Chapter 7
Current and Future Industrial Water Use in the Zayandeh Rud Catchment

Wolf Raber and Shahrooz Mohajeri

7.1 Introduction

The Zayandeh Rud catchment is one of the most important industrial regions in Iran with a value added of approx. 14% of the GDP. Of strategic importance for Iran are large industry branches like steelworks, cement mills and oil refineries in the catchment. About 110 local mines supply industry with raw materials. Of the three main water using sectors – agriculture, domestic water services and industry – the latter consumes a proportion of 6–7% of the surface and groundwater resources of the catchment.

Industry in the catchment can be grouped into about 30 large industry units and about 13,000 small and medium sized commercial enterprises and manufacturers. Large industry is found exclusively in Isfahan province whereas smaller enterprises can also be found in the neighbouring province Charmahal va Bakhtiari. These approx. 180 small industrial units located outside of Isfahan province, while supplied by the Zayandeh Rud catchment, are of minor importance for the water management in the catchment.

In Isfahan province, around 315,000 employees work in the industrial sector. Small commerce and industry employ approximately 210,000 people and large industry 100,000, whereas about 90% are employed by two steel works alone. About 70% of the employees of small industries work in metal, non-metal and textile industries. An additional 3600 people work in mines and 1200 in industrial agriculture (e.g. large livestock and poultry farms) which is, according to Iranian legislation, a part of the industrial sector. From a (quantitative) water management perspective, mines play a minor role and are not discussed here.

W. Raber (✉) • S. Mohajeri
inter 3 GmbH Institute for Resource Management, Berlin, Germany
e-mail: raber@inter3.de

S. Mohajeri, L. Horlemann (eds.), *Reviving the Dying Giant*,
DOI 10.1007/978-3-319-54922-4_7

Although there are various surveys on the potentials and risks of further industrial development in the region (e.g. Bakhtiari et al. 2002; Reisi et al. 2011; Ghasemian et al. 2012), there is little known about the effects of – particularly future – industrial water consumption on the water resources in the catchment. Based on different criteria like groundwater tables, distance from water supplies, current land use etcetera Reisi et al. (2011) show that areas in and around Isfahan city suitable for industrial establishments are becoming less and less. Bakhtiari et al. (2002) found that resource efficiency in Isfahan province is very low posing a risk to further development. Yekom Consulting Engineers Company (2013a) suggest some measures for sustainable water use in industry, like reuse of industrial wastewater, based on data up to 2006. In three future scenarios Yekom Consulting Engineers Company (2013b) calculates the future water demand of industry based on the estimated increase of employees in the sector by 2041. Zayandab Consulting Engineers Company (2009) studied water resources and water use in industry in Zayandeh Rud catchment with the focus on industry in Isfahan province. The study indicates the main challenges related to water use in industry including the lack of statistical data and information as well unspecified amounts of water used in individual industries and hence pinpoints the basic reason for the survey presented in this chapter.

This chapter presents the findings of the industrial water consumption survey conducted within the IWRM Zayandeh Rud project. The survey's aim was to get an overview of current and future industrial water consumption and its relevance for IWRM implementation in the catchment, and to develop a coherent set of data which can be fed into the Water Management Tool (WMT, see Chap. 12).

7.2 Overview

The content of this chapter is selected and formatted according to available data and the specific requirements of the German-Iranian IWRM research project. It concentrates on the most relevant industries from an integrated water management perspective, which comprises more than 13,000 small, medium and large industrial units.

The presented figures originate from or are based on data selected in close collaboration with (1) local institutions like: Isfahan Water Board Company, Isfahan Water and Wastewater Company, Isfahan Industrial Organization and Industrial Settlement Organization, (2) interviews with representatives of large industrial units as well as (3) the review of reports on water consumption in the Zayandeh Rud catchment provided by Zayandab Consultancy Co. and Yekom Consultancy Co.

According to findings the total industrial water consumption in the catchment is approximately 200 MCM/a (reference year: 2006) including 48 MCM/a water consumption by industrial agriculture (reference year 2012). Next to a large quantity of small industries with minimal uptake of the overall water consumption, a few

large water consumers, mainly from the metal, petrochemical and power generation sector, are intense water users. In consideration of the diversity of industrial units in the catchment, we divided the industrial water consumers into four groups:

- The 30 largest single industrial units with a consumption higher than 500,000 m^3/a per unit, which currently have a share of approximately 57% of the total industrial water consumption in the catchment;
- More than 10,000 small and medium sized industrial units are clustered into 29 large industrial settlements and zones. Each settlement is expected to have a consumption higher than 500,000 m^3/a by the year 2025. These industries currently account for approximately 14% of the industrial water consumption in the basin;
- About 3000 small scale industries within Isfahan municipal boundaries. They are currently supplied with approximately 10 MCM/a drinking water by the Isfahan Water and Wastewater Company, which amounts to approximately 5% of the industrial water consumption in the basin;
- Industrial agriculture with livestock and poultry farms, aquaculture and greenhouses which currently account for about 24% of the industrial water consumption in the basin.

Large single industrial units, industrial settlements and zones and industrial agriculture are presented separately in this document, since the respective data sources and analyses follow different concepts. The water consumption of small industries within Isfahan municipal boundaries are expected to be constant and only represented in the overall conclusions (Sect. 7.6). Since these small industries are supplied mainly from the drinking water network of the Water and Wastewater Company there might be overlaps with the water balance of urban water use.

The water extraction of industries is presented with a certain volume per year (m^3/a) and for the different water sources: surface water, groundwater and water supplied by the Water and Wastewater Company.

Current industrial water consumption is presented and discussed with data from the reference year 2006 (and 2012 for agricultural industry). 2006 was a normal and wet year and due to water scarcity in the basin and limited economic development[1], consumption patterns of industry have not changed significantly over the past 10 years. Therefore, data from the year 2006 are presented in the following as current consumption patterns.

Furthermore, different trend and development scenarios are presented and discussed as an outlook for industrial water consumption in the year 2025.

[1]The international trade embargo on Iran was an important factor for a limited industrial development in the country.

7.3 Large Industrial Units

In close collaboration with the Isfahan Water Board Company the 30 largest industries were selected to be included in this study. The selection criterion for large industrial units was a current minimum water consumption of 500,000 m^3/a.

The analysis of the selected industries was based on provided data and communication with the Iranian institutions as well as quantitative surveys and interviews with specific industries. Quantitative surveys and interviews with selected industries contributed to a better understanding of water and wastewater management practices of the industrial units. Based on our interviews we learned that industrial waste water volumes and disposal are very complex and unexplored topics and require further investigation. Water management in large industries only partly follows international standards. Water efficiency is rather high and parts of the produced wastewater are evaporated in open ponds or used for onsite green space irrigation. Nevertheless further research can pave the way to more efficient water use and internal wastewater reuse, as well as possibilities of using treated urban wastewater in industry or reusing industrial wastewater in agriculture.

7.3.1 Current Water Consumption (2006)

The current surface and groundwater consumption of large industries were estimated based on water licenses of industries for the year 2006 transmitted by the Water Board Company.

During interviews with representatives of the largest industrial water consumers, it was found that three companies, Mobarakeh Steel Company, Esfahan Steel Company and Polyacryl Iran, combined use approx. 24 MCM/a less water than permitted by their licenses. In contrast, with 12 MCM, the consumption of the Power Plant Islamabad is twice as high as their water license. The compiled consumption patterns for the selected 30 large industries are formatted in yearly water extraction and presented in Fig. 7.1.

All selected large industries combined consume approximately 114 MCM freshwater per year. Four of these industries are named “other industries”. These virtual industries have been defined in collaboration with the Isfahan Water Board Company in order to represent unaccounted for large water users in the catchment.

Drinking water supply for workers of industrial units is already included in the calculations of the urban water sector, hence not considered in the industrial water balance and not further discussed in this report.

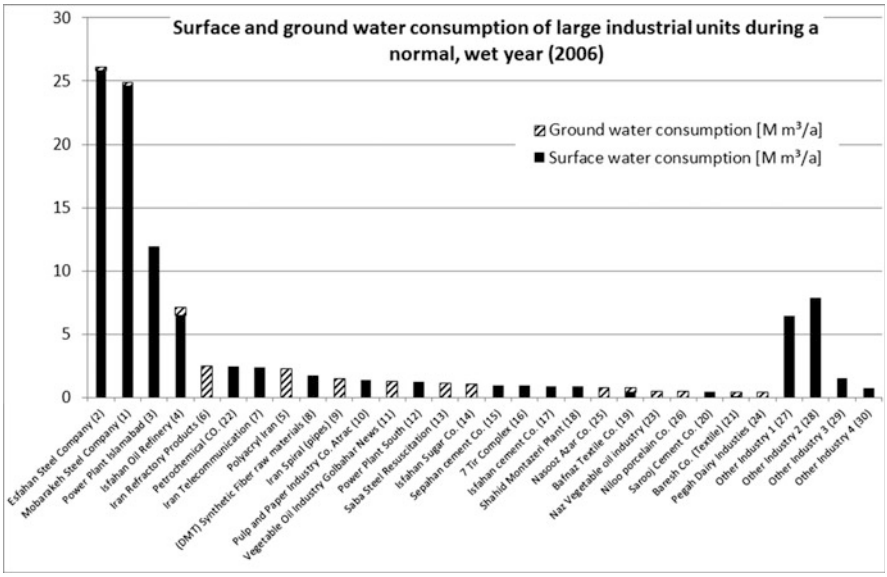

Fig. 7.1 Large industrial units in the catchment area with reference number in brackets

7.3.2 Current Water Sources (2006)

Different water sources were identified as important information for a water management process:

- Surface water
- Extracted directly from the Zayandeh Rud river;
- Extracted from one of the irrigation canal networks;
- Extracted from shallow wells close to the river, defined as bank filtration;
- Groundwater from industrial wells
- Water supplied by the Isfahan Water and Wastewater Company.

The share of surface water and groundwater extraction is specified by the water licenses of the specific industries (see Fig. 7.1). In 2006, large industries used about 100 MCM of surface water and 14 MCM of groundwater.

In collaboration with the Isfahan Water Board Company and the Water and Wastewater Company, it was found that during dry years, some large industries (Mobarakeh Steel Company, Esfahan Steel Company and Polyacryl Iran, Power Plant Islamabad, Isfahan Oil Refinery, Shahid Montazeri Plant, Petrochemcial Co. and Pegah Dairy Industries) compensate a temporal lack of surface water access by water supplies of around 6 MCM/a from the Water and Wastewater Company. The overall water consumption of all industries is constant during wet and dry years.

7.3.3 Future Water Consumption in 2025

The future trend of industrial water consumption is important for the meaningful planning of water resources. However, future industrial water consumption highly depends on global and regional socio-economic and political developments. Vice versa, the availability and development of regional water resources and management of the relevant sectors are the limiting factor for possibilities to settle new, water intense industries in the future.

As a result of scarce water resources in the catchment, new industrial development is currently limited. The establishment of new industries is only permitted exceptionally and requires a complex administrative process between Industrial Organization and the Water Board Company, and has to be approved by a regional committee of authorities (Committee # 24).

In the course of the IWRM Zayandeh Rud research project and through constant communication and exchange with the Iranian partners, two different scenarios for future water consumption of large single industrial units in the year 2025 were set up.[2] The two scenarios are largely similar but comprise some differences which result in a 107 MCM/a variance in the estimated future water consumption of large industries.

The first (and in view of the authors more likely) scenario is based on the fact that water resources are continuously decreasing and that water scarcity will have its respective impact on industrial water management decisions. The outlook expects a comparably moderate expansion of existing water consumption and settlement of new large industries, due to limited freshwater resources and moderate economic growth in the region. It includes the hypothesis that the ambiguous development goal for the industrial sector in terms of water consumption will not be fully implemented, but to a limited extent only. Scenario 1 anticipates that a production increase of large industry is granted rather by increased water efficiency and on-site wastewater reuse than on an expansion of their water licenses and consumption.

The second scenario is based on regional and national development plans, if these were to be fully implemented. The outlook assumes a stronger increase of water consumption of some existing industries as well as the establishment of additional new large industries.

7.3.3.1 Scenario 1(Allowing for Decreasing Water Resources)

For the water extraction outlook for 2025, the research team assumes that at most four additional large industries will settle in the Zayandeh Rud basin and influence

[2]While decisions on small and medium industrial settlements are rather taken at provincial level, the location of large industries is a national and strategic matter. For this reason the scenario development was only facilitated for this industrial segment and with the participation of national representatives.

the current water balance of the catchment. Existing extraction licenses will rise only for power plants and one refinery by 2025. The following four aspects are included in the scenario:

- During interviews with the industrial organization it was found that it is very likely that four new large steel and petrochemical industries are to be developed in the eastern part of the catchment due to development planning of the central government. These industries are expected to consume a total of 30 MCM/a in 2025, but their location and sources of water extraction remain unknown;
- The three companies mentioned in Sect. 7.3.1 (Mobarakeh Steel Company, Esfahan Steel Company and Polyacryl Iran) that currently use 24 MCM/a less water than their license permits them, will reach extraction rates up to full license capacity in 2025;
- Due to current limited production capacity, the Isfahan Oil Refinery will be expanded significantly. This will more than double the freshwater extraction with an increase of approx. 17 MCM/a;
- Due to population growth and increased industrial activities it is expected that all power plants will increase their water consumption by 10% by 2025. This also applies to the Power Plant Islamabad with its current overconsumption. The Shahid Montazeri Plant is directly connected to the Isfahan Oil Refinery and will increase its capacity and water consumption by almost 60% to 1.5 MCM/a, equivalent to the expansion of the oil refinery. All development factors will increase the water consumption of power plants by 2 MCM/a in total.

In scenario 1 the annual water consumption of large industry will rise by more than 60% to 187 MCM/a by the year 2025.

7.3.3.2 Scenario 2 (Full Implementation of National Development Plans)

For the water extraction forecast for 2025, it is assumed that most of the existing extraction licenses will not be expanded until 2025. Nevertheless the following increases in water extraction and new developments are expected:

- 12 new large industrial units will be developed within the Zayandeh Rud catchment according to development goals, with a total annual water consumption of 98 MCM. The focus of new developments will be on the steel and petrochemical and chemical sector. The specific location and water sources of these industries are still unknown;
- The three companies mentioned in Sect. 7.3.1 (Mobarakeh Steel Company, Esfahan Steel Company and Polyacryl Iran) that currently use 24 MCM/a less water than allowed according to their licenses will reach an extraction volume up to full license capacity in 2025. Furthermore, the two steel works will increase water consumption beyond that and combined will extract 28 MCM/a more than permitted according to their current water licenses;

- Due to current limited production capacity, the Isfahan Oil Refinery will be expanded significantly. This will more than double the freshwater extraction with an increase of approx. 20 MCM, which is 3 MCM/a more than expected in Scenario 1;
- Due to population growth and its direct connection to the Isfahan Oil Refinery and the Said Montazeri Plant, the power plants Islamabad and Sahid Montazeri Plant are expected to be expanded by 2025 and increase their combined water consumption by 11 MCM.
- In Scenario 2 the annual water consumption of large industry will rise by 160% to 294 MCM/a by the year 2025.

7.3.4 Interim Conclusions

Currently the total freshwater withdrawal of the selected large industrial units is 114 MCM.

Figure 7.2 shows the location and current water consumption of large industrial units in four classes, from less than 1 MCM/a to more than 10 MCM. The map displays the locations of the large industrial water consumers (grey circles) with their reference number (red number) from Fig. 7.2. The map shows that the majority of water extraction takes place upstream of Isfahan City along the Zayandeh Rud

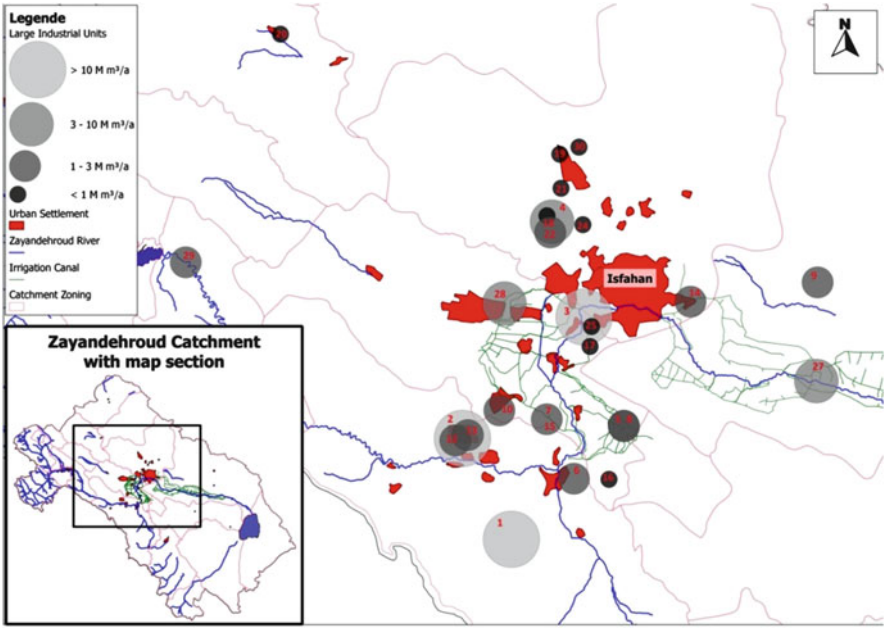

Fig. 7.2 Location and classes of current water consumption (*grey circles*) of large industrial water consumers (*red reference number* from Fig. 7.1) in the catchment

Table 7.1 Current and future water consumption of industrial sectors according to development scenarios

Sector of water consumption	Steel	(Petro) Chemical	Power	Building material	Building material
Current consumption (2006)	MCM	54	17	14	3
	% of total water extraction (114 MCM)	47%	15%	12%	3%
Future consumption (2025) Scenario 1	MCM	89	53	16	3
	% of total water extraction (187 MCM)	48%	28%	9%	2%
Future consumption (2025) Scenario 2	MCM	151	89	25	3
	% of total water extraction (294 MCM)	51%	30%	9%	1%

River or through irrigation networks which have their headwork there. It should be noted that the Borkahr irrigation system, which is located north-west of Isfahan city, is not on the map.

Table 7.1 shows that currently the dominant industrial segments of the large individual industries are steel, petrochemical and chemical industries as well as power plants. The four largest water consumers (Mobarakeh and Esfahan Steel Companies, Power Plant Islamabad and Isfahan Oil Refinery) consume 70 MCM/a (see Fig. 7.1), which is more than 60% of the total water consumption of large industries.

Furthermore the future trend scenarios presented in Sect. 7.3.3 anticipate a further expansion and increase of water consumption of the already dominant sectors. In Table 7.1 the sectoral increase in water consumption is presented for both scenarios outlined above. The calculation for these figures was based on the assumption that the industries which will be developed in the future are either steel or petro-chemical or chemical industries. Therefore the water consumption of these sectors rises extensively in both future scenarios.

The map in Fig. 7.3 shows which industrial units are expected to grow by 2025 according to Scenario 1. The displayed green number is the expected growth of water consumption by 2025 of the industrial unit (in percent, grey circle) where the number is written on top. The map shows that few large industries that extract water upstream of Isfahan city are expected to grow. The Isfahan Oil Refinery as well as the connected Shahid Montazeri power plant north west of Isfahan extract water directly from the Zayandeh Rud upstream of Isfahan. In scenario 2 mainly the same industrial units will grow, but to a higher degree (see Sect. 7.3.3). New industrial developments of both scenarios could not be located on the map.

Regarding the sources of water, currently (2006) only nine large industrial units rely mainly on groundwater and 21 companies rely mainly on surface water. The total groundwater consumption of large industries is only 14 MCM, in contrast to the surface water consumption of 100 MCM/a (88% of total consumption). Freshwater is mainly extracted directly from the Zayandeh Rud River (see Fig. 7.4).

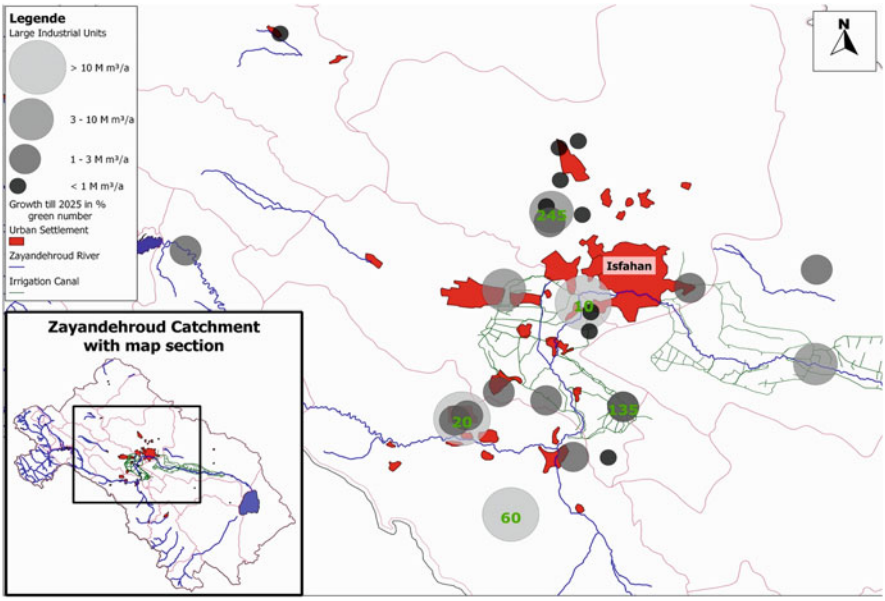

Fig. 7.3 Expected growth in water consumption of units (*green number* as %) on the map of location and current water consumption of large industrial units (Scenario 1)

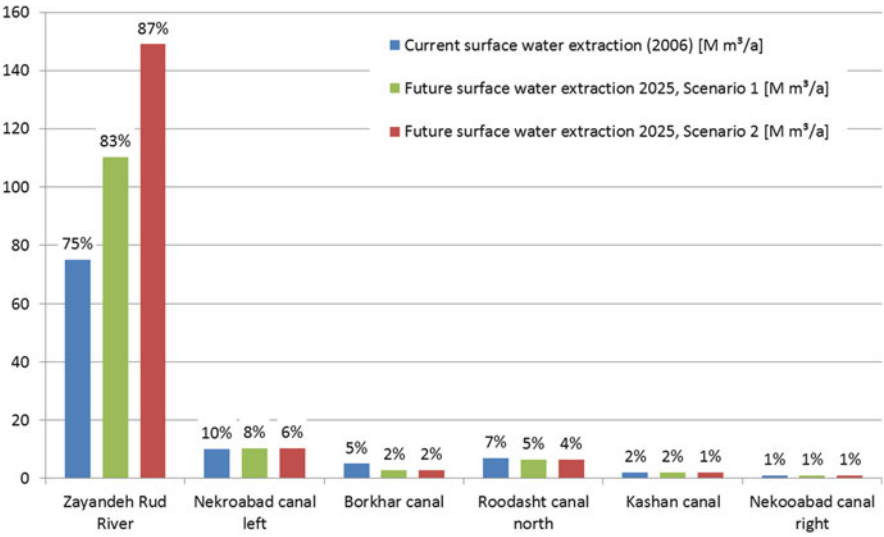

Fig. 7.4 Sources of surface water extraction in 2006 and in the future in 2025 according to scenarios 1 and 2, with percentage of total surface water extraction of large industry

In Scenario 1, the total water withdrawal of large industries is expected to grow up to 187 MCM/a by 2025. The four new industrial developments in the eastern part of the catchment (see Sect. 7.3.3) are expected to have a total consumption of about 30 MCM, while the water source is unknown and therefore not included in the

following figure. For the industries that have already been established, the water sources are expected to develop towards higher surface water use. In the forecasted water withdrawal scenario for 2025, groundwater extraction is expected to stagnate at approximately 14 MCM, and water supplied by the Water and Wastewater Company will rise to 10 MCM. The surface water extraction is expected to grow to 133 MCM/a (without the new developments) mainly due to increased extraction by large industrial units directly from the river (see Fig. 7.4).

Analogue, the expected surface water extraction of large industry in 2025 according to Scenario 2 is presented in Fig. 7.4. The planned 12 additional industries with approx. 98 MCM, water consumption are not included in the figures due to unknown water source and location. Besides the 172 MCM/a (without the new developments) expected surface water extraction, the amount of groundwater and water supply by the Water and Wastewater company is equal to Scenario 1.

Presented figures indicate that the high water consumption of large industries, particularly of the steel and petrochemical segment in the central part of the basin, are expected to grow even further in the near future.

7.4 Industrial Settlements and Zones

There are industrial settlements and industrial zones in the catchment. In the past, there have only been industrial zones, which are industrial units, clustered in one area. Industrial settlements have several industrial units in the same area, but also have a common administration in terms of a management board and are handled as one legal entity in terms of distribution of water licenses etc. In the future, the entire industrial development will be organized within industrial settlements; the only exceptions are very large or heavy polluting units. For simplification, in the subsequent document, the term industrial settlement will be used for settlements as well as for zones.

In close collaboration with the Isfahan Water Board Company, Industrial Organization and Industrial Settlements Organization, the 29 largest and most important industrial settlements with at least 10.000 single units were selected.[3] The entities either already have high water consumption or are expected to grow intensively by 2025, reaching a minimum water consumption of approximately 500,000 m^3/a. Currently the 29 settlements together consume approximately 28 MCM.

The locations of the industrial settlements were communicated by the Water Board Company. The Mahmoodabad and Jarghuyeh settlement is, geographically, located a few hundred meters outside the catchment, but since it is supplied by the Water and Wastewater Company, it is included in the water balance of the Zayandeh Rud catchment.

[3]The following zones and settlements were selected: Khomeinishahr, Mahmoodabad, Dolatabad, Morchehkhort, Faridan, Se Rahe Mobarakeh, Tiran, Karvan, Esfidvajan, Oshtorjan, Najafabad1, Najafabad2, Jey, Segzi, Kohpayeh, Harand, Varzaneh, Ezhieh, Meimeh, Alavijeh, Dehagh, Large north Isfahan settlement, Komshecheh, Mohamadabad, Jarghuyeh, Chadegan, Poodeh, Tudashk and Montazeriah.

Following the suggestion of the Water Board Company we clustered the following neighbouring settlements into five compound industrial settlements: Greater Area of Najafabad (Tiran, Karvan, Esfidvajan, Oshtorjan, Najafabad1 and Najafabad2), Greater Area of Jey (Jey and Segzi), Greater Area of Harand (Kohpayeh, Harand, Varzaneh and Ezhieh), Alavijeh and Dehagh, as well as Mahmoodabad and Jarghuyeh settlement. This approach results in 18 settlements in total, which are presented in the following.

Due to missing data, no quantitative information on wastewater production or management could be included in the study. However, it was communicated by the Industrial Settlement Organization that six industrial settlements: Mahmoodabad, Se Rahe Mobarakeh, Oshtorjan, Najafabad1, Alavijeh and Morchehkhort, have a wastewater treatment plant installed, and constructions for a treatment plant are ongoing in Jey industrial settlement. By 2025, 17 industrial settlements are supposed to be equipped with a wastewater treatment plant. Effluent from wastewater treatment plants is intended to be used for green space irrigation and in Morchehkhort settlement 50% of treated wastewater is being reused in the production process. To better understand these situations and their progressive approaches, the aspect of wastewater management in industrial settlements requires further investigation. In order to reach higher water efficiency in industrial settlements, detailed research on different industrial branches and the possibilities of wastewater reuse between industrial units should be elaborated on to reduce water withdrawal and the amount of polluted water emitted into the sewage system and open water bodies. Currently a case study on wastewater reuse between selected industrial units of the Morchehkhort settlement according to the Eco Industrial Park concept is being prepared by the IWRM research project.

7.4.1 Current Water Consumption (2006)

The water demand of each settlement is calculated according to a calculation formula (Formula 1) used and communicated by the Isfahan Industrial Settlement Organization. The formula is based on the built-up area of the industrial settlement in hectares. This way an estimated water demand of the settlement with the currently built-up area is calculated.

Formula 1

$$\text{current water demand of settlement} \left[\frac{\text{L}}{\text{s}}\right] = \text{build surface of settlement [ha]} \times 0.3$$

This calculation is applied for each settlement without considering the branches and other criteria for water consumption of the industries in the settlement. Using

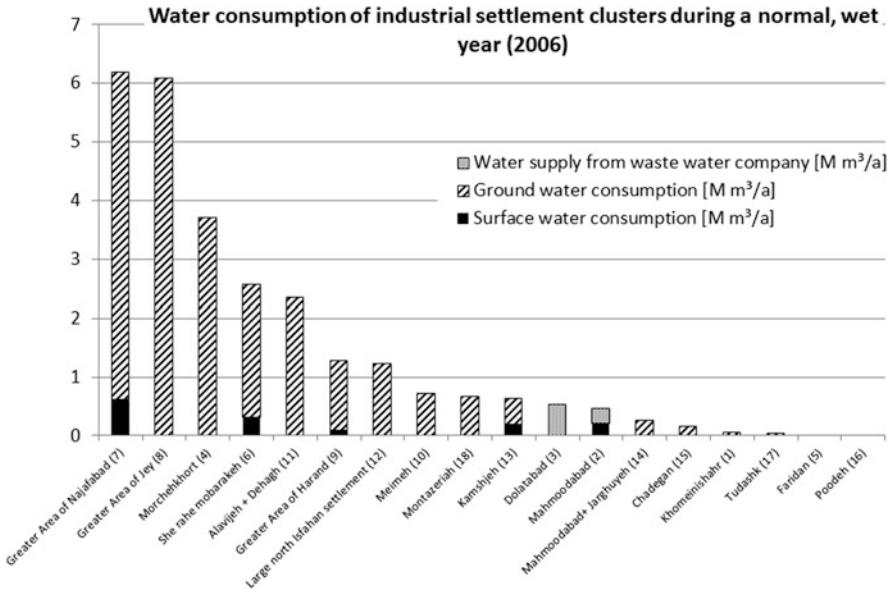

Fig. 7.5 Industrial settlement clusters with water consumption (2006)

this approach, the current (2006) water consumption of the 18 settlements was calculated and is displayed in Fig. 7.5.

7.4.2 Current Water Sources (2006)

The surface water consumption of industrial settlements is based on surface water licenses received from the Isfahan Water Board Company. Figures for water supplied by urban water[4] have been communicated by the Isfahan Water and Wastewater Company. The groundwater extraction of each settlement is calculated according to Formula 2 by adding the supplied surface water and urban water and subtracting it from the calculated water demand of the settlement.

Formula 2

$$\text{Ground water extraction} = \text{water demand (Formula 1)} - (\text{supplied surface water} + \text{urban water})$$

Analogue to large industrial units, the sources of water are:

[4]The water is usually treated and diverted from the urban drinking water supply network and as such is called urban water.

- Groundwater extraction from wells located in the area of the industrial settlements;
- Surface water extraction from the river and canals which are close to the industrial settlements;
- Water supplied by the Water and Wastewater Company, which was initially extracted at the Chamaseman Dam for drinking;
- The Alavijeh and Dehagh settlement is supplied by the Kashan Canal which has its headwork at the main Zayandeh Rud dam and is accounted for as surface water.

During dry years, the Water and Wastewater Company provides water to more industrial settlements than in normal wet years. The overall water consumption of all industrial settlements is constant in dry and wet years.

7.4.3 Future Water Consumption in 2025

Future water consumption in 2025 was forecasted by taking the following approach. For each settlement there exists a total settlement area and a currently built-up area. The assumption is that by 2025 all industrial settlements will develop their full surface and reach maximum water extraction. With the total settlement area and Formula 3, the future water demand of settlements can be calculated.

Formula 3

$$\text{future water demand of settlement} \left[\frac{\text{L}}{\text{s}}\right] = \text{total settlement area [ha]} \times 0.3$$

The establishment of new industrial settlements is currently restricted by the administration, due to water scarcity in the catchment. Requests from investors for new water licenses posed to the Water Board Company are currently pending.

7.4.4 Interim Conclusions

Figure 7.6 shows a map section of the Zayandeh Rud catchment with the locations of industrial settlements including their water consumption (grey circles) and their reference number (red number) from Fig. 7.5. The map shows that the settlements are loosely scattered throughout the catchment and are not as concentrated along the river as large industrial units. Compared to the large industrial units presented in Fig. 7.2, the total consumption of each displayed industrial settlement (grey circle) is smaller.

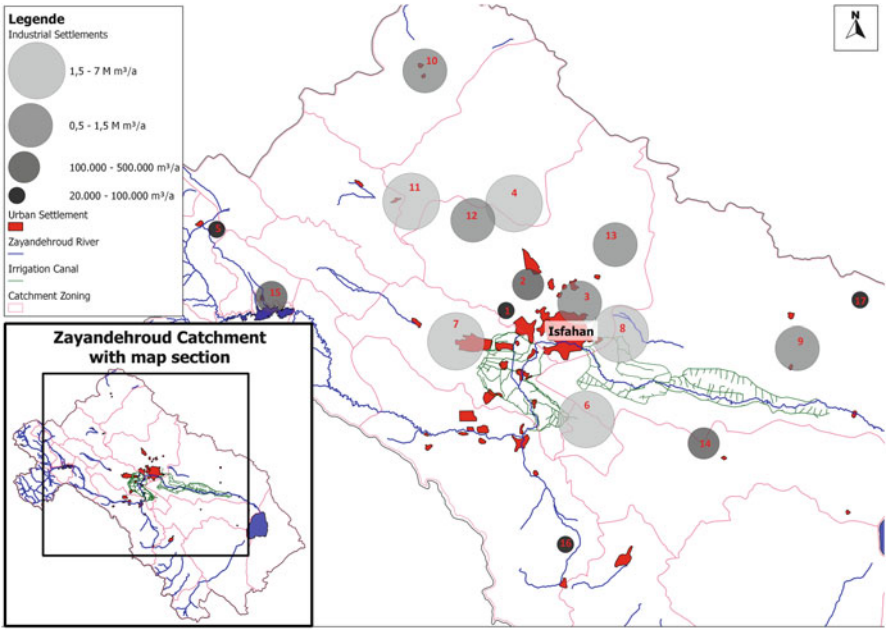

Fig. 7.6 Location and classes of current (2006) water consumption (grey circles) of industrial settlements (with red reference number) in the catchment

Currently (2006) the water consumption of industrial settlements is 27 MCM, of which about 92% (25 MCM) originates from groundwater. By 2025 all industrial settlements are expected to be fully built-up which will more than double the total water consumption to 62 MCM.

The map in Fig. 7.7 shows the industrial settlements that are expected to grow by 2025. The green figure represents the expected percentage growth of water consumption of the industrial settlement (grey circle) by 2025 where the number is written on top. The map indicates that particularly small settlements scattered throughout the catchment are expected to grow excessively by 2025.

In 2025 groundwater is expected to account for 83% (51 MCM) of the total water consumption of industrial settlements.

The presented figures show that the water consumption of industrial settlements will grow intensively in the next few years, putting pressure particularly on groundwater resources. If wastewater treatment capacities of industrial settlements do not grow as predicted, increased water consumption is expected to also impact negatively on the quality of surface water bodies.

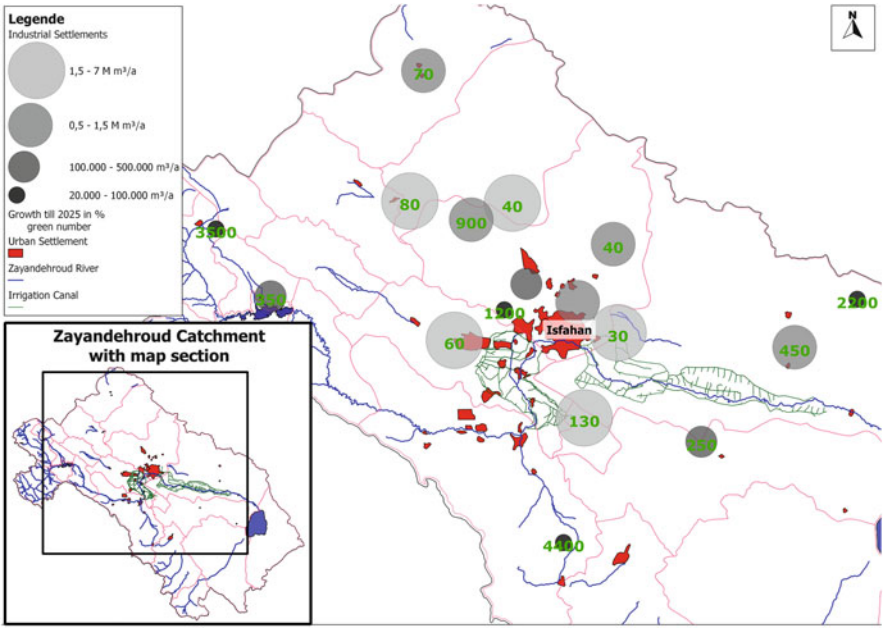

Fig. 7.7 Expected growth in water consumption of industrial settlements (green number in %)

7.5 Industrial Agriculture

Large agricultural production sites have been identified by the Jihad Agricultural Organization and it was decided by the Water Board Company to include them in the industry sector due to their industrial water consumption patterns. Specifically poultry farms, livestock farms (cattle, calves, sheep, goats and camels), greenhouses (vegetables, nursery of flowers and ornament plants) as well as aquaculture production sites (cold and thermal water fish) are defined as industrial agriculture and presented in this section.

The data originate from the Jihad Agricultural Organization and were provided by the Water Board Company.

7.5.1 Current Water Consumption

In contrast to the previously presented data, no specific units or exact locations of agricultural production sites could be presented due to a lack of data. Nevertheless, water consumption in the reference year 2012 is assigned to the counties in the Zayandeh Rud catchment in Table 7.2.

According to the Isfahan Water Board Company, consumption data are based on existing water licenses and county based statistics. No information on the amount of

Table 7.2 Current (2012) water consumption of industrial agriculture by county (source: Jihad Agricultural Organization)

Aquaculture	Greenhouses	Livestock	Poultry	Location
Total water demand (m3/a), 1391	Total water demand (m3/a), 1391	Total water demand (m3/a), 1391	Total water demand (m3/a), 1391	County
7,764,163	2,300,900	2,921,958	1,038,632	Isfahan
346,896	190,000	925,122	207,324	Borkhar
324,821	562,250	579,487	432,655	Tiran&karvan
368,971	14,100	558,188	46,969	Chadegan
63,072	1,264,700	641,445	125,005	Khomeynishahr
1,103,760	600,000	756,197	658,241	Shahinshahr& Meymeh
0	591,000	776,105	466,336	Shahreza
151,373	20,000	479,942	108,617	Faridan
3,815,856	25,650	116,272	22,794	Freydoonshahr
372,125	6,385,800	1,076,282	210,656	Falavarjan
387,893	27,000	211,799	121,585	Lenjan
977,616	2,423,000	597,481	114,776	Mobarakeh
1,056,456	383,260	1,163,503	738,694	Najafabad
0	1,333,500	0	0	Samirom (dehaghan)
16,733,002	16,121,160	10,803,780	4,292,283	

agricultural units or wastewater production could be delivered. Nevertheless, it is assumed that the single units consume less than 500,000 m^3/a each, and are dispersed widely throughout the basin.

7.5.2 Current Water Sources

No data regarding water sources or geographic locations of extraction points could be transmitted. According to the Isfahan Agricultural Organization, all industrial agriculture units cover their water demand by groundwater extraction.

7.5.3 Future Water Consumption in 2025

For the water extraction forecast for 2025, the Isfahan Water Board Company communicated data on the expected percentage growth of the different types of industrial agriculture. The predicted consumption is presented in the conclusions.

Table 7.3 Current and future water consumption of industrial agriculture (source: Isfahan Water Board Company)

	Aquaculture	Greenhouses	Livestock	Poultry
Current water consumption (2012) in MCM	16.7	16.1	10.8	4.3
Future water consumption (2025) in MCM	30.0	30.4	19.3	7.7

7.5.4 Interim Conclusions

Currently (2012), the overall water consumption of different sectors of industrial agriculture is 48 MCM. According to the Water Board Company, water consumption will rise by 55% to 87 MCM/a in 2025 (Table 7.3).

The current and expected future water consumption of industrial agriculture is significant. In particular aquaculture and greenhouses have very high consumption patterns and should be localized and analysed in detail.

7.6 Overall Conclusions and Outlook

The more than 13,000 industrial units analysed (reference year 2006) currently consume a total of approximately 200 MCM/a freshwater. Industrial water consumption is expected to increase by more than 70% to 347 MCM/a in 2025 according to future Scenario 1. In the future, according to Scenario 2, industrial water consumption rises by 130% due to excessive growth of large single industries to 454 MCM. In this calculation, water demand of new large industries which are expected to be settled in both future scenarios was added to the surface water extraction (see Table 7.4).

Currently, 50% of water originates from surface water, 45% from groundwater and 5% from urban water supplied by the Isfahan Water and Wastewater Company. In the future scenarios the proportion of urban water is expected to grow slightly, and in Scenario 2 the surface water proportion will grow by 10%, reducing the share of groundwater.

The expected growth of industrial water consumption in the future is a serious challenge for water management in the Zayandeh Rud catchment. All new or expanding water users in the closed basin will curtail available water resources of other users. The focus of development should therefore lie on a modern, water efficient industry with high economic return and low water consumption, as well as wastewater reuse.

114 MCM or 57% of the total 200 MCM of total industrial water consumption, are accounted for by the 30 largest industrial water consumers. The four largest water consumers (Mobarakeh and Esfahan Steel Company, Power Plant Islamabad and Isfahan Oil Refinery) alone consume - with a share of 70 MCM/a - around 35% of the total industrial water used in the basin. With few large production sites, steel

Table 7.4 Summary of industrial water consumption in the Zayandeh Rud catchment

Summary of industrial water users in the basin	Withdrawal (2025)			Withdrawal (dry year)			Withdrawal (normal & wet year)		
	WW (m^3/a)	GW (m^3/a)	SW (m^3/a)	WW (m^3/a)	GW (m^3/a)	SW (m^3/a)	WW (m^3/a)	GW (m^3/a)	SW (m^3/a)
Single Industrial Units (Scenario 1)	10,530,000	13,855,000	163,000,000	6,140,000	13,960,000	93,980,000	0	14,090,000	99,980,000
	187,000,000			*114,000,000*			*114,000,000*		
Single Industrial Units (Scenario 2)	10,530,000	13,860,000	269,930,000						
	294,000,000								
Industrial Settlements (Scenario 1+2)	9,100,000	51,650,000	1,240,000	5,400,000	21,690,000	0	800,000	24,840,000	1,450,000
	62,000,000			*27,000,000*			*27,000,000*		
Small Units is Isfahan municipality (Scenario 1+2)	10,000,000	0	0	10,000,000	0	0	10,000,000	0	0
	10,000,000			*10,000,000*			*10,000,000*		
Industrial Agriculture (Scenario 1+2)	0	87,350,000	0	0	47,940,000	0	0	47,940,000	0
	87,000,000			*48,000,000*			*48,000,000*		
Summed up consumption (Scenario 1)	29,630,000	152,855,000	164,240,000	21,540,000	83,590,000	93,980,000	10,800,000	86,870,000	101,430,000
	347,000,000			*199,000,000*			*199,000,000*		
Summed up consumption (Scenario 2)	29,630,000	152,860,000	271,170,000						
	454,000,000								

industry is the dominant water consumer in the catchment and sustains a large number of industrial units as suppliers, sub-contractors or subsequent processers. Steel and petrochemical industries are most likely going to expand their dominance in water consumption in the future (see Table 7.1). The total share of the largest industrial water users of total industrial water consumption is - with 55% according to Scenario 1 and 65% according to Scenario 2 – not expected to change or only to grow slightly by 2025 (Table 7.4).

The IWRM Zayandeh Rud project focuses its ongoing research on the reduction of freshwater consumption of large single industries. By applying results of a systematic flow analysis of water, energy and other consumed resources in large industries, processes are intended to be interwoven more efficiently, reducing the overall water and energy demand of industries while preserving productivity. The German research team collaborates closely with one of the large steel works to present state of the art approaches to develop solutions for more water efficient industrial production and internal reuse of process water. As a second pillar, options for reusing treated municipal wastewater as process water in large industries are assessed by the research project, aiming to reduce the overall freshwater consumption in the basin.

With 14%, the approximately 10,000 small industrial units within settlements do not have a high share of the current overall water consumption. Also in the future (2025), small industries are expected to increase their share by up to only 18%, even though their water demand is expected to more than double. However, the small industries' share of groundwater extraction, currently at 45% and around 55% in the future, can be considered significant. Furthermore, wastewater from industrial settlements is not currently, nor will it be in the near future, treated comprehensively. The impact of wastewater discharge is a threat to the quality of water resources and a technical problem for municipal wastewater treatment plants if released into the sewer.

The IWRM project addresses these issues with a research focus on more efficient water management within industrial settlements. The goal is the reduction of freshwater demand and wastewater emission of industrial settlements and as a result reducing groundwater extraction and wastewater emissions. The concept of Eco Industrial Parks is the guiding principle to improve collaboration and coordination amongst small industrial units within industrial settlements to improve water efficiency by trading and reusing process water flows amongst units.

The small industrial units within Isfahan municipality are expected to receive constant water consumption supplied by the Isfahan Water and Wastewater Company and are not part of further research.

Industrial agriculture is, with a current and future share of 24% of the total industrial water withdrawal, a relevant industrial water user. In comparison to agricultural water consumption in the basin, though, industrial agriculture has only a minor share of the water consumption of this sector.

It is important to gain a deeper understanding of the water use and wastewater production of industrial agriculture. More detailed analysis and monitoring of water consumption patterns and water productivity as well as a spatial localization of

water users is required. Currently, one important component of the IWRM research project is the analysis of the water productivity of different agricultural practices and the evaluation of alternatives to traditional agriculture in the basin.

References

Bakhtiari S, Iravani M, Hosseini D (2002) The structure of industry in Isfahan Province. Iran J Trade Stud (IJTS) 6(24):7

Ghasemian M, Poursafa P, Amin M, Ziarati M, Ghoddousi H, Momeni SA, Rezaei AM (2012) Environmental impact assessment of the industrial estate development plan with the geographical information system and matrix methods. J Environ Public Health 2012:407162. doi:10.1155/2012/407162

Reisi M, Aye L, Soffianian A (2011) Industrial site selection by GIS in Isfahan, Iran. In: 19th International Conference on Geo informatics

Yekom Consulting Engineers Company (2013a) Report of water use and need in industry and mining and produced wastewater until summer of 2006 in Gavkhuni basin, studies of the country water master plan in salt lake, Gavkhuni, Siahkuh-Rig Zarrin and Kavir Markazi, vol 8. Deputy of Water and Wastewater, Ministry of Energy, Tehran

Yekom Consulting Engineers Company (2013b) Report of water use and demand and produced wastewater in industry and mining until 2041, studies of the country water master plan in salt lake, Gavkhuni, Siahkuh-Rig Zarrin and Kavir Markazi, vol 20. Deputy of Water and Wastewater, Ministry of Energy, Tehran

Zayandab Consulting Engineers Company (2009) Studies of water resources and water use in Zayandeh Rud Catchment, vol 9. Industry, Isfahan Water Board Company, Ministry of Energy, Tehran