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Water Statistics and Accounts for Jordan: Part I

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Abstract
Jordan ranked as one of the world's poorest countries in terms of water availability. In the face of scarcity of water and the opportunities to increase supply are few and very expensive, the government is trying to solve part of the problem through redistributing the available sources of water to different uses. Presently, the redistribution of available sources and the usage of sewage treated water for agricultural purposes is enough to meet the demand for water. Population and industries development and increase of demand for food will grow the demand for water. Such increase requires radical and efficient solutions. The government's planning and future projects take into consideration alternative sources for water supply. Some of these projects depend on dams building, while others depend on the usage of non-traditional sources such as the reuse of treated water and desalinization of sea water.

1. Introduction

The effect of human activities upon the environment has been an important policy consideration throughout the last part of the twentieth century (Zhou et al., 2015). On the one hand, there has been growing concerns about the impact of each country's economic activity on the global and local environment, while on the other hand there has been increasing recognition that the continuing economic growth and human welfare are dependent upon the resources provided by the environment (Stefen et al., 2015). These resources include the provision of raw materials and energy used to produce goods and services, the absorption of waste from human activities, the basic role of life support and the provision of other amenities, such as landscape.

These concerns are translated into questions about whether the environmental endowments are being used responsibly. Is the use of the environment posing a threat to economic development now, either by being used up too quickly with no prospect of replacement or by generating a level of pollution, which threatens human health and the existence of species? Even if current behaviors do not pose threats at present, would it do so if continued without change into the future? These are some of the basic questions underlying the desire for sustainable development (Luo and Zhang, 2006).

The purpose of this paper is to highlight some water statistics dynamicity in different activities and analyze the interactions between the economy and the environment. Only by integrating these two areas can the implications for sustainability of different patterns of production and consumption be examined or, conversely, can the economic consequences of maintaining given environmental standards be studied.

Policy makers who set environmental standards need to be aware of the likely consequences on the economy. In particular, those determining the development of industries making extensive use of environmental resources either as inputs or sinks, need to be aware of the long-term environmental effects.

2. Water Sector Challenges

Jordan faces a number of specific challenges with respect to water. In summary they are:

- Scarcity of renewable water resources
- Depletion of ground water
- High losses during distribution and weakness in delivery
- Limited waste water plants efficiency
- High population number and forced immigration, and
- Low per capita water supply (145 liter/day in 2005) and expected to decrease to (90 m3/year in 2025).

The principal challenge facing water sector is the scarcity of renewable water resources. Rainfall is considered as the main source for renewing. The low rainfall amounts compared to the long term average will limit the renewing of water resources, forming high pressure on these resources to meet the demand.

Rainfall is the main source for recharging the ground water. The high evaporation of rainfall (more than 90%) limits the amount of recharging the ground water. The high abstraction of ground water and the low recharge through rainfall will cause a high depletion of ground water.

The high loss of water through distribution forms other challenge for water sector. The losses of distributed water exceeded 20% of the distributed water. The government is working effectively to decrease this percentage to minimum value through renewing the distribution network. The privatization of domestic water distribution contributes to searching for the illegal uses of water through the distribution network. These efforts will decrease the losses of water through distribution our time.

The use of treated sewage water for agricultural purposes decreases the pressure on fresh water

resources. The low capacity of the sewage treatment plants and the lack of continuous maintenance, to reserve the quality of treated water, make the use of this secondary source less effective and entrusted for agricultural purposes. The future plans should consider the increase of sewage water treatment capacities and the usage of advanced technology, insuring high quality of treated water.

The continue increase in population naturally and through non-organized immigrations increases the demand for water for domestic uses. This increase with constant or slight increase in domestic water distribution will lead to decrease water supply per capita. This will form a challenge for water sector to increase per capita distribution to the acceptable levels, knowing that in common conditions the distribution of water per capita is less than the international amounts.

3. Data Sources

In order to provide information to help address the water challenges faced by Jordan, DoS has compiled data from a range of sources, including its own surveys. The following list shows the available sources of data for the purpose of preparing this report:

- Ministry of Water and Irrigation
- Department of Public Health
- National Accounts Division (DoS)
- Foreign Trade Statistics (Imported water) (DoS)
- Environment Div. Surveys (DoS)
- Agricultural Surveys (DoS)

The Ministry of Water and Irrigation (MWI) is the official body responsible for the overall monitoring of the water sector, water supply and wastewater system and the related projects, planning and management, the formulation of national water strategies and policies, research and development, information systems and procurement of financial resources. Its Role also includes the provision of centralized water related data, standardization and consolidation of data. The Ministry of Water and Irrigation embraces the two most important entities dealing with water in Jordan: The Water Authority of Jordan (WAJ): In charge of water & Sewerage Systems, The Jordan Valley Authority (JVA): Responsible for the socio-economic development of the Jordan Rift Valley, including water development and distribution of irrigation. MWI is considered as one of the major sources for data on water in Jordan.

The other important source of water data is the Department of Public Health, affiliated to the Ministry of Health. The Department is responsible for monitoring fresh water quality for all the distribution points, producing licenses for the new wells, observing the quality of treated sewage water and licensing water importation for Jordan.

The Department of Statistics (DoS) is considered as one of the important sources for water consumption and values through the executed population, industrial and agricultural surveys in Jordan. Environment Division is concerned with the collection of data on water through the executed surveys related to environment. The National Accounts Division is responsible for the collection of data related to the monetary value of water used by different sectors and industrial activities in Jordan. The Foreign Trade Statistics provides data on the quantities and monetary value of imported water for Jordan.

4. Surface Water Budget

Rainfall is the main source for nourishing surface and ground water in Jordan. The amount of seasonal rainfall compared to the long-term average determines the availability of water for different uses. Volume of seasonal rainfall determines the volume of water storage in reservoirs and the extent of recharging groundwater. The experience of dry rainfall seasons (2007/2008 – 2009/2010) causes depletion of the existed surface water and groundwater resources (Figure 1). In very dry seasons such as 2007/2008, the extent of water depletion of surface and ground water resources will be very high. Successive dry seasons cause accumulation of water shortages and magnify water scarcity problems.

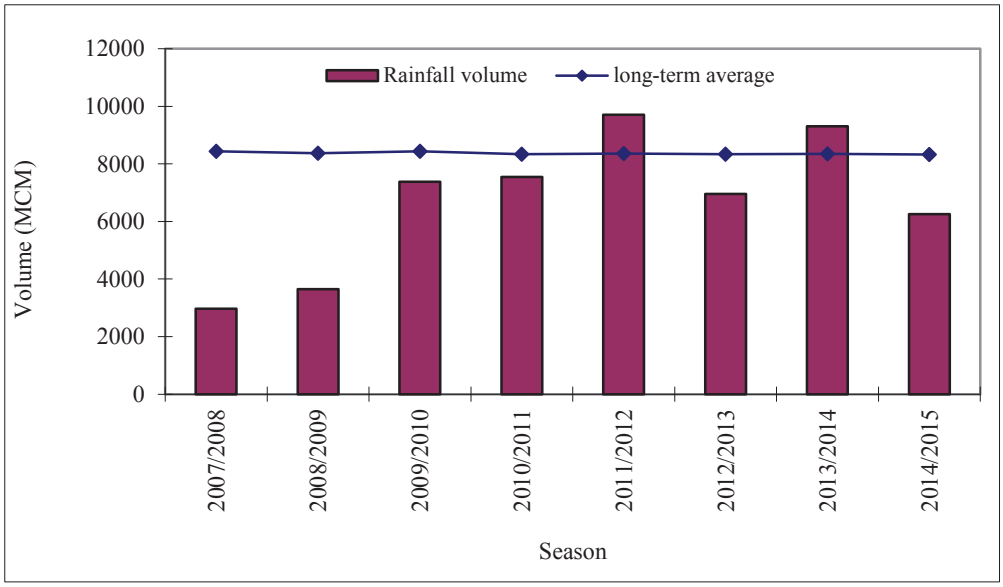


Figure 1: Annual rainfall volume, 2007/2008-2014/2015

Most of rainfall received is lost through evaporation. Table 1 shows more than 90% of rainfall received is lost through evaporation. The maximum percentage of rainfall water utilized was in 2011/2012 reaching 7.06%, followed by season 2013/2014 by 7.02%. The low utilization of rainfall in general reflects the low available water through this major source for different uses.

Table 1: Annual rainfall changes

Season	Rainfall volume MCM	Long-term average (MCM)	Evaporation (MCM)	% of rainfall	Floods (MCM)	% of rainfall	Infiltration (MCM)	Infiltration long-term average (MCM)	% of rainfall	% of rainfall utilized
2007/2008	2972.8	8441.4	2919	98.2	10.3	0.3	435	43.50	1.5	1.8
2008/2009	3651.1	8366.4	3473.9	95.15	75.16	2.06	102.05	439.95	2.8	4.86
2009/2010	7375.3	8436.0	7062.3	95.76	148.43	2.01	164.42	435.64	2.23	4.24
2010/2011	7545.0	8338.5	7011.8	92.93	162.30	2.15	370.80	434.64	4.91	7.06
2011/2012	9708.0	8359.3	9026.4	92.98	275.43	2.84	406.20	434.0	4.18	7.02
2012/2013	6951.0	8338.0	6550.5	94.20	134.2	1.9	266.03	431.5	3.8	5.7
2013/2014	9304.0	8352.0	8671.0	93.9	269.7	2.2	364.1	432.0	3.9	6.1
2014/2015	6258.0	8322.0	5812.7	92.9	156.6	2.5	288.8	429.4	4.6	7.1

5. Water Supply

The Development of Total Water Supply

The demand for water is increasing for all purposes. This increase is resulted from the increase in the number of population over time and the vertical and horizontal expansion of the productive sectors in Jordan. Figure (2) shows that there is an increase in water supply for different purposes between 2008 and 2015, hitting increase approximately 108.07 MCM with a percentage of 13.00%. The increase in demand for water has not been accompanied by the provision of alternative sources. Most of increase in demand was met through depletion of available sources particularly groundwater, the redistribution of water among different sources, or the use of treated wastewater. For example, the recent trend is the use of sources of water of good quality for domestic purposes despite the costs of pumping to the targeted areas, and use of less water quality for agricultural purposes.

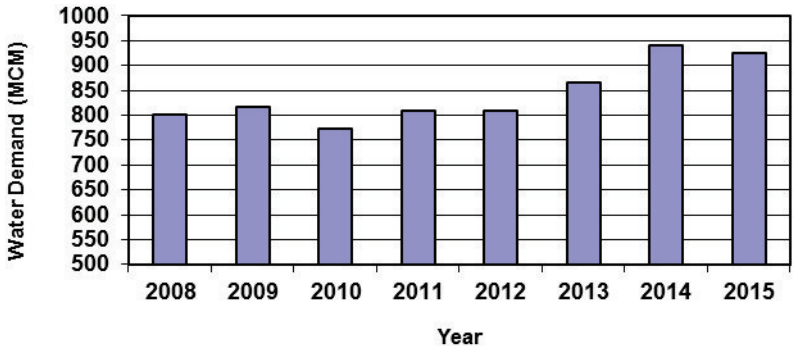


Figure 2: Water supply for all sectors (2008-2015).
(Source: Ministry of Water and Irrigation)

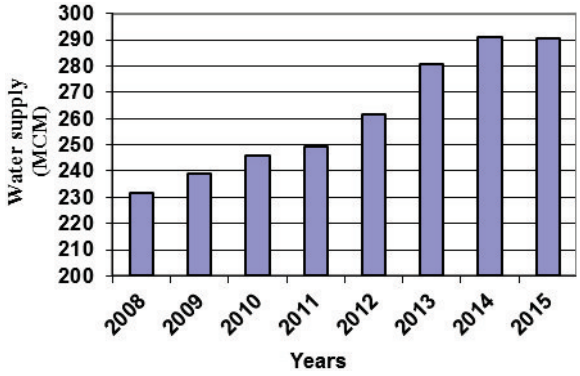
Water Supply by Sector

The domestic sector is one of the most important sectors with a priority to the provision of water in Jordan. Water demand in this sector is directly linked to the increase in population, expansion in services and tourism sector in Jordan. Therefore, there is a steady increase in water supply in this sector compared to other sectors (Figure 3a). The increase in supply for domestic uses exceeded 30 MCM during the eight years. The percentage of increase reached 25.52% in 2015 compared to 2008.

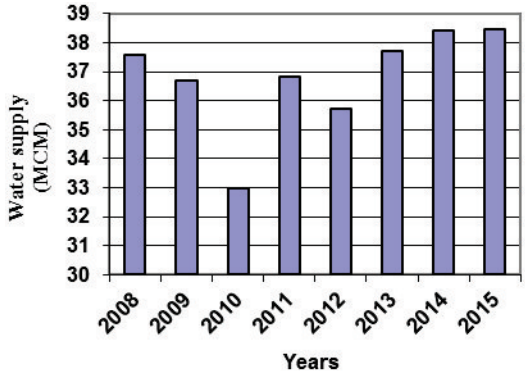
There is a little fluctuation in water supply for the industrial sector. As the difference between the lowest value of demand for water and the highest is nearly 5 MCM (Figure 3b). This small fluctuation is resulted from the small number of industries that use large quantities of water and confined to the mining industries. In addition, there is awareness of the issue of water scarcity in Jordan. This made many factories treat the used water in industry to be reused for other purposes such as for forestation. Most of water used in the industrial sectors is extracted from ground water of private wells.

The highest demand for water among the various sectors in Jordan is for the agricultural sector. Data show that there is a considerable fluctuation of the amount of water available for agriculture. The reason for this is due to the provision of water for other uses especially for domestic uses. Water supply for agriculture increased from 487.59 MCM in 2008 to 588.34 MCM in 2015 (Figure 3c).

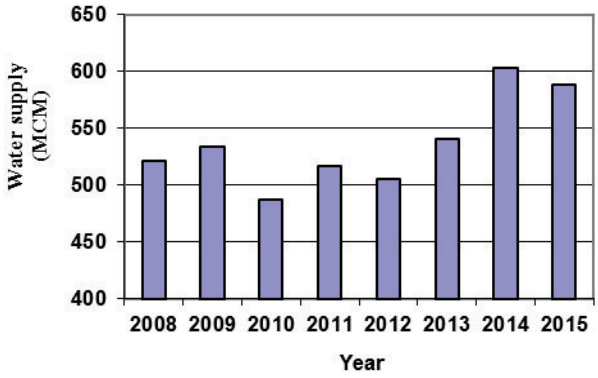
The gap between water supply and demand for the agricultural sector is very high, which made the concerned bodies search for untraditional sources of water to decrease the gap. In the last years, the government started to mix the treated wastewater according to specific criteria with other freshwater to meet the increase in water demand for agricultural sector. The use of treated water was accompanied with widespread protests. The protest was a result of the low quality of products to compete with foreign markets. Crop patterns application was one of the strategies implemented by the government to decrease the demand for water in the agricultural sector. Also decreasing the areas planted with high water requirement crops such as melon was another alternative to decrease water demand for the agricultural sector.



a. Domestic sector



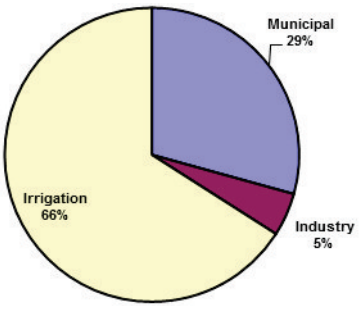
b. Industrial sector



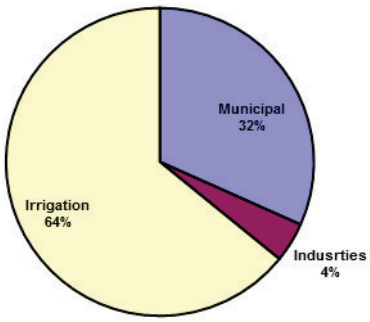
c. Agricultural sector

Figure 3: Water supply for all sectors (2008-2015).
(Source: Ministry of Water and Irrigation)

To meet the high demand for water, the portion of water supply for the different sectors changes slightly over years. In 2008, the percentage of water supply for the agricultural sector forms 66% of the total water supply (Figure 4). This percentage decreased to 64% in 2015 to meet the shortage of water, while the supply for the domestic uses increases from 29% in 2008 to 32% in 2015. The share of the industrial sector decreased slightly from 5% in 2008 to 4% in 2015. This reflects the priority of using good quality water sources for domestic uses over agriculture sector. Also, this indicates meeting the increase in demand for water by domestic sector is handled through decreasing water supply of other sectors.



2008



2015

Figure 4: The distribution of water supply by sector (2008-2015).
(Source: Ministry of Water and Irrigation)

Change of Water Supply Generally and by Sector Over Time

Time series for the change of freshwater water supply is presented in Table 2. The change of water supply decreased by -3.41% in 2010, while it continued increasing in the successive years. The change of water supply increased from 1.04% in 2011 to 17.41% in 2014, then dropped slightly to 15.45%. The logic trend of water supply of freshwater reflects the increase in demand by time. The increase in demand should be treated through providing new water sources. The high pressure on freshwater requires more control on the quality of water used

for domestic purposes.

Table 2: Change of total fresh water supply during the period 2008-2015 (MCM)

Year	Total Demand	Change Percentage
2008	801.44	
2009	817.15	1.96
2010	774.07	-3.41
2011	809.77	1.04
2012	810.14	1.09
2013	865.90	8.04
2014	941.00	17.41
2015	925.22	15.45

Source: Ministry of Water and Irrigation

The highest change of freshwater supply was recorded for domestic uses. The percentage of change of water supply for domestic uses was 25.52% (Table 3) compared to 12.91% (Table 5) for the agriculture sector and 2.42% (Table 4) for the industrial sector. The high change of water supply for domestic uses is resulted from the increase in population number and immigrations of Jordanian and other Arab nationalities to Jordan for political causes. The population increased by 862000 from the period 2008 to 2015. Such increase in population requires additional supply of water (Department of Statistics, different issues). The response of the increase in water supply for domestic uses has resulted from listing it as one of the country's priorities.

Table 3: Change of fresh water supply for domestic uses during the period 2008-2015 (MCM)

Year	Total Demand	Change Percentage
2008	231.50	
2009	239.04	3.26
2010	245.65	6.11
2011	249.23	7.66
2012	261.82	13.10
2013	280.80	21.30
2014	291.30	25.83
2015	290.58	25.52

Source: Ministry of Water and Irrigation

The change of freshwater supply for the industrial sector decreased in 2009, 2010, 2011, and 2012 by 2.32, 12.22, 1.97, and 4.87; respectively (Table 4). The increase in water supply increases by 2.42% in 2015 only. This indicates that the expansion of the industrial sector from 2008 to 2015 was restricted compared to other sectors.

Table 4: Change of water supply for industrial uses during the period 2008-2015 (MCM)

Year	Total Demand	Change Percentage
2008	37.37	
2009	36.70	-2.32
2010	32.98	-12.22
2011	36.83	-1.97
2012	35.74	-4.87
2013	37.70	0.35
2014	38.40	2.21
2015	38.48	2.42

Source: Ministry of Water and Irrigation

The change of water supply for irrigation increased to reach 12.91% in 2015 (Table 5). The demand for water for agricultural purposes is higher compared to the supply. The supply of water for the agricultural sector depends on water balance and the rainfall season. In dry seasons, the supplied amount for agricultural sector decreased to meet the demand for domestic uses.

Table 5: Change of supply of fresh water for agricultural uses during the period 2008-2015 (MCM)

Year	Total Demand	Change Percentage
2008	521.09	
2009	534.00	2.48
2010	487.59	-6.43
2011	516.87	-0.81
2012	505.94	-2.91
2013	540.60	3.74
2014	603.50	15.81
2015	588.34	12.91

Water Supply Per Capita

Water supply per capita changes from year to another depending on population increase and dryness of rainfall season. Water supply decreased by 3.21% in 2009 compared to 2008 (Table 6). This decrease in water supply is a result of water dry season experienced in 2008. Water supply decreased in 2015 by 1.05% as a result of the dry season conditions. The solution of shortage of water is by decreasing water supply for domestic uses. Water supply faces critical challenge represented by water seepage through the distribution network. The seepage amount reaches 20% of water supply. This reflects that water supply is less than water consumption per capita.

Table 6: Change of water supply per capita, 2008-2015

Year	Water supply per capita (L/day)	Change Percentage
2008	137.2	--
2009	132.8	-3.21
2010	131.6	-0.90
2011	132.0	0.30
2012	135.5	2.65
2013	141.2	4.21
2014	143.5	1.63
2015	142.0	-1.05

Pressure on Water Abstraction

The results of the comparative figures assure that the supply of water does not match with the effective demand for water by the different sectors. Despite the increase in water supply for the municipal sector, the amount of water per capita per day is below the international standards. Moreover, the supplied amount of water for agriculture sector does not meet the demand for plant the arable lands.

In Jordan, there are two types of groundwater; the renewable and the non-renewable groundwater. The pumping of non-renewable groundwater is considered as depletion of this source regardless of the objective of using it. That is why the use of such a source should be subject to vigorous oversight in order to prevent its draining in a short period of time. In Addisi Water Basin, which is a non-renewable ground water, high amounts are pumped for agricultural purposes.

Data show that the volume of water infiltrated to the groundwater was less compared to the volume of abstraction over years (Figure 5). In dry seasons, where the amount of infiltrated water to the groundwater is small, the percentage of depletion of the groundwater source is very high. In the years 2008 through 2015, the amount of abstracted water exceeded the volume of groundwater feeding. This indicates that in most areas, the usage of groundwater exceeds the safe yield. Such depletion of this source is a result of the increasing in demand for water in the different sectors. The average percentage of abstraction to the volume of infiltration was 326.32% during 2008-2015. In the last years, the percentage decreased to reach 140.79% in 2012 and 166.13% in 2015. The depletion of groundwater to meet the high demand will lead to decrease the productivity of wells and decrease water quality. So, the governmental policies related to groundwater should consider the infiltration volumes to determine the allowed quantities of abstraction to reserve sources and quality.

The pressure on all water sources practiced is inevitable to meet the requirements of water demand. The pressure on sources differs according to the type of source. Figure 5 shows that the pressure on groundwater is very high compared to the pressure on surface water. The pressure on groundwater decreases in the rainy seasons, where the surface water is more available. In dry seasons, the pressure on groundwater increases to meet the requirements of water demand. In general, the high pressure on groundwater and extensive abstraction led to poor groundwater quality in different areas. The pressure on groundwater is higher because many farms and different industries depend on their private wells to provide the required amounts of water to run their activities. Figure 6 shows that the use of groundwater compared to surface water increased in the last years. The percentage of using groundwater to surface water increased from 41.25% in 2012 to 76.17% in 2015.

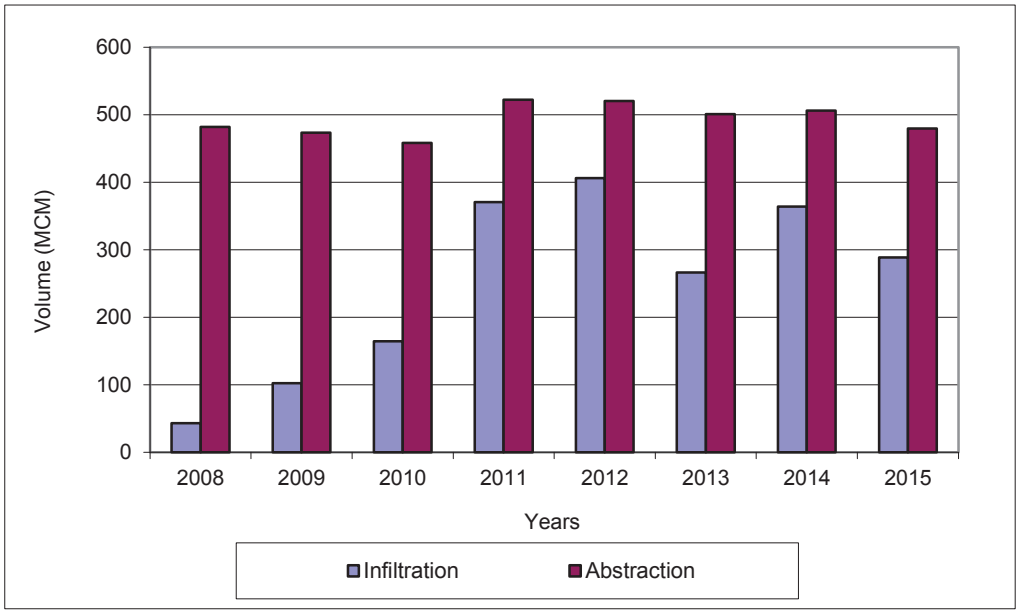


Figure 5: Annual recharge and discharge of groundwater (M.C.M).
(Source: Ministry of Water and Irrigation)

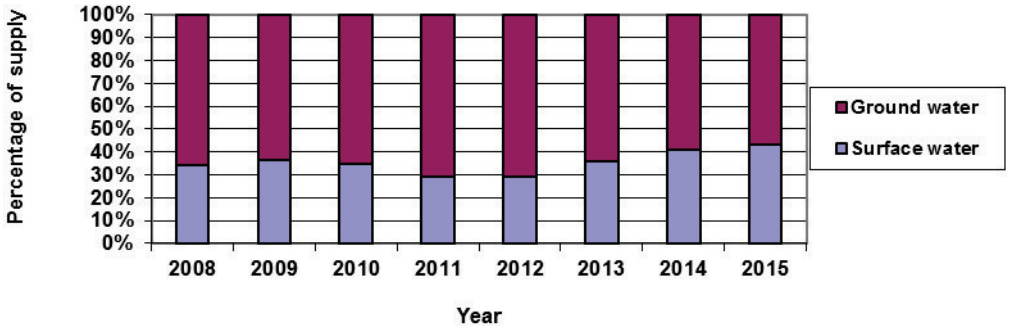


Figure 6: The pressure on surface and groundwater sources to meet the high demand (2008-2015).

Water Quality

Water turbidity changes according to water availability for domestic uses which relies mainly on annual rainfall volumes. Water turbidity increases in dry seasons compared to less dry ones (Figure 7). In 2013, when dry season conditions were practiced, percentage of turbid samples increased compared to other years even these samples are within the standard. In years 2014-2015, the percentage of turbid samples was high as the annual rainfall did not reach the average long term. The percentage of samples above the permitted level was high in all years and was the highest in 2011. Even there is a considerable percentage of samples from different sources used for drinking purposes exceeded the maximum limit for turbidity (Figure 7). This considerable percentage of samples exceeding the maximum limit is a result of the high pressure on water supplies and low recharge of groundwater in different years.

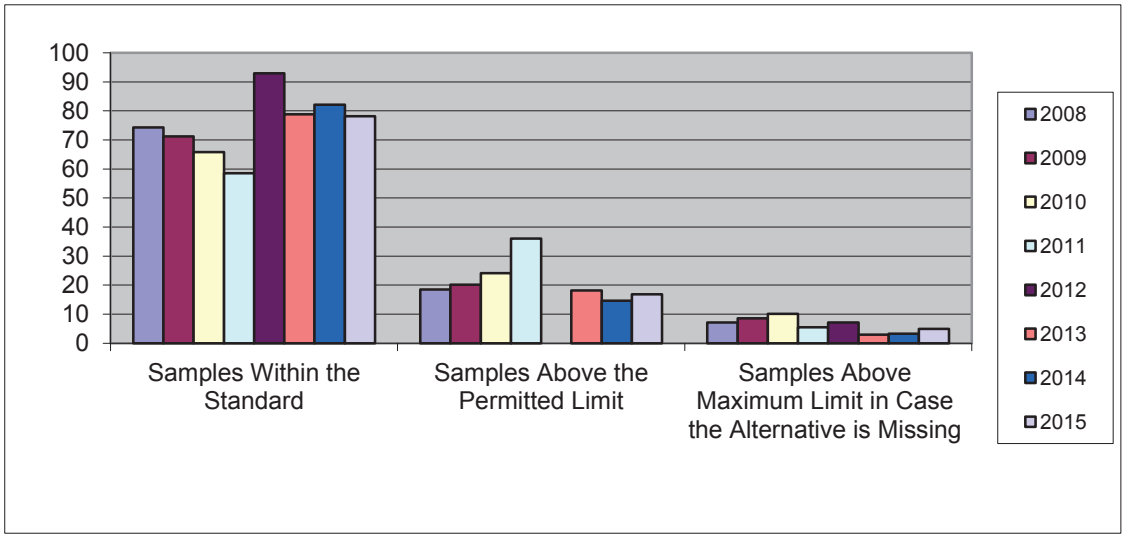


Figure 7: The percentage of samples within standard, above permitted limit and maximum limit in case of lack of alternative for turbidity.

Water color is one of water physical properties that receive less care due to scarcity of sources. Almost water color did not vary from year to another concerning the percentage of samples within the standard limit (Figure 8). The percentage of water samples exceeding the standard limit is very small and the percentage of water sample exceeding the maximum limit is marginal too.

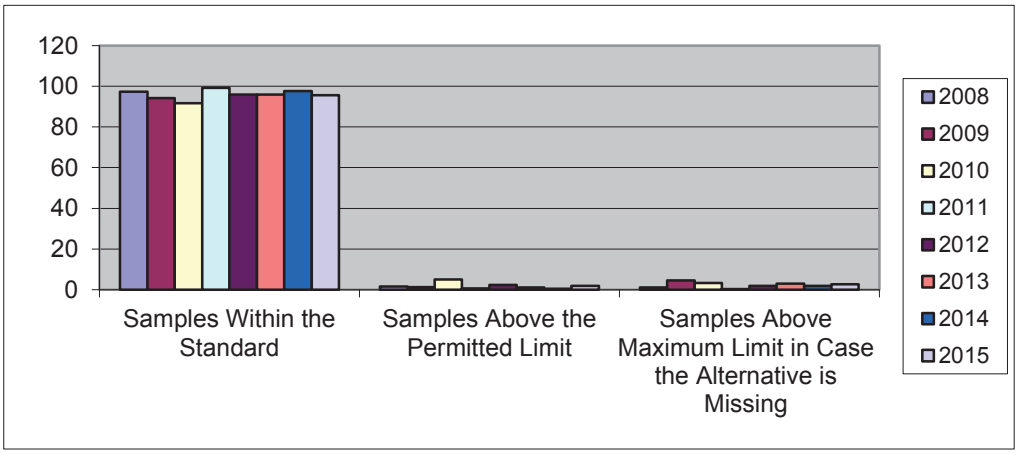


Figure 8: The percentage of samples within standard, above permitted limit and maximum limit in case of lack of alternative for color.

Total hardness is one of less interest water physical properties. The percentage of sample above the permitted limit is very high in all years (Figure 9). The acceptance of water resources with such criteria is due to the lack of alternative resource that is within the standard. The concern of the hardness property is to find sources that are not reaching the maximum limit.

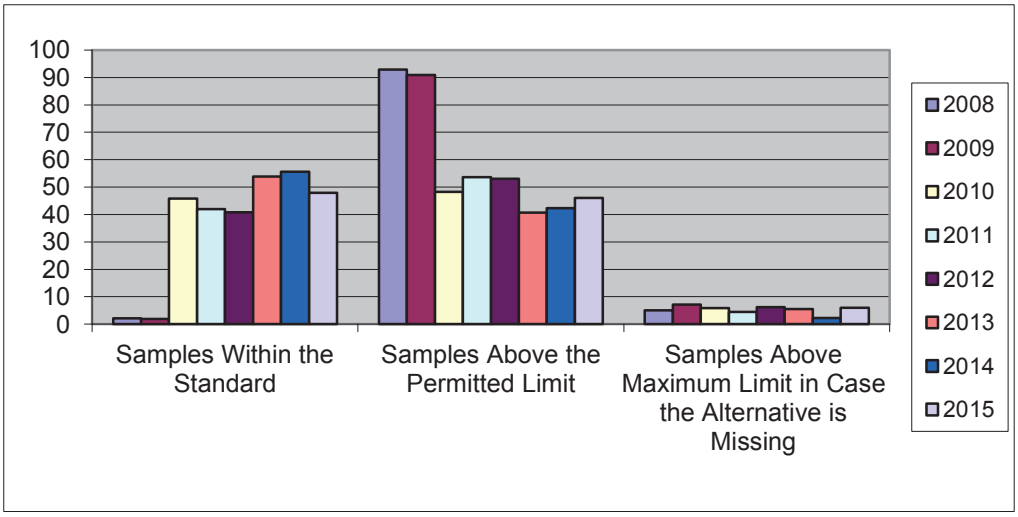


Figure 9: The percentage of samples within standard, above permitted limit and maximum limit in case of lack of alternative for total hardness.

The percentage of sample with chloride above the standard is high (Figure 10). This is possibly due to the treatment of water with different concentration of chloride. For drinking purposes, the chloride concentration is accepted if being within the standard or below the maximum level. The lack of sources for drinking water makes this alternative accepted.

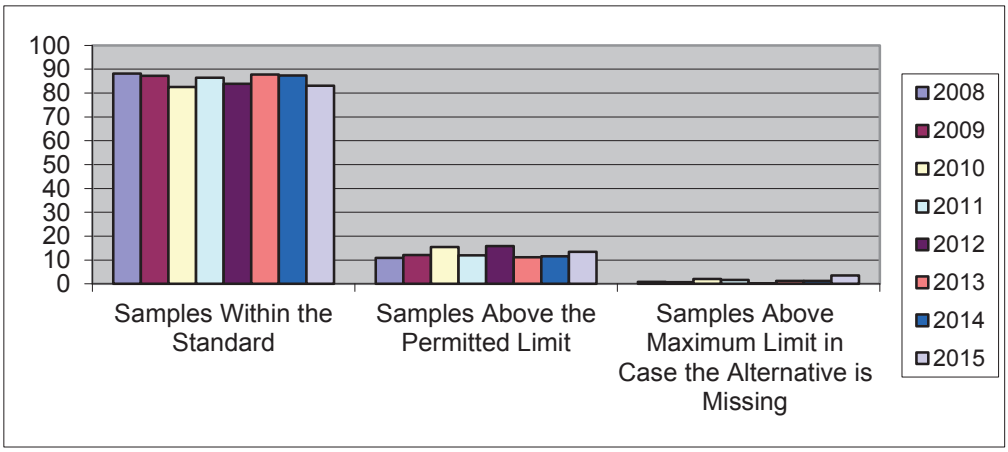


Figure 10: The percentage of samples within standard, above permitted limit and maximum limit in case of lack of alternative for chloride.

The analysis for microbial detection is shown in Figure 11. In general, the percentage of violated samples existed yearly even being high or small. The highest percentage of sample violated the standards existed in 2008. The percentage of sample with microbial infection decreased till 2014. In 2015, the percentage increased compared to 2014 (Figure 11).

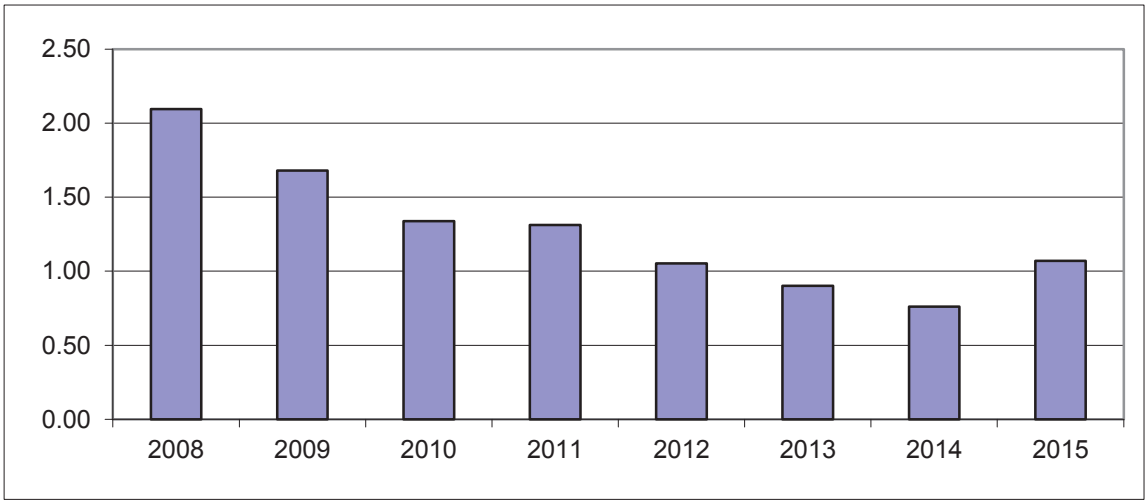


Figure 11 Percentage of Dis-Conformed Drinking Water Samples, 2008-2015

Natural, filled and imported water is considered as alternatives for drinking purposes. Even these sources are considered as ideal sources for drinking water, but still these sources witnessed violations for the standards (Figure 12). The percentage of samples violated chemically is the highest over years. The other tests witnessed some violations in different years but with very small percentages.

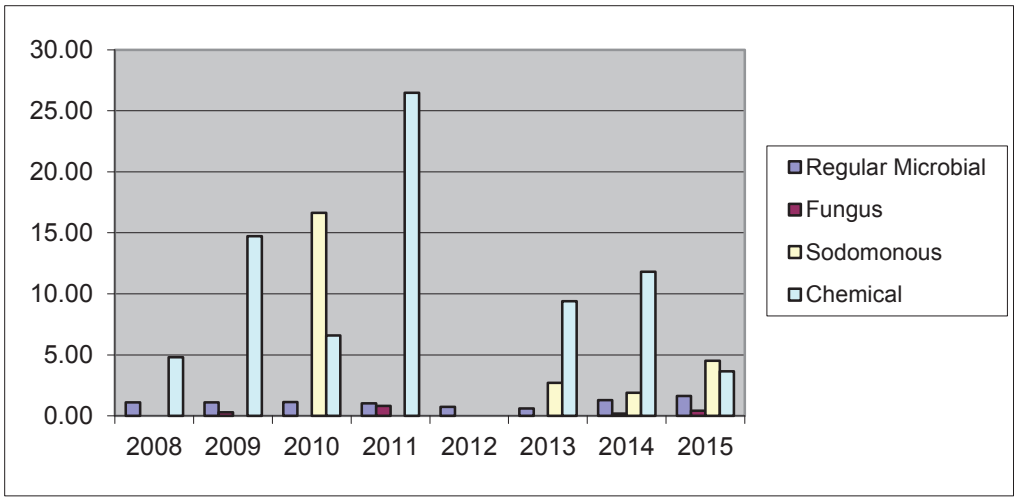


Figure 12: Analysis Results of Desalinized, Natural, Filled, and Imported Water by Year and Analysis Type, 2008-2015

5. Imported and Exported Water

This section has been, for the first time, given interest as part of water statistics. The data represented in Table 7. Figures indicate the lack of policies for the exports and imports of water as a good. In 2005, exports were higher than imports while in 2006 the contrary existed.

Table 2.7: Volume of imported and exported water (1000 CM)

Year	Exports	Imports
2014	22.78573	17.08212
2015	10.19631	23.72819

6. Water Treatment Plants

Water treatment plants capacity remained constant over a long period of time. The designing hydraulic and organic load does not meet the requirements of operating hydraulic load or organic load (Table 8). The increase in population resulted in the increase in the demand for water treatment plants with higher capacity. The low designing capacity of treatment plants leads to low treated water quality (Table 8).

Table 8: Water treatment plants design and effective load in Jordan

Year	Design Hydraulic load (m^3/day)	Design Organic load (mg/L)	Operating Hydraulic load (m^3/day)	Organic load (mg/L)	COD	BOD	TSS	TDS
2008	236526	19208	217805.0	19105	10402	6887	5342	31649
2009	170866	22798	224931.0	16967	8827	6120	5253	33424
2010	170866	22798	243112.5	16967	8316	5505	5128	74246
2011	157041	18128	242609.9	19130	8116	4523	5545	30431
2012	148865	17494	257819.0	15922	10117	7232	6097	42458
2013	163065	18559	279189.0	15314	6059	2891	6392	28070
2014	172965	18109	244549.0	13340	4098	2225	2083	--
2015	161645	17659	283463.0	14184	9263	4490	3643	--

Source: Directorate of Environmental Health- Ministry of Health

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