WATER RECYCLING IN MASHHAD PLAIN (EFFLUENT MANAGEMENT: OPPORTUNITIES AND THREATS)

RECYCLAGE DE L'EAU DANS LA PLAINE DE MASHHAD (GESTION DES EFFLUENTS, LES OPPORTUNITÉS ET MENACES)

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ABSTRACT

The Mashhad plain in the North East of IRAN is confronted with an extended and in-creasing water crisis. The volume of water exploitation is more than mean of renewable water. The groundwater balance is disturbed and its level declines every year. But the population and industry growth require more water every year. In Mashhad plain, the quantum of raw wastewater from houses, hospitals and industrial sites is increasing and this can become a serious threat to useable water availability in Mashhad plain. If the untreated waste water contaminates the surface and the groundwater or is directly used for irrigation, the environmental pollution and pollution of water resources will create a catastrophe in the region. Whereas the water availability could be greatly increased if the raw wastewater is properly treated for safe agricultural use.

The water recycling plan for Mashhad plain has begun from 2008 in Mashhad. In this paper, we present the plan and its performance till date in qualitative and quantitative management of water for various types of water consumption without causing undesirable after effects.

Key words: *water basin, aquifer, deficit of ground water, wastewater, effluent, recycling water.*

RESUME ET CONCLUSIONS

Les plaines de Mashhad avec 2222 km² (2% de Khorassan Razavi province) a une moyenne annuelle de précipitations de 251mm, et 51% de la population éthnique de Khorassan Razavi et de villes de Chenaran, Torghabe, Shandiz et Razavieh habite ici. Il n'y a pas de cours

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d'eau permanent ayant un débit élevé dans la plaine de Mashhad. Ainsi, 82% des eaux souterraines de la plaine est prélevée pour buts agricole, potable, sanitaire et industriel. Le volume de prélèvement des aquifères Mashhad est devenu déséquilibré depuis 1968. A partir de cette année jusqu'à l'an 2010 le prélèvement d'eaux souterraines fut poursuivi. En outre, la tendance de la pollution des eaux souterraines s'est aggravée, et la contamination des eaux souterraines a un rythme croissant. Basé sur une recherche pour la prédiction du niveau d'eau souterraine, il est dit que la population de 2031 (1400 du calendrier iranien) de la métropole de Mashhad, sera de 4,4 millions de personnes qui consomment 267 millions de mètres cubes d'eau potable pour les services et la santé. La quantité des eaux usées est de l'ordre de 253 000 000 mètres cubes. L'utilisation de ces eaux soit par filtrage, soit par percolation au niveau du sol aura un effet ad-verse sur l'environnement, et pourra affecter le peuple de cette région. Si le total des eaux usées sont collectées et transférées aux usines de traitement standard, avec la coopération des coopératives des effluents, le recyclage des eaux usées dans la plaine de Mashhad atténuera en partie la pénurie d'eau de la métropole de Mashhad. Pour l'avenir, Mashhad aura un niveau durable d'eau souterraine, la dégradation des aquifères sera terminée et la crise de l'eau avec l'équilibre de la nappe phréatique sera réduite. Le plan d'effluents de Mashhad comprend 4 pro-jets. Les deux premiers projets furent achevé avec succès, et les deux autres projets sont main-tenant en cours d'exécution. Pour la première fois, se font la collecte des eaux usées de Mash-had, le transfert d'usines de traitement des eaux usées et de distribution des eaux usées re-cyclées (effluents) aux terres agricoles.

L'expérience montre que les problèmes pourraient être résolus avec la collaboration des usagers d'eaux usées, et avec la coopération et la collaboration des agences gouvernementales locales. L'établissement des coopératives des usagers et la gestion participative et la coopération de ces coopératives donne pleine satisfaction aux agriculteurs. Quoiqu'il y ait des problèmes, les responsables sont certains de la rentabilité de ce projet.

Mots clés : *bassin d'eau, aquifère, déficit de l'eau souterraine, eau usée, effluent, recyclage d'eau.*

1. INTRODUCTION

Mashhad plain is a sub basin of Kashafrud and Qaraqum catchment. The area of Mashhad plain is 9999 km^2 where 7777 km^2 are highlands and 2222 km^2 is Mashhad plain. In this basin the mean yearly precipi-tation is 272 mm equivalent to 2695 MCM. The volume of evapotranspiration is 1492 MCM and the vo-lume of renewable water yearly is 1203 MCM. From this volume 252 MCM is surface water of the plain and 951 MCM consists the water infiltration into aquifers. The climate of Mashhad is semi dry and the flow direction of surface and ground water is from west to east.

The metropolitan city of Mashhad is located in this plain and is the second largest and populated city in Iran. Also it is the fifth holiest city of the Shiite in the world and the first Holy city of Iran. The cities of Chenaran, Torghabe, Shandiz, and Razavieh are also located in Mashhad plain. While the area of this plain is 2% of the land of Khorassan province but 53 % of Khorassan population live in Mashhad plain Figure (1) shows the location of Kashafrud River, Mashhad catchment including the six dams in the plain of Mashhad.

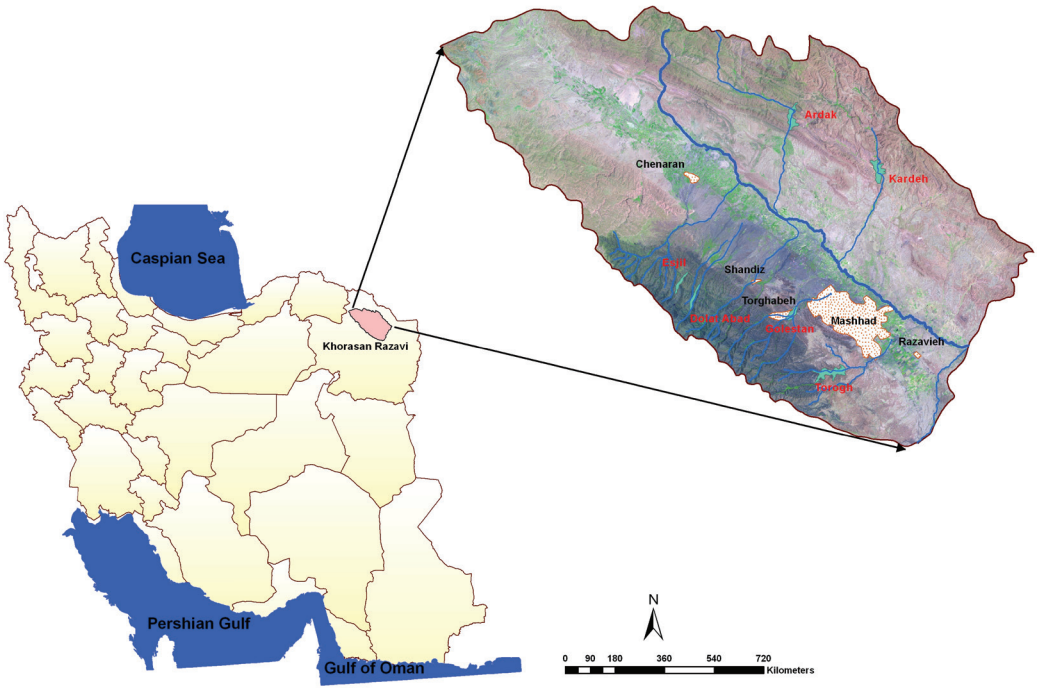

Fig. 1. Location of Khorassan province, Mashhad catchment, Metropolitan Mashhad, the six dams in Mashhad catchment : Kardeh,Torogh, Sajil, Dowlatabad, Golestan and Ardak

2. THE CHANGES IN MASHHAD PLAIN IN THE LAST FIVE DECADES

The Mashhad plain had been confronted with a lot of changes since last 5 decades from 1335(1956) to 1385 (2006). The following are the most important changes in the last 5 decades:

- The data in 1347 (1968) shows that the trend of withdrawal of rgroundwater had been more than the volume of water infiltrations. Therefore withdrawal of water was forbidden by order.
- The explosive population growth of Mashhad metropolitan particularly in years of 1972 to 1986 with a growth rate of 6.1 % required increased attention to the level of health care and welfare of the people .
- Increasing the area under agriculture, which needed higher quantity of water for for irrigation.
- the increase in area of orchards and also the development of Industry.

The industrial growth accompanied with agricultural development has not been based on an approved program. The compatibility with science and nature and capacity of natural resources of Mashhad plain was ignored in such developments. A huge population migrated from war affected villages and small towns to Mashhad. Mashhad religious metropolitan became

a developing market for consumer goods and foods which necessitated development in agriculture and industry in Mashhad. Both industrial and agricultural developments were in need of water while the only available water in Mashhad plain was the limited sources of groundwater. The irrigation was performed in traditional methods, which were inefficient The growth in industry too, was not ideal. The high water consuming industries with high pollution hazard were selected while they were not matched to Mashhad water situation. The industries developed in sub-urbs of Mashhad, Shandiz , Torgabe and Chenaran where wastewater treatment facilities did not exist. Unfortunately, the withdrawal of groundwater from the prohibited and critical plain of Mashhad is continu-ing even now with increasing rate.

Surface water utilization from the plain of Mashhad

To utilize Mashhad surface water, several dams were constructed including Karde, Torogh, Dowlatabad and Esjil . Ardak dam is under construction. The location of the dams is shown in Fig. 1. According to development plans, about 150 million m^3 water from the friendship dam (Doosti dam –located in 167 km of Mashhad) will be carried to Mashhad from the beginning of 1390 (2011) to be added to drinking and health water supply of Mashhad and surrounding villages.

Withdrawal from underground water

In Mashhad, more tube wells with greater depths are constructed every year (Figs. 2 and 3).

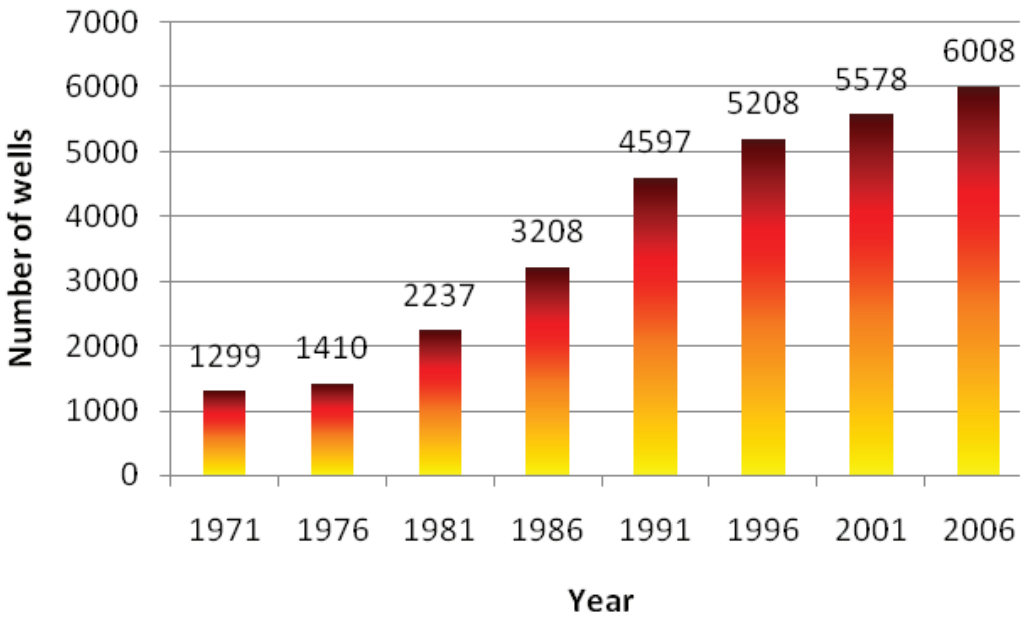

Fig. 2. Increasing trend of well numbers in Mashhad plain

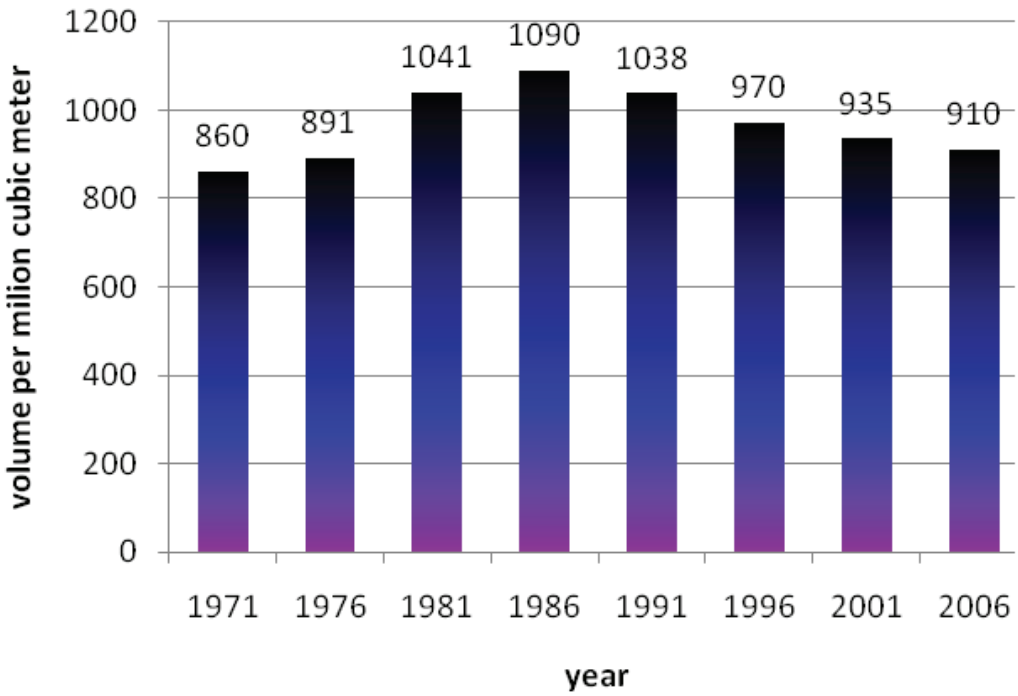

Fig. 3. Volume of water withdrawal from deep wells in Mashhad plain. Decreasing withdrawal began from 1986 because of water crisis in the plain.

3. GROUNDWATER WITHDRAWAL MORE THAN THE NATURAL REPLENISHMENT IN MASHHAD PLAIN

In the last 5 decades, groundwater withdrawal more than natural capacity and recovery potential from un-derground aquifers of Mashhad plain, has had the following effects:

- Decrease in the water availability from springs, qanats and wells and also drying up the water flows.
- While the level of underground water is decreasing , water is withdrawn from the deeper wells with higher energy consumption.
- Water Salinity and mixing of saline and fresh groundwater
- Irreversible decline of the groundwater table.
- Land subsidence and threat to sustainability of roads, rail roads, bridges, energy transmission towers, optical fiber installations and all construction.

Most of above results are being observed with increasing trend in Mashhad plain. The fall of Mashhad ground water level in the last 40 years is shown in Fig. 4.

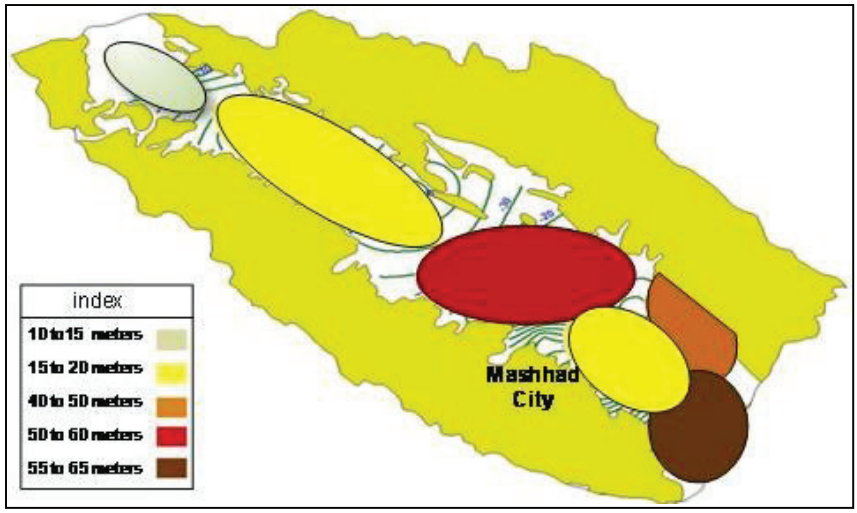

Fig. 4. Fall in groundwater table level of Mashhad plain in the last 40 years

4. POPULATION GROWTH, POTABLE WATER NEED AND WASTE WATER PRODUCED IN THE METROPOLITAN CITY OF MASHHAD

The growth of population in metropolitan Mashhad from the year 1335(1956) to the year 1410(2031) and the need for potable and health water and also the total volume of produced wastewater during the period of 1385(2006) – 1410 (2031) is shown in Fig. 5 and Fig. 6.

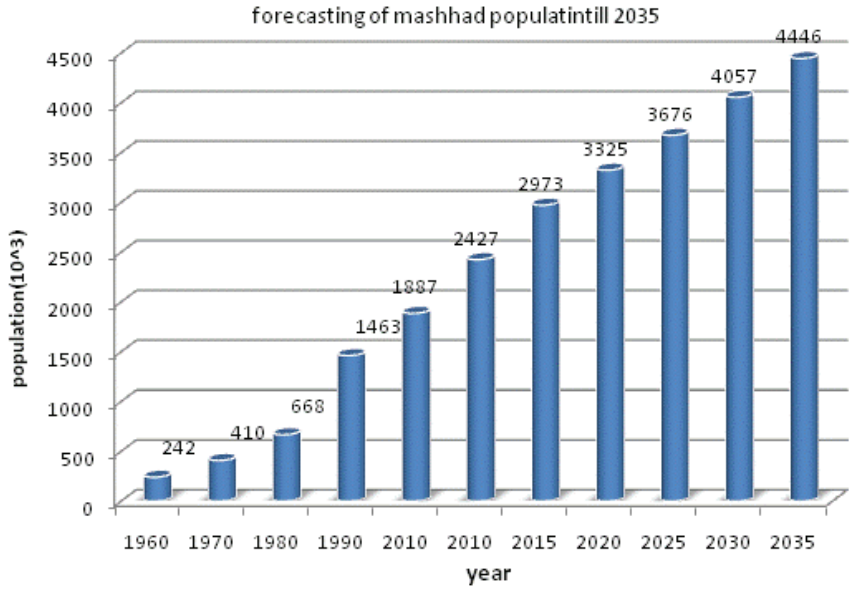

Fig. 5. Increasing trend of population in metropolitan city of Mashhad

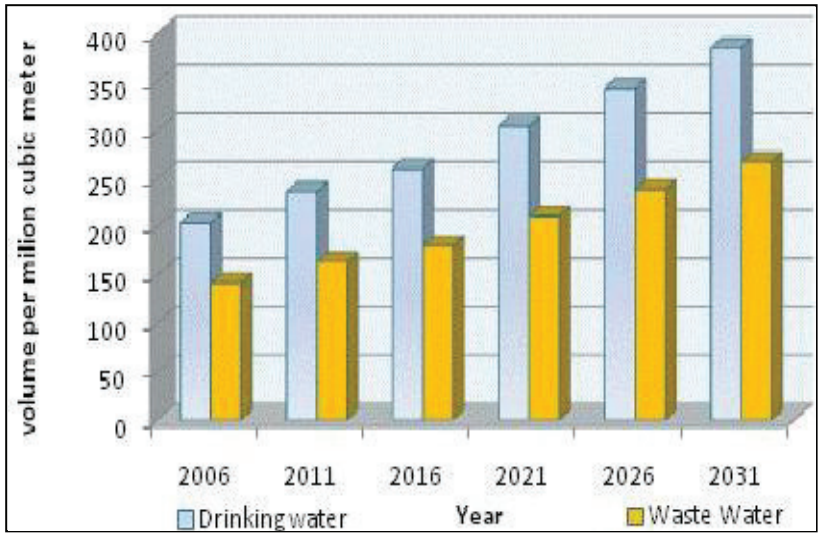

Fig. 6. Total supply of drinking water and production of wastewater

The growth in population and the greater demand of water accompanied with increasing wastewater gen-eration in the critical plain of Mashhad, although with a declining rate; from 1355 (1976) to 1365 (1986), has brought a lot of challenges and threats to water management in Mashhad.

The waste water generated in the metropolitan city of Mashhad

From the consumption of water in houses, health, industry, services and agriculture, part of it is polluted with different materials, making the wastewater. In Mashhad plain the largest volume of wastewater is produced as home sewage from the metropolitan city of Mashhad. There is no authentic data of waste-water generated from the agricultural sector.

In Mashhad plain from the year 1384(2005), some of the most untreated wastewater from houses, indus-tries , hospitals and public services were injected through wells into the aquifers and a little wastewater runoff flowed into the Kashafrud river and its tributaries .This method of wastewater management had the following consequences:

- Injection of increasing volume of wastewater with all kind of pollutions into the underground “Ab-khan“ of Mashhad has contaminated the groundwater. The eastern part of Mashhad Abkhan is depleting now and has already affected the well being of the city of Mashhad and the services provided.The pollution is so high that the drinking & health water wells in the east of Mashhad had to be abandoned.
- According to recent investigation, the volume of raw wastewater; about 1.5 m3/s, from the east and northeast of Mashhad flows through the lanes, streets and some merges with the Kashafrud river. The microbiological and parasitic pollution in such waters are very high relative to the permissible amounts to be released into surface water and the environment. The farmers in the suburbs of Mashhad use this polluted wastewater for growing vegetables and summer products. This phenomena will have disastrous results such as :

1. The serious pollution of surface and ground water in the east of Mashhad plain.
   - KashafRud River, the life line of the ancient civilization in the productive land of the KashafRud basin and a source of potable water is today polluted by raw effluent , has become a center of pollution and diseases with an unpleasant odors.
   - Production of vegetables and summer products irrigated with raw wastewater, is a severe threat to health, food security and in meeting the nutritional requirement of the population.
   - The irrigation of lands in surrounding of KashafRud will deteriorate the soil and its productivity in a long wastewater use in irrigation.

2. Concerning the above explanation, the following are the important threats when raw effluent is used for irrigation:
   - A trend of increasing and irrevocable deterioration of Mashhad underground aquifer and reduc-tion in withdrawal potential from wells even from the very deep wells , will create disastrous irrevocable results.
   - The severe scarcity of drinking and health water because of long period irrigation by wastewater, declining the surface and groundwater qualification while in the same time because of population severe growth, the demand for purified water will increase too. Utilization of more water will pro-duce more wastewater and more pollution of underground water.

5. A PLAN FOR COLLECTION, TRANSFER AND TREATMENT OF WASTEWATER IN MASHHAD CITY

Concerning the above discussion on scarcity of fresh water, the progress of crisis of water quality and quantity and the supply of potable water needed for drinking and health, the guidelines proposed here is the multiple use and recycling of Mashhad wastewater. According to the studies carried out in Mashhad under the subject of “Population growth, per capita water consumption and the need for health and pota-ble water “, the total volume of Mashhad wastewater and the total of purified effluent was estimated until 1410 (2031).Figure 7 shows this estimation.

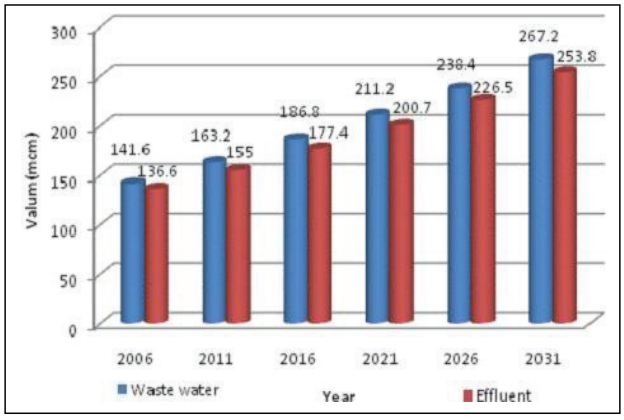

Fig. 7. Estimation of wastewater and effluent production of Mashhad metropolitan city (million m^3/y)

With the collection, transfer and treatment of Mashhad wastewater according to scientific standards and to replace this treated wastewater with agricultural water right of farmers from the dams of Mashhad, a threat will be changed to an opportunity, the groundwater situation will improve and the city will have enough water to be allocated for city needs of potable and health water.

The operational execution of collecting wastewater has begun since 1372 (1993) but the execution of re-cycling plant and utilization of effluent from some wastewater treatment plants actually began from 2002 and is in progress now. According to the development program of Mashhad wastewater, there are two operational wastewater treatment plants in Mashhad, producing treated sewage now and one is under construction. Three other wastewater treatment plants are to be conin the future. The program of produc-tion effluent acceptable for irrigation is shown in Figure 8 and Table 1.

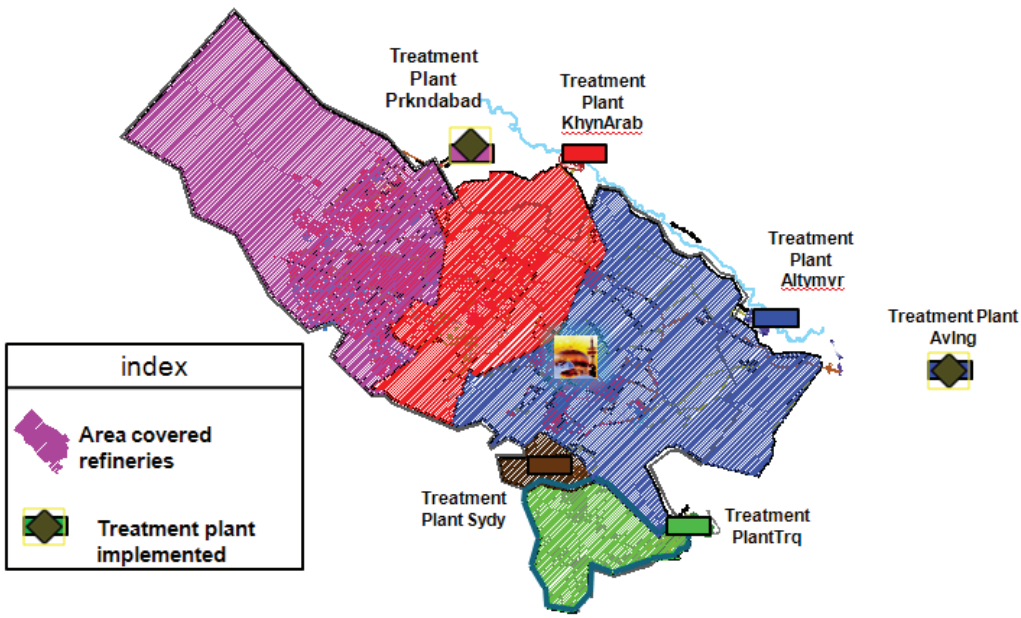

Fig. 8. Location of wastewater treatment plants

Table 1. Waste water treatment plants program in the Holy City of Mashhad

1410	1405	1400	1395	1390	1385	Year / Title	
1836	1640	1412	1202	906	655	Populations to humans	Treatment Plant Prkndabad
330	267	202	148	110	51	Average waste produced: 1000 cubic meters per day	
1280	1166	1034	911	819	725	Based on 1000 population	Treatment Plant KhvnArab
230	180	120	81	47	7	Average waste produced: 1000 cubic meters per day	
2117	1906	1730	1552	1424	1304	Based on 1000 population	Treatment Plant Avlng and Altymvr
173	173	173	99	40	10	The average wastewater production Avlng 1000 cubic meters per day	
200	117	12	0	0	0	The average wastewater production Altymvr 1000 cubic meters per day	
153	130	123	103	9	7	Based on 1000 population	Treatment Plant Sydy
26	22	17	10	4	0	Average waste produced: 1000 cubic meters per day	
285	200	136	109	85	54	Based on 1000 population	Treatment PlantTrq
49	31	19	9	2	0	Average waste produced: 1000 cubic meters per day	

Iran year:	1385	1390	1395	1400	1405	1410
English year:	2006	2011	2016	2021	2026	2021

6. THE PROJECT OF RECYCLING WASTEWATER IN MASHHAD PLAIN

The project of water treatment in Mashhad plain was executed considering the threats of wastewater on deterioration of the groundwater, subsidence of lands because of over withdrawal and continued scarcity of water in Mashhad city and in small towns of Torgabe, Shandiz, Golbehar, Chenaran, Razavieh and the surrounding villages. The purposes of execution of this project were:

- To save the underground Abkhan of Mashhad and to stabilise the water table.
- Prevention from salinity of water resources and mixing of saline and fresh groundwaters.
- To supply drinking water, health water and industrial water for Mashhad.

Based on study project, 253 MCM/y is allocated to different sections as follows :

- 150 MCM/y to replace the use of existing and permitted ground water that is used now for drink-ing and health maintenance of the population of Mashhad city and the other towns in the suburb of Mashhad

- 95 MCM/y to replace the permitted water withdrawal in the west of Mashhad to stabilize ground-water table and to prevent mixing of saline and fresh groundwater.
- 8 MCM to supply water needed for industry and green spaces. Then the water from the reservoirs equivalent to water rights were allocated to Mashhad for drinking and health.

To implement the replacement project, the social consultant investigated the social and economic issues. First of all Associations of wastewater users were formed and the contract of cooperation between the association and the Regional Water Company were signed. Then the transfers of treated wastewater (ef-fluent) from the treatment plants to the fields of farmers in the down stream of dams were executed. In total, the project of recycling wastewater of Mashhad has four sub-projects. The location of sub-projects in recycling water project of Mashhad plain is shown in Fig. 9 and the location of the cities and recycling plants in Mashhad plain are shown in Figure 10.

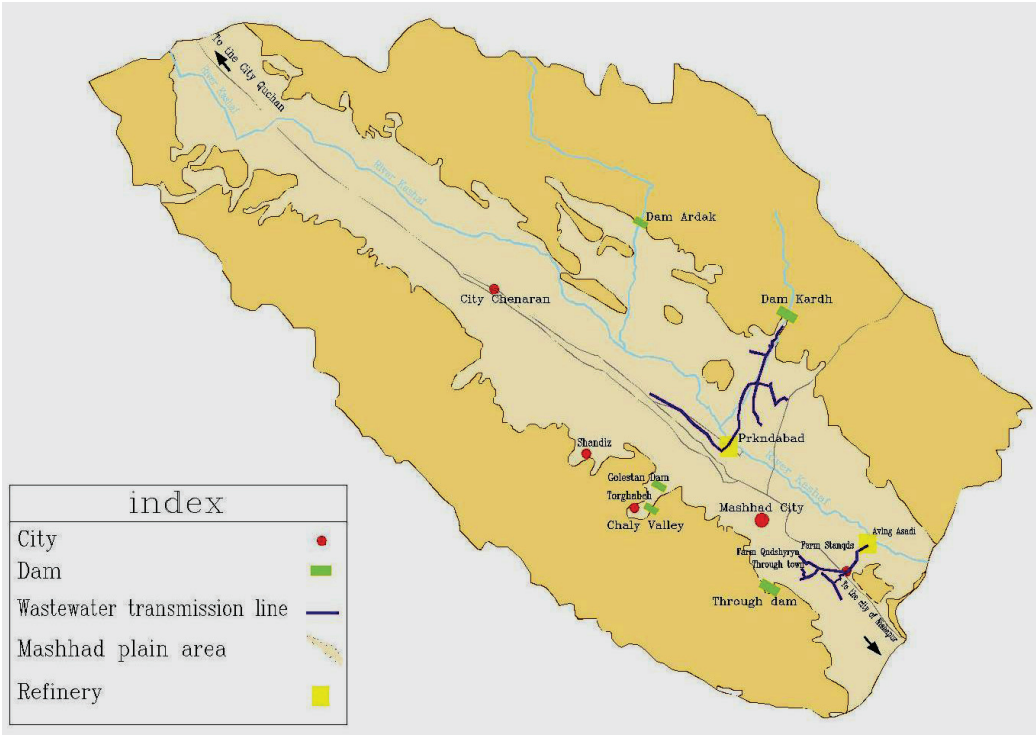

Fig. 9. Waste water treatment plantd in Mashhad plain

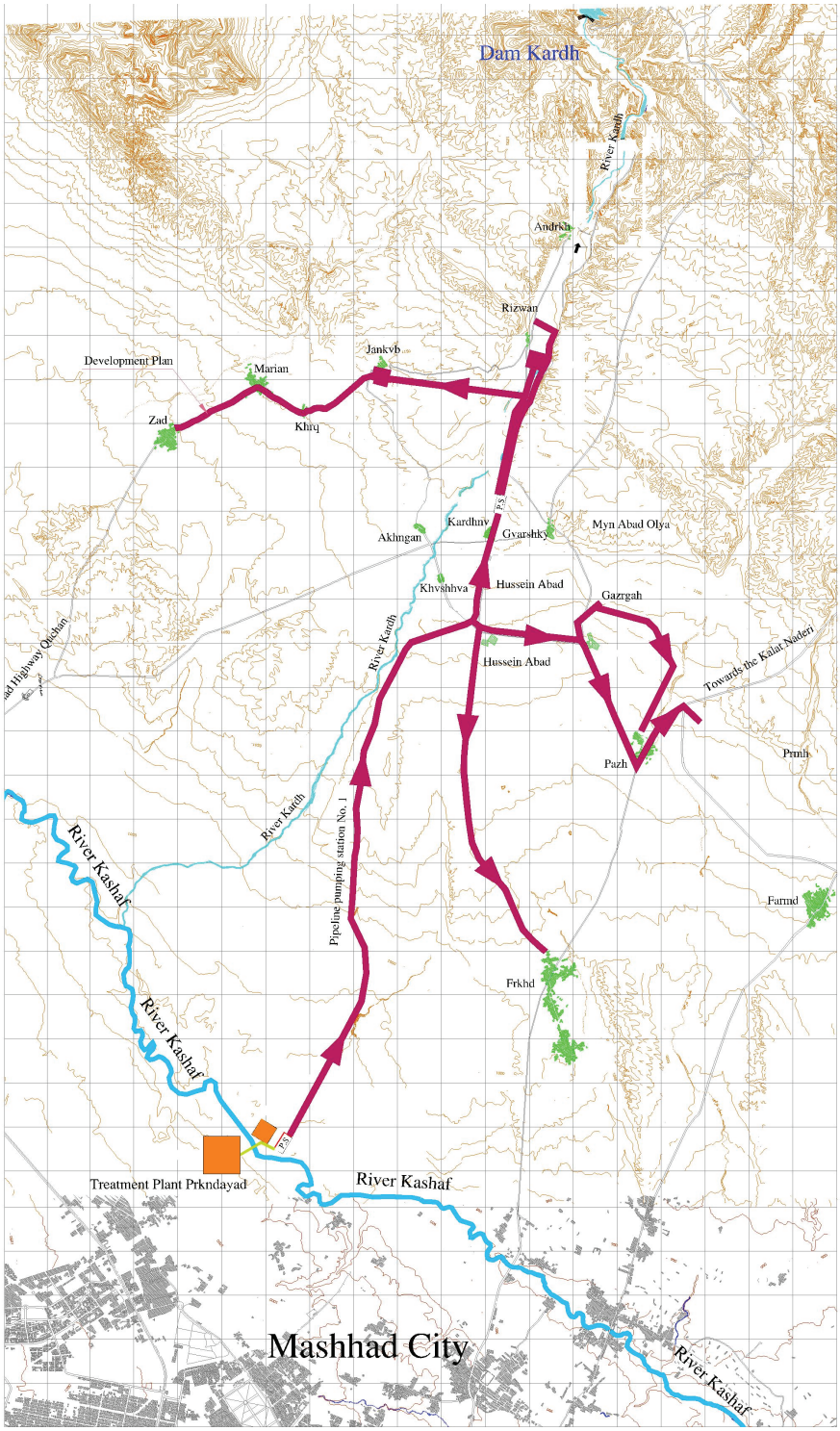

Fig. 10. location of the cities and recycling plants in Mashhad plain

6.1 Sub-projects of Recycling wastewater in Mashhad plain

- Replacing treated effluent with water rights of the farmers in the down stream of Kardeh dam :

Over the study area, 15 villages have the water right of 13 MCM from the reservoir. the equivalent allo-cation of treated effluent for them considering an enhancement by 1.2 times was 15.6 MCM. The project began in 1384 (2005). From then until now the treated effluent is pumped uplands to the agricultural fields and the agricultural water from the dam is transferred to the city of Mashhad to supply drinking water .

- The replacing effluent from wastewater treatment plants with water rights of farmers in the down-stream of Torogh dam

  The average water rights of farmers from the Torogh dam are 7.8 MCM in a year. This amount of water from the dam is replaced with 9.36 MCM of treated effluent .The project began its utilization from 1387 (2008) and at present the effluent is pumped to the agricultural lands while the equiva-lent water from the dam is transferred to Mashhad for drink and health.

- The replacing effluent with the right of withdrawal ground water in the sample fields of Astane Ghods Razavi

  This sub project is under execution. The right for exploitation of water from 52 deep wells with average of 32 Mm^3 right of exploitation in the year will be replaced by treated effluent. A part of the well water will be supplied to meet Mashhad drinking needs and a part will remain in ground reservoir to stabilize the groundwater table.

- Substituting treated effluent with the right of exploitation from the wells in the west of Mashhad

In the recycling water project in Mashhad plain and replacing effluent with water wells in the fields of Mashhad, the transfer distance covers the largest area. The maximum recycled wastewater, about 160 Mm^3, will be allocated in this sub-project.

7. PATHOGENS IN WASTEWATER RECYCLING PLANT IN MASHHAD PLAIN AND THE GUIDELINES TO REMOVE THEM

In the two sub projects of replacing effluent with water of Karde and Torogh dams the following problems exist that may be resulted in disastrous situation :

- In recycling plan and utilization of effluent it is necessary to distinguish the kind and quality of wastewater that is going to be collected and also the type of utilization of treated effluent, the ef-fluent users' commitments, location of utilization and the degree of effluent treatment. The waste-water treatment plant should be selected, designed and constructed so that least damage is caused to the environment, region and particularly to the settlements of the surrounding area. The potential of purification and treatment in determined volume should be defined beforehand.

- Because all the above condition were not considered in the total recycling project, the quality of effluent has not met the standards in utilization for agriculture. Although with continued examina-tion and tests the quality of effluent is improving, but the effluent is not completely qualified and we hope the out put of the wastewater treatment plant would be improved to meet the required standards.
- The effluent user cooperatives and their families have not been trained as needed for their protec-tion from health threat. In this connection the regular and timely training courses should be orga-nized for them.
- The cultivation and agricultural product in the region of effluent utilization should be selected commensurate with the quality and kind of effluent used. This improvement should be performed as soon as possible in the study area.
- At present, there is no control and no investigation on the effects of effluent utilization on the health and environment. There is also no study on the influence of effluent utilization on ground water and soil as well as the pollution effects on effluent using products and product users. It is necessary to examine and do a scientific and comprehensive survey with respect to all the above mentioned items so that the probable vulnerability and damages be recognized and guidelines and solutions to remove the problems be proposed and executed. Regular, periodic and conti-nuous control of mentioned issues, their documentation and continuous improvement is neces-sary to prevent the undesirable consequences of using the effluent.

To protect the soil from accumulation of pollutants, it would be necessary that few times in the year the agricultural lands in the study area be irrigated with the fresh reservoir water. At present time there is no fixed and official water allocation for animal husbandry. Certain amount of water from Karde and Trogh dams should be allocated for this purpose also.

8. CONCLUSIONS

The Mashhad plain, where the second largest populated metropolitan city of Iran is located, is confronted with severe qualitative and quantitative water crisis, which has been aggravating with time.

The growth and development of Mashhad city is not based on a scientific plan suitable and compatible with natural capacity of Mashhad plain. To supply water for Mashhad, considering water needs for a growing population and their various activities and the prevalent inefficiency of water use, it was planned to supply water through construction of several dams from some of the rivers. However, utilizable water in them is limited. Groundwater has been a reliable fresh water source, but many unauthorized wells with increasing depths are dug frequently, resulting in a strain on groundwater availability. Falling groundwater quality and land subsidence due to over mining of groundwater are common phenomena and the water depended structures are in danger of destruction . At the same time a lot of raw wastewater of Mashhad metropolitan city produced from citizen's overuse of water is flowing into the seasonal dry Kashafrud river and its tributaries contaminating the environment and posing a risk to the health of population and pollution of ground water. The farmers of the villages in the suburbs of Mashhad city located on both the sides of Kashafrud, cultivate vegetables and summer products using the raw wastewater from Kashafrud which threat severely the health and environment of Mashhad.

Day by day the water consumption by citizens is increasing and the volume of wastewater used for irrigation is also increasing. One solution to this problem is the multiple use of Mashhad waste water by suitable treatment. By substituting the treated effluent for agricultural water from the reservoirs of the constructed dams and allocation the reservoir water to the citizens in Mashhad the problem could be alleviated. So the threatment of wastewater and its use for agriculture could provide an opportunity to allocate fresh river water for drinking purpose and for maintenance of health in the metropolitan city of Mashhad. By recycling wastewater and preventing over exploitation of groundwater, the water table will come up and will be stabilized and the risk of water, land and soil pollution will be avoided.

The water treatment plant started in 1385 (2006) in Mashhad under four sub-project . Two sub projects have been implemented and two other projects are under execution. The rwater treatment plants had some strong and some weak points.

The most important strong points were recycling the Mashhad wastewater with cooperation and presence of active farmers' cooperatives; changing the great threat of raw wastewater to an opportunity of using the recycled water in irrigation, and save the land and people from the risk of pollution.

The most weak points were:

- Insufficient training of effluent users
- Lac of compatibility between quality of effluent with user need according to the established stan-dards
- The cultivation and products pattern were not adjusted with attention to effluent quality
- Lack of control on consumption of products irrigated with effluent and as a result no control on the result of consumption the products, on ground water table and water quality and quantity and on the change of soil quality. In this connection and to remove the threats, a scientifically drawn programme is under preparation and execution[2].

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