World Environment 2014, 4(5): 213-218
DOI: 10.5923/j.env.20140405.03

Municipal Landfilling Practice and Its Impact on the Water Resources - Jordan

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Abstract Jordan is considered one of the most water-stressed countries in the world, with less than 150 cubic meters freshwater available per capita annually. Groundwater resources are clearly vital for Jordan´s population and economic wellbeing. It´s quality and amount has therefore to be managed in a sustainable way avoiding possible contaminations. Unfortunately the groundwater quality is threatened by several factors including unsafe landfilling. Jordan has been facing a unique situation in solid waste management due to sudden population and the change in living standards. Serious environmental problems are connected to this, which could threaten human, surface water and ground water. With the current regulation and attention focused in many environmental aspects in the country, the risk of water resources contamination is not completely recognized. The aim of this study is to provide an overview of environmental problems associated to the mismanagement of solid waste and the possible threats for human and water resources.

Keyword Water Resources, Uncontrolled Landfilling, Jordan

1. Introduction

Jordan has a total area of 90,000 km^2 and a population of 7 million in 2014. The country lies in dry and semi dry climatic zones, which are characterized by their minimal rainfall and high percentage of evaporation. The climate is a mix of Mediterranean and dry desert; temperature varies from a few degrees below zero in the winter to around 46 degrees centigrade in the summer season [1-3]. The generation of solid waste has become an increasing environmental and public health problem everywhere in the world and Jordan. As in much of the developing countries, the fast expansion of urban, agricultural and industrial activities in Jordan spurred by rapid population growth and the change in consumer habits has produced vast amounts of solid wastes. Landfills have been identified as one of the major threats to groundwater resources. Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site [3-8]. Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment [9]. In this study we will have an overview of the environmental problems associated withthe sudden and rapid increase in population and to the mismanagement of solid waste and the possible threats for human and water resources.

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Published online at http://journal.sapub.org/env

2. Water Resources in Jordan

Jordan is facing a future of very limited water resources, it is considered among the lowest renewable water resources in the world on a per capita basis [10, 11]. A global comparison recognizes Jordan as one of the ten countries with the lowest volumes of available renewable water resources per capita [12], these resources are projected to decline from more than 150 m^3 per capita per year for all uses at present to only 91 m^3 per capita per year by 2025, putting Jordan in the category of having an absolute water shortage [13-15]. Water resources in Jordan are limited and depend mainly on precipitation, which is very low. The water resources are divided into two main parts: conventional (surface and groundwater) and non-conventional (treated wastewater, cloud seeding and desalination of sea water, and brackish water). Seasonal rainfall of 8.3 billion cubic meters is the main source of water in Jordan.

Annual precipitation ranges from 50 mm in the desert to 600 mm in the northwest highlands. Only 9% of Jordan's area receives more than 200 mm of the rainfall annually [16]. Approximately 92.2% of the rainfall evaporates, 5.4% recharges the groundwater and the rest 2.4% goes to the surface water [17]. Jordan's renewable natural water resources are estimated to be in the magnitude of 780 Million cubic Meters per year (MCM/year). The uses of water are divided among municipal (32%), industrial (4%), irrigation (62%), and livestock uses (2%). The irrigation sector

consumes most of the water resources in the country, and there is a gradual decrease in the water resources for all uses. Due to the semi-arid climate of Jordan, coupled with increased population growth rates at 7,5 Millions in 2014, Influx of refugees due to political instability in the region, in addition to the changes in way of life have contributed to such an decrease. Jordan's municipal uses witnessed significant increase during the past decades. Only about 66% of the total country's demand is supplied, with a per capita supply share of 94 l/day still falls far below that of neighbouring countries. Current deficits are being covered through mining of groundwater resources at 130 % of their safe yields, and through exploitation of non-renewable groundwater. The overexploitation of aquifers has resulted in the lowering of water tables and degradation of ground water quality (increasing salinity) and thus threatens the sustainability of such resources for future use.

Despite the current high irrigation share of the total water uses, irrigation use during the past decade has decreased. Factors contributing to such decrease include restrictions on well drilling since 1992, nationwide achievement of significant improvements in irrigation application efficiency, equipping private wells with water meters, and reduction in irrigated areas. The major problems facing conventional water resources development are quality deterioration and resource depletion. The non-conventional resources could increase water supply enough to overcome the shortage and to satisfy the different water needs of the country. Presently about 91% of the treated wastewater estimated at 79 MCM/year is reused in irrigation. By 2020, some 232 MCM of treated wastewater will be available; almost 24% of the total irrigation demand on fresh water resources and about 84% of the demand on renewable groundwater supplies, thus posing increasing pressure on the replacement of fresh water with treated wastewater. As the additional naturally occurring fresh water becomes less available, domestic, and industrial water needs will eventually be met by desalting brackish and saline groundwater or seawater, while agriculture will be forced to use treated wastewater for a larger portion of the irrigated area.

Figure 1. Groundwater basins in Jordan. Arrows represent the direction of flow. Source: [20]

By 2020, Jordan's demand on water is expected to reach some 1616 MCM/Year, while it is envisaged that the country will have developed an estimated 1300 MCM of water resources. It is forecasted that even with the heavy investment in water resources development, coupled with improved water demand management, water deficit in Jordan will still remain at about 320 MCM in the year 2020. The current status shows an imbalance between Jordan's water resources and water demands. Water deficit has been and continues to be a challenge.

Groundwater plays a central role in Jordan where it represents 55-60% of the available water resources, equaling 800 MCM/a in 2006. Groundwater in Jordan is of two types, renewable and nonrenewable fossil water distributed among 12 basins as in figure 1. The annual safe yield of groundwater is 275 MCM/y while pumping in the year 2000 is more than 450 MCM to meet the required demand [18]. Jordan also possesses limited resources of fossil - nonrenewable – groundwater in the Disi aquifer in the South, with a yield of 350 MCM/year that can be abstracted for 50 years according to latest estimations [19]. There are more than 25 dams located in different parts of the country with total storage of about 204 MCM.

3. Landfill Situation in Jordan

Landfills have been the most common and cheapest methods of waste disposal in many countries around the world, especially in developing countries. It is considered to be cost effective and reliable method if the land is available. However the inadequate management and operation of these landfills could pose serious environmental impact. Landfills have been identified as one of the major threats to groundwater recourses. The placed waste in landfills is subjected to infiltration form precipitation or from co-disposal of liquid and sludge with municipal solid waste (MSW).

In Jordan, Sanitary landfilling of MSW has evolved over the past 15 years as the recommended method for the dispose of solid wastes [21]. Previously since 1950, waste disposal was basically open dumping and burning without complying with the proper regulations, while in the beginning of 1980 the awareness increased for establishing sanitary landfills. Nowadays landfilling practiced in Jordan is simply dumping the waste in trenches with leveling and compacting by trash compactors to reduce the size and the thickness of the layers, and finally cover the waste with soil [22]. There are at present 21 landfills in Jordan, the location of these landfills was not choosen according to the international standards, it was choosen according to population density as to serve the largest possible number of municipalities. The exception is the Al-ghabawi landfill which receives more than 50% of the volume of the generated solid waste in Jordan [23]. It was designed and engineered according to international standards while constructed. The rest of the landfills that receives 40% -50% of the volume of waste in the country are not designed according to international standards for landfills in terms of health or environmental requirements.

The methods of dumping practiced and the lack of lining could lead to contamination of groundwater, Figure 2 illustrates landfilling practices in the country. For example, Al-Ekader landfill which was located near the Syrian borders and in the vicinity of Yarmouk river basin gives rise to some political tension with Syria, since effluents from the Al-Ekader landfill pose a threat to the Yarmouk basin. Also, Mafraq landfill was located on a geological fault and represents a threat to the groundwater aquifer. Al-Hamra is located in a bedrock area where no soil is available for daily covers, leachate produced is flowing out from the dump site threatening the public health and polluting the soil [21].

3.1. Ground Water Contamination

Ground water contamination is generally irreversible once it is contaminated; it is difficult to restore the original quality. In Jordan ground water quality has been deteriorating by point and non-point source including domestic agricultural and industrial uses and become an increasing problem in recent year.

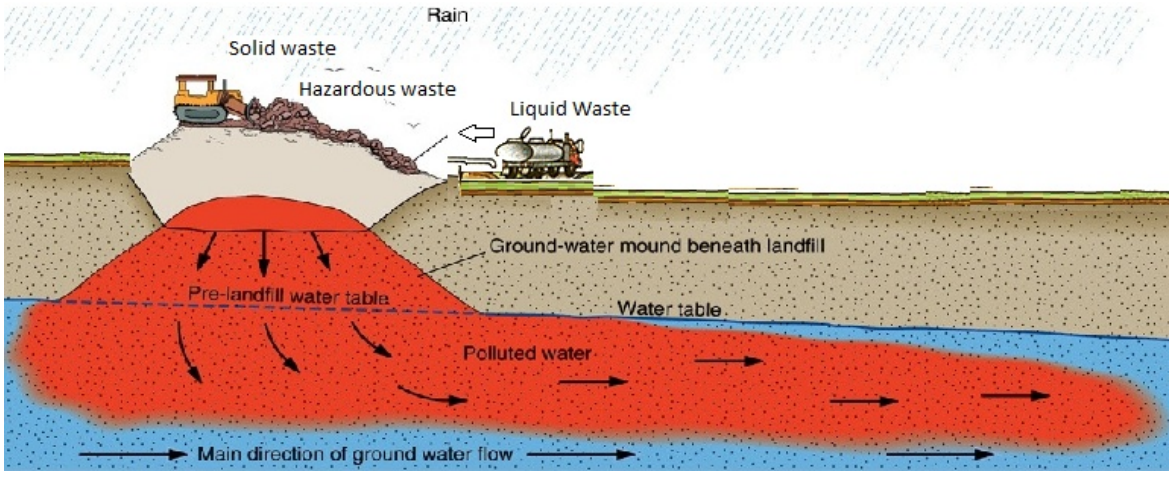

Figure 2. Landfilling practice at Jordan

Leaching of pollutants from landfills may result in groundwater contamination, especially when it comes to uncontrolled landfills with the absence of lining system and without monitoring the type of the waste received. Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site [9]. The generation and the chemical characteristics of leachate in arid climate countries depends upon the MSW characteristics, moisture content, capillary action, water content of subsurface soil and ambient temperature [24]. Landfill leachate contains a variety of contaminants including heavy metals such as cadmium, nickel, zinc, copper, and lead. Usually these metals are found at moderate concentration levels in municipal landfill leachate. Typical values are in the range: Cd 5–10μg l^{-1}, Ni 100–200 μg l^{-1}, Zn 500–2000 μg l^{-1}, Cu 50–100 μg l^{-1}, and Pb 50–100 μg l^{-1}[25]. Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment. During the last twenty years many evidences for ground water contamination has been occur especially in northern part of Jordan. El-Naqa et al. (2006) they stat that the major cause of groundwater contamination for the most important aquifer in Jordan which is known as Amman- wadi sir (B_2/A_7) is the presence of Russeifa solid waste disposal site, also Abu-Ruka et al. (2001) and Abu-Ruka (2005) revealed in their study that Al-Ekader landfill leachate constitutes a serious threat to the local aquifers in the Yarmouk Basin see table 1. [26] [27, 28]

Table 1. Characteristics of the leachate samples collected from Al-Ekader landfill site [27]

Parameters	L1	L2	L3	L4	L5	L6
pH	7.79	7.63	7.96	7.93	7.91	7.84
Temp.(c)	20	20	20	20	20	20
Turbidity (NTU)	40	40	150	160	130	110
EC	3.6	3.75	4.86	4.72	4.89	4.84
Alkalinity (mg/1)	670	665	2300	2400	2000	2700
Cations (mg/1)						
Fe	0.16	0.15	18.16	15.25	11.34	13.55
Mn	1.1	0.11	0.78	0.52	0.41	0.44
Ca	219	332	443	181	233	340
Na	556	538	485	778	735	256
K	65.2	61.6	1266	1273	1282	1371
Anions (mg/1)						
Cl	10.3	11.2	1996	2650	2170	2338
So_4	73.0	82.5	1105	1088	1164	11065
Heavy Metals (mg/1)						
Cd	0.012	0.013	0.16	0.52	0.42	0.37
Zn	95	90	261	169	174	159
Cu	0.12	0.25	0.52	0.044	0.048	19.45
Pb	0.19	0.89	1.70	1.50	0.65	1.5

Ali (1998) reported a gradual increase of element concentrations in the groundwater wells around the Al-Akader landfill starting from 1985, where nitrate concentrations raised dramatically, doubling more than ten times in ten years; this indicates that the previously unsaturated zone had become saturated with polluted water. Also Obeidat et al. (2008) and awawdeh et al. (2009) found that the Yarmouk basin is contaminated with high nitrate concentration; exceeding the maximum acceptable concentration for drinking water standard. This was identified previously by Abu Rukah at el. (2004) in their study on groundwater in northern part of Jordan; they found high concentration of HCO^-_3 and NO^-_3 of 307 and 51 mg/l, respectively. Another study by Obedat et al. (2007) showed high nitrate concentrations in groundwater at Amman-Zarqa basin; it ranged from 10 to 330 mg/l, and increased dramatically from the year 2001 to 2006, where about 92% of the samples have NO^-_3 concentration more than 20 mg/l. [29, 30] [31, 32] [33]

4. Conclusions

The increasing population and economic development coupled with the unsustainable waste management are leading to rapid changes in the quality and quantity of the available water resources. From the previous studies it is clearly evident that the leachate generated from the landfill site is affecting the groundwater quality in the northern part of Jordan through percolation in the subsoil. Leachate from MSW landfills typically has high values for total dissolved solids (TDS) and chemical oxygen demand (COD), and a slightly low to moderately low pH. MSW leachate contains hazardous constituents, such as volatile organic compounds and heavy metals. However, high concentration of heavy metals, Electrical Conductivity, Hardness, Nitrates, Chlorides Sulphates, in ground water near landfill deteriorates the quality of water. The removal of contaminants from contaminated landfill is generally difficult.

To minimize the impact of the landfill emissions on ground water quality and the environment in general, it is necessary to properly design and build facilities (Gas and leachate collection system) to prevent pollution. In Jordan the contaminate present in most of landfills used are not identified or quantified yet and the influence of seasonal variations on the contaminant concentrations with time is not acknowledged; their public health implication are unknown. Therefore, it's recommended that regular reliable long-term monitoring must be carried out over a large period, in order to stand on quantity and quality of leachate generated and the possible effects on ground water quality. Moreover, it is important to educate all levels of society including stakeholders and civil society on the importance of groundwater and the possible threaten from the mismanagement of solid waste and landfilling practices in the country and their participation can and must be encouraged. Therefore, urgent need to adopt more integrated approach to water resources and solid waste management

that will take into consideration the element of sustainability through introducing new and policy measures to guarantee the protection of valuable water resources and for future generations.

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