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The peri-urban to urban groundwater transfer and its societal implications in Chennai, south India – A case study

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ABSTRACT

The aquifer of the peri-urban/rural areas of Chennai Metropolitan Area in Tamil Nadu acts as a source of informal water market, and a huge amount of water is transferred and marketed by entrepreneurs, such as private water suppliers and packaged water industries. Water transfer from agricultural to non agricultural uses is not only common in India but most of the water starved developing countries experience it. It leads to temporal and spatial changes in the groundwater quantity and quality, and generates the inequity and affordability issues in accessing the water especially to the peri-urban poor. The paper analyzed the above issue with a case study conducted at Perumbakkam, a Chennai peri-urban village. The multivariate statistical analysis of field findings has been conducted in the peri-urban village for understanding the socio-economic implications of the groundwater market. The study identifies the major findings due to the prevailing informal groundwater market and emphasizes the institutional mechanism through regulatory and legal measures to protect the resource base and conservation and restoration mechanism to replenish the depleting resources.

Key words: Agriculture, Groundwater, Groundwater depletion, Groundwater degradation, Groundwater market, Multivariate statistical analysis, Peri-urban, Socio economic implication.

INTRODUCTION

In India, groundwater resources play a very important role in meeting the ever increasing demands of the agricultural, industrial and domestic sectors. At present, more than 85 percent of the domestic water supply in rural areas, about 50 percent of the water requirements in urban areas(domestic and industries) and more than 55 percent of the irrigation water requirements are being met only from groundwater (Romani, 2007). Many cities in India experience water shortage and the Water Boards are not able to provide an adequate quantity of protected water, particularly in summer or periods of monsoon failure. During these periods, the aquifer of the peri-urban areas or villages acts as a source, and a huge amount of water is transferred to the city formally and informally. In Chennai, round the clock operation of tanker supply plays a major role in managing water demand and there is no record with government department about their size, scale and mode of operation though they are having registered associations (Shah,2007). As the water becomes scarce worldwide, the transfer of water from the rural (agriculture) to the urban areas is inevitable, and it should be ensured with compensation and without any third party impacts or negative externalities (Singh, 2007;Zahra et al 2016; Bariot 2016). In the developed countries, the approach of sectoral reallocation of water in terms of agriculture water reorganization measure (AWRM), which captures excess water from agriculture for other uses, is adopted, by relying on the modernization of the existing irrigation infrastructure, and increasing the application efficiency etc.(Manjunatha et al. 2011).

The water markets that exist in India are informal, and are generally limited to localized water trading among the farmers for irrigation uses and between the peri-urban/ rural and urban areas for urban uses. Based on the data collected from Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB), in Chennai, the capital city of Tamil Nadu, the projected water demand for the year 2021 is 1763 at 140 lpcd. Whereas, the water supply including proposed schemes is estimated as 1562 MLD. Thus urban demand for water is increasing, and augmenting the groundwater resources from the peri-urban villages by private water entrepreneurs, has become common practice. The majority of the private water entrepreneurs target the land and water resources of the peri-urban interfaces. This leads to temporal and spatial changes in the groundwater quantity and quality, and generates inequity and affordability issues in accessing water, especially to the peri-urban poor. This paper analyzes the above issue of the peri-urban –urban groundwater market, especially for urban uses, with a case study conducted at Perumbakkam, a southern Chennai peri-urban village. The main aim of the study is to draw the

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attention of the policy makers to formulate a formal water transfer mechanism in order to eliminate the negative externalities.

MATERIALS AND METHODS

Frequent field visits were made to identify the villages which experience the potential water market. The study area is digitized using Arc GIS software on the 1:50000 topo sheet 66D/1(1975) collected from the Survey of India. Besides, official sources of data collected from the village panchayat (local governing body), social tools of stakeholder meetings, semi structured interviews and detailed interview schedules were conducted with a view to collect the information on various aspects of the groundwater market and its socio economic implications.

Stakeholder meeting is conducted in the preliminary process to understand the prevalence of groundwater market related issues and around 50 participants were participated from three water marketing villages. Out of three villages, Perumbakkam is selected to conduct the interview schedule with the households since it is located very closely with the urban networks than other two villages. Semi structured interview is conducted for water sellers and approximately 30 participants were participated to discuss the issue of water transfer, their water sources and cost analysis from source to consumer end. Enumerators are appointed to count the total number of tankers, by which the groundwater is transferred from the source village, through a well inventory survey, and these data were further verified by a round-the-clock counting of tankers at important road intersections for six consecutive days. The total number of packaged water industries was counted in the study village and the interviews were conducted separately with the owners of packaged water industries. In Perumbakkam, out of 3720 households, 186 (5% of the total households) were selected on the basis of stratified random sampling technique, and the interview schedule is conducted with the village households to know the socio economic implications, due to the informal water market. Data such as total residing years in the village, income level, education, water sources, quality, water level, status of agriculture, opinion on agriculture, water quality and water quantity collected from the interview schedule were analyzed using the Statistical Package for Social Sciences (SPSS). The multiple regression model has also been developed using the analyzed interview schedule conducted with the village people.

Study Area Description: Perumbakkam (located in Tambaram Taluk, Kancheepuram District), is one of the southern peri–urban villages of Chennai, selected to analyze the potential inferences of the groundwater market. The field survey indicated that a substantial amount of groundwater is transferred from the village by the tanker/packaged water suppliers to meet the urban demand. The village is situated around 15 Kms from the city boundary and 10 Kms from the coastal boundary (Figure 1). Once it was a typical agrarian village; now it has urbanized drastically due to its proximity to the city as well as people's migration from the city to the peri-urban area for improved residential facilities. The village covered an area of about 832 Hectares and the population is about 12000. It is surrounded by two tanks, namely the Peria Eri, and Sitteri and five ponds. The

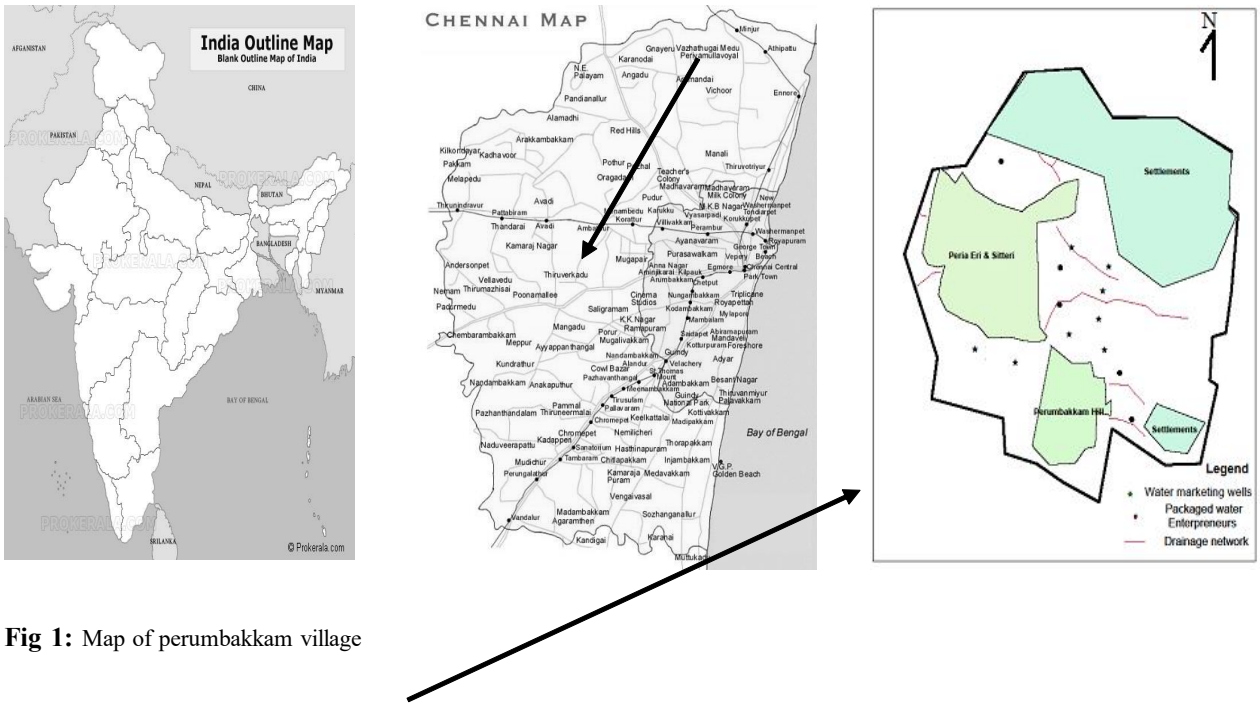

Fig 1: Map of perumbakkam village

Perumbakkam hill, fully covered with shrubs and bushes, and the areas located in and around the tanks and hills have appreciable groundwater potential. Earlier, the village people depended on the tanks (surface waterbodies) and open wells for their irrigation and drinking needs and were involved in intensive agricultural activities. Emerging urbanization activities and the water market in the Perumbakkam village impacted significantly on the water resources and agriculture.

Process of informal groundwater market: The increasing trend of the demand for water and the decreasing trend of supply sources make the demand-supply gap unavoidable, and this necessitates the informal groundwater market to cope with the demand. About 70% of the total supply of water for urban use is met through governing boards and people's own groundwater sources and the remaining 30% is met through the formal and informal groundwater market, i.e., transferred from peri-urban aquifers (Dattari, 2005 and Srinivasan, 2008). The transferred peri-urban groundwater reaches urban Chennai from the northern, western and southern directions, and from each direction approximately 20-40 MLD of groundwater is transferred informally for urban use alone. The estimated amount of peri-urban groundwater does not include the packaged water extracted by digging deep bore wells. Generally, the informal water suppliers (private water providers) target the peri-urban agricultural wells for their substantial water potential. Most of the agricultural wells in the study area (village) act as a source of informal water extraction, and the groundwater is extracted and transported through water tankers. The transported water does not reach the consumer directly. The private water entrepreneurs purchased the groundwater from the agricultural well owners, and sold it to the consumers without any treatment (tanker water). The tanker water is primarily used for domestic purposes. The packaged water industries extract the water by installing deep bore wells and treat it before selling it to the consumers for drinking purposes.

The packaged water is marketed not only for urban areas, but for a majority of households even in the peri-urban villages, depending on this water for their drinking purposes alone, as the quality of groundwater (raw groundwater) is getting changed over a period, whereas, the raw/untreated groundwater transferred through tankers is used mostly for domestic purposes. Some of the industries purchased the tanker water at a lesser price (Rs 50-75 per 12000 litres), and treated and sold it at a cost of Rs 25-30 per 20 litres. The demand for water has increased rapidly due to increased residential and industrial development and the prevailing uncontrolled commercial development of groundwater has added to the stress in the peri-urban village, resulting in severe depletion of water in the village. The total number of water tankers by which water is transported from the village is enumerated. Approximately 100 loads (12000 litres/load) of ground water per day from the 8 agricultural wells are transferred from Perumbakkam village, and the total quantity is 12, 00000 liters, that is, 1.2 MLD.

Besides, five packaged water companies are extracting a huge amount of groundwater, and disposing the rejection water, which has levels of high total dissolved salts (TDS) that are injurious to crop growth. The interviews conducted with selected owners of the packaged water industries revealed that approximately 4000 to 4500 water cans with a capacity of 20 litres each are transported to the customers everyday from the existing five packaged water companies. To make one 20 liter can, the groundwater extracted is twice that amount, and the rejection water is disposed either on the ground or the nearby agricultural field. Out of the five companies, one company has installed a recycling unit which utilizes 75 percent of the extracted water, while the other companies utilized only about 50 percent of the extracted water. Approximately 0.4 MLD of groundwater is extracted per day by each of the packaged water companies, and this quantity goes to produce 20 litre cans, pet bottles, water packets etc. Hence, it can be inferred that, a minimum of 2 MLD of groundwater is processed and packaged by the water companies. The water companies pump license/approval only for the day shift (8 hours). The total estimated commercial extraction from the study area by the private water tankers and packaged water industries is 3.2 MLD. But this estimated quantity varies highly due to the increased demand and unpredictable monsoon pattern.

RESULTS AND DISCUSSION

Perumbakkam is located close to the city limit, and is well connected by the road network. Since there are major developments in and around the village and the city is also easily accessible, people find it easy to commute and seek employment elsewhere in the city. Farmers, whose land is most in demand for urban activities, and owners of the agricultural plots with appreciable groundwater potential, are the real gainers and make windfall profits. An empirical research has been conducted to identify whether the prevalence of groundwater market creates any potential social impacts or threats. 186 households (5% of the total households) were selected on the basis of stratified random sampling technique, and the interview schedule is conducted in the Perumbakkam village. At the first stage of stratification, the households were divided in to farming and non-farming households and the second stage subdivided the households as long term settlers and recent settlers. The households which are residing more than 10 years considered as long term settlers.

Table-1 indicates the people's responses on the depletion and degradation of groundwater resources.

Though the responses are their perception but the identified respondents have undergone water related stress

Table 1: Reasons for the changes in water quality and quantity of groundwater resources in Perumbakkam village

Reasons for changes in quality	Percentage of responses	Reasons for changes in quantity	Percentage of responses
Disposal of wastewater	27.40[51]	Increased domestic and industrial demand	38.3[59]
Commercial extraction	31.20[58]	Commercial extraction	29.2[45]
Others	14.00[26]	Both	10[6.5]
Don't know	27.4[51]	Don't know	40[26.0]
Total	100.00[186]	Total	100.0[154]

(Source: Primary survey, 2010)

through the changes in the quality and quanity of their water resources over a period. They have opted the reasons for those changes based on their indigenous knowledge and their affinity with their resources. Among the total of the surveyed samples, 100% (186 respondents) reported the changes in groundwater quality, and 83% (154 respondents) of the samples stated the changes in the groundwater level. 31.2% of the respondents reported that commercial extraction is the major reason for the changes in groundwater quality, followed by 27.4% who opined the reason of disposal of waste water. The reason of local geologic conditions and the effects of monsoon variation were cited the option of 'others'. 27.4% of the respondents experienced the changes in the quality, but were unaware of the possible reasons for such causes. During the survey, the people stated that five years back the groundwater was used for drinking purposes, but now the quality as well as the taste is not fit for drinking. Due to the improper disposal of waste water from the industries, particularly from an edible oil processing company located near the village, and is on the upstream side of the tank, which disposed the waste water during the rainy season into the tank (surface water body) the water becomes unfit for any use. It is affecting the farmers who are dependent on the tank water for irrigation, and it causes a reduction in the agricultural yield. The major crop cultivated in the village is paddy. Earlier, the yield from the land was approximately 5625-6563 kgs per hectare, without the use of any chemical fertilizer except organic manure; but now the yield is reduced to 3750-4125 kgs even after applying fertilizers. Non- farming people stated that the increased settlements, improper sewage disposal and construction activities by the real estate developers, are the major reasons for such changes in the water quality.

During the survey, people said that their shallow open wells are defunct, and they have to go in for deep bore wells for a secure supply. Real estate developers have been constructing townships and apartment complexes for which they need giant open wells and very deep bore wells. The majority opined the reasons to be the increased domestic and industrial demand within the village itself and commercial extraction for urban purposes, for the changes in the groundwater quantity. The effect of urbanization in the peri-urban zone increases the emergence of settlements, and the industrial explosion augments the demand for water significantly. In the urbanized environs, the informal commercial development of groundwater increases the additional stress on the peri-urban aquifer. Among the samples surveyed, 26% of the respondents, who are unaware of the reason for the changes in the groundwater level stated the option of 'don't know'; the majority of that category is the recent settlers, who have been residing for less than five years, and they did not show any interest to express their opinion.

Spending pattern of drinking water in the village:
Social survey conducted with village people indicated that groundwater is the main source of drinking water in the village. Emergence of packaged water industries and commercial extraction of groundwater from agricultural wells distorted the groundwater quality and quantity significantly when compared with earlier years. During the discussion with the people they indicated the degraded quality of groundwater than the depletion status. Increased settlements and related unplanned sanitary systems, disposal of rejection water from packaged water industries and negligence of surface water sources and its contamination causes the changes in groundwater quality. As the present quality is not fit for drinking purposes, situation forces the people to depend on purchased water from the industries located in their own village. This questioning the imbalance and exploring equity issues as the common property resource is utilized only for well off people who own the deep bore wells and water industries.

The multiple regression model has been derived to explain the relationship between the dependent variable of the amount spent on packaged water(Y) and the independent variables of income X_1, household size X_2, their perception on groundwater quality X_3 and quantity X_4 for Perumbakkam village. The principle of multiple regression is to predict a single variable from one or more independent variables. Multiple regression with many predictor variables is an expansion of linear regression with two predictor variables. The computations are more multifaceted, however, because the interrelationships among all the variables must be taken into considerationin the weights assigned to the variables.

The prediction of Y is accomplished by the following equation:

Table 2 : Multiple regression on spent on packaged water and related independent variables in Perumbakkam village

Variables	Unstandardized co-efficient	SE of B	Standardized co-efficient Beta	t value	LOS
X_1	31.253	6.128	0.442	5.1	0.00
X_2	25.643	10.724	0.198	2.391	0.01
X_3	10.341	7.724	0.115	1.339	NS
X_4	7.323	5.859	0.107	1.25	NS
Constant	-32.444	27.298		-1.189	0.01

SE of B- Standard error of intercept

$Y'_i = b_0 + b_1X_{1i} + b_2X_{2i} + \ldots + b_kX_{ki}$

The "b" values are termed as regression weights and are estimated in a way that minimizes the sum of squared deviations

$$\sum_{i=1}^{N}(Y_i - Y'_i)^2$$

Table 2 shows the level of significance (LOS) of all the independent variables, and this explains the influence of independent variable on the dependent variable. Among the samples surveyed, 66 percent of the households use packaged water for drinking purposes in the peri-urban village and the amount spent is very significant, in view of their income, household size and their affordability. Standardized co-efficient expresses the relative importance of each independent variable in standardized terms. LOS values indicated that only income and household size are significant predictors, and income level has a higher impact than household size (beta = .442 and beta = .198). A Higher income level and household size influence the amount spent on purchased water. It is also evident, that though the lower income groups were well aware about the groundwater quality in the village, their income level prevents the usage of purchased water and people of higher income only influence the significant amount spent on packaged water. The following regression equation indicates the relationship between the dependent and independent variables.

Y (Amount spent on packaged water) = 32.253 X_1+25.643 X_2+10.341 X_3+ 7.323 X_4-32.444 ———— (1)

It concludes that changes in water quality has created the water related stress on poor than well off. The people of below poverty are not able to spent money to get protected water and the situation is forces them to use available marginal quality water even though they are well aware with the water quality.

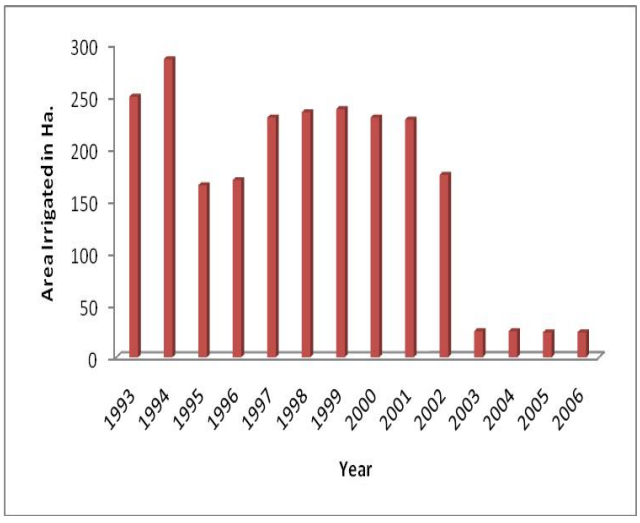

Fig.2 :Declining trend of agriculture in the peri-urban village

Status of agriculture: Increased urbanization and the issue of the water market started during 2000 and from that period onwards, the rigorous declination of agriculture also started. Fig. 2 depicts the decline of agriculture during 1993-2006 in the peri-urban village of Perumbakkam.

The increased labour cost, fertilizer cost, the profitable business of the sale of water for non-agricultural uses, and adequate non-agricultural employment opportunities, decrease the dependency on agricultural activities in the village (Shanmugam *et al*. 2010). Furthermore, the agricultural lands are used for residential purposes due to the increased land value in the peri-urban village (as the lands are highly demanded for non agricultural purposes), which is located very close to the urban centres. The area of agriculture has been reduced drastically from 300 hectares to 30 hectares during the period 1993-2003 and after 2003 it has stabilized. It proves that in recent years the peri-urban village has attained the crucial state of urbanization and related land use changes. Most of the agricultural land owners transformed as the real estate developers (for residential developments) due to its remarkable profits. The agricultural lands and their water sources highly demanded for urban activities with high economic value than agriculture. The declining trend of agriculture, transfer of groundwater beyond its boundaries, increased runoff due to the changes in land use, decreased recharge components, and increased discharge components, distorted the groundwater balance significantly in the peri-urban village. The studies conducted by several researchers were reported the similar evidences in the decline of agriculture and the related implications particularly in the

peri-urban contexts (Keith *et. al,* 2003; Shanmugam et. al, 2010). Out of the total households in Perumbakkam village, 63% opined as declined, followed by 25% and 12% who stated no opinion and no change. Among the 22% of the total households who have been in the village for less than 5 years, 90.5% stated no opinion. All households except those who settled in the village within the 5 year period could experience the changes in agriculture. Out of 42 responses among the recent settlers (less than 5 years of residing) 38 responses are 'No opinion' whereas long term settlers (above 15 years), out of 63 responses, 59 are 'accepted the changes in agriculture'(Refer Appendix-1). It is also evident that the long term settlers in the village experienced the declining trend of agriculture more than the recent settlers. Recent settlers have moved into the Perumbakkam village only for residential purposes. They have no affinity with the village community and its resources.

Geographically, the village is located near the east coastal boundary, the flow direction is towards the eastern side, and the drainage pattern is in the NW-SE direction. The agricultural wells and packaged water industries are located in the south-east direction; thus, the surface water as well as the groundwater is well captured and utilized, whereas the settlements are in the northern direction of the village. Since geologically, the settlements are located at the extreme end of the water potential area, the uncontrolled extraction for commercial purposes increases the stress on the water resources. A similar impact had also been experienced in Bangalore (Diwakara & Nagaraj, 2003), and the northern and western parts of Chennai (Ruet et al.2007). The rural-urban water market is increasingly common, adjacent to the large urban areas as well as the intermediate towns and it is unavoidable (Moench & Janakarajan, 2002). As the value of water increases for non agricultural uses, water will continue to move towards municipal, commercial and industrial users. But the quantification of the transferred water and updated groundwater data base is essential in order to ensure an efficient mechanism for sustaining the resources for the future. The diversity of institutional, legal and management measures across states is an issue, it is not only in the developing countries, but developed countries are also facing this critical issue as watersheds are not state delineated. Brookshire *et. al,* 2004, Bogardi *et. al*, 2012; Filimonau, 2016; Golin 2015).

The Chennai Metropolitan Area Ground Water (Regulation) Act, 1987, and the Tamil Nadu Groundwater (Development and Management) Act, 2003 for the whole state of Tamil Nadu have given the direction to regulate, control, and conserve the groundwater. The Chennai Metropolitan Area Ground Water (Regulation) Act 27, 1987, envisages the registration of the existing wells, regulations for sinking new wells, issuing licences to extract water for non-domestic use and for the transportation of groundwater. This act covers the city and the adjoining 302 notified villages, which have an appreciable groundwater potential. Most of the peri-urban water marketing villages are listed under these notified villages. But the governing authorities find it difficult to control or regulate the prevailing informal mechanism as per the given policy guidelines since it aids in minimizing the risk of water accessibility and serves to bridge the supply–demand gap. The governance and legal provisions in the peri-urban interface tends to be severely fragmented with multitude of actors and no single organization provides direction and regulation. Hence, the prevailing informal water market can be institutionalized through effective regulatory and legal mechanisms or by appointing apex body to regulate the entire process; Further, involving stakeholders from all the levels and bottom up approach rather than top down, attitudinal changes at all levels of authorities and political will without any self-benefit is also essential for creating the enabling environment. In this way, traditional users can protect their resource base, and enhance the environmental sustainability.

CONCLUSIONS

This paper analyzed the potential socio economic implications of an emerging informal groundwater market in the study village on the people's livelihood. Though the analyzed study focused on regional village scale, The village experienced on the one hand, a declining trend of agriculture, drinking water scarcity (quality-wise as well as quantity-wise), the necessity of depending on private water and the related economical burden; on the other hand, a huge quantity of groundwater was transferred from the village informally without any quantification.

The survey conducted in the village revealed that the existing open wells are defunct and the quality of water from the bore wells is not appreciable, except in the bore wells located near the water bodies. 36 percent of the households stated that the packaged water companies and the transfer of groundwater through tankers are the major reasons for the quality degradation and depletion of the water level. The results of the analysis show that dependence on packaged water increases the economical burden on the peri-urban poor and the prevailing issue of the groundwater market creates a potential impact in the village. The existing market system in the study village does not have any formal right or regulatory mechanism. Conservation and recharge measures should be adopted immediately in the hard rock areas, by constructing open shafts / open wells in and around the water bodies (till it reaches the fractured zone to inject the storm water effectively in monsoon times), by the construction of percolation ponds, adopting rainwater harvesting structures at the household level, protection of water bodies etc. The conducted study suggested that conservation and recharge measures should be implemented in the peri-urban villages particularly for the water marketing villages. In most of the Asian countries, the development of

groundwater is highly disorganized and it is dominated by the tiny well off private users (Shah et al. 2003; Punit kumar and Ajay kumar, 2017). Finally, the study stresses the necessity of a formal water market, and it is argued that the policies and legal framework should be more effective for the conservation and protection of water resources to provide an equitable and sustainable water transfer mechanism. Water management should consider not only freshwater management but also "used water management". Further, the study strongly suggests that local governance is to be strengthened to adopt the necessary action to improve the water accessibility in the peri-urban villages, thereby reducing the inequity issues.

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