in the atmosphere coupled with the aerosols present due to pollution and combustion processes in urban areas may create heavy fog that can be extremely detrimental to the road, railroad, and air-traffic. Therefore, sunshine large-scale rainwater harvesting projects in urban areas may have possible impacts on the overall infrastructure in the watershed, which calls for their proper evolution and incorporation in overall long-term in an area.

CONCLUSIONS

The rainwater harvesting has become very popular in recent times due to its apparent advantages of bringing water for all, economic prosperity, drought proofing, sustainable development of the available water resources. However, there are potential impacts of large-scale rainwater harvesting in large catchment that need special considerations. This paper highlights some of them e.g. its impacts on the hydrologic cycle, surface and groundwater, foundations of buildings and other structures, its effects on climate and in areas of high seismic risks, etc. It appears that the impact of the rainwater harvesting efforts in a catchment would be to limit the surface water availability in

the rivers initially. However, a sustained rainwater harvesting effort over a long period of time may lead to increase of groundwater tables, increased surface flow, interflow, and base flows. Such increased water storage conditions in a catchment can be beneficial to certain extent but may become potentially harmful over time. Therefore, there needs to be a trade-off and an optimum level of sustained efforts of integrated catchment management and rainwater harvesting needs to be determined that does not affect the hydrology of the catchment to a large extent. The interference presented here are conceptual and to validate them a lot of research work is needed to be carried out to evaluate the impact of large-scale and sustained rainwater harvesting projects in large catchments. It is hoped that the future research decision makers to evaluate the possible impacts of the large-scale sustained rainwater harvesting practices in a catchment.

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