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GROUNDWATER QUALITY IN THE SURROUNDINGS OF MAFRAQ LANDFILL, JORDAN

Grundvattenkvalité i närheten av Mafraq-deponin, Jordanien

by NICOLAS SCHOEFFLER[1], MOHAMMAD ALJARADIN[1], and KENNETH M PERSSON[1,2]*
1 Department of Water Resources Engineering, Lund University, Box 118, 221 00 Lund, Sweden.
2 SYDVATTEN AB, Skeppsgatan 19, 211 19 MALMÖ
** Corresponding Author: e-mail: Mohammad.Aljaradin@tvrl.lth.se*



Abstract

The aim of this study was to gather information about the Mafraq landfills sanitary status as well as assessing its leachate quality and the groundwater quality in its surroundings. The Mafraq landfill is located upon one of Jordan's most important groundwater aquifer making it a possible threat to the water quality. The aquifer is used for drinking and irrigation purposes. Groundwater quality was therefore compared with drinking and irrigation water quality standards. Based on the result of this study, the Mafraq landfill clearly does not fulfill the requirements to be classified as sanitary. The leachate is free to interact with the groundwater aquifer. Furthermore, the leachate analysis showed that the soil under the landfill is contaminated. Groundwater from various wells is unsuitable for household purposes due to its high concentration of fluorine and mercury. This may cause severe health damages to humans if indigested. The groundwater from nearly all wells was found to have slight to moderate restrictions for its use as irrigation water due to high salinity and sodium, and toxic concentrations of chloride and sodium. The restrictions imply that special care should be taken when selecting crop and irrigation management in order to maximize crop yield.

Key words – Groundwater quality; Uncontrolled Landfilling, Jordan

Sammanfattning

Syftet med denna studie var att samla information om den sanitära status som gäller för Mafraqs-deponin och att bedöma lakvattnets och grundvattnets kvalitet i dess närområde. Mafraqs-deponin befinner sig på en av Jordaniens viktigaste akvifer och utgör därigenom ett potentiellt hot mot grundvattnets kvalitet. I området runt om deponin används grundvattnet som dricksvatten och för konstbevattning, dess kvalitet jämfördes därför med standardvärden inom dessa användningsområden. Följande slutsatser drogs i samband med studien. Mafraqs-deponin uppfyller inte kraven för att kvalificeras som sanitär. Lakvattnet är i direkt kontakt med grundvattnet under deponin och analyser tyder på att förorening äger rum. Grundvattnet från flera brunnar hade för höga kvicksilver- och fluorhalter, vilket gör det skadligt för människors hälsa och därigenom olämpligt som dricksvatten. Grundvattnet från närmast alla brunnar visade sig vara olämpliga för konstbevattning på grund av för växter toxiska salthalter och natriumhalter. Konstbevattning med detta vatten medför att val av grödor och bevattnings skötsel måste ske med eftertanke om full avkastningspotential skall uppnås.

1 Introduction

The situation of the water resources in Jordan is critical. On a per capita basis it has one of the lowest amounts of water in the world. The reasons for such a scarcity have their roots in a combination of disadvantageous natural conditions and human induced stresses.

Jordan is located in a semi-arid climatic zone and hence inherits a limited amount of rainfall recharging its surface and groundwater reservoirs. This renewable amount of wa-

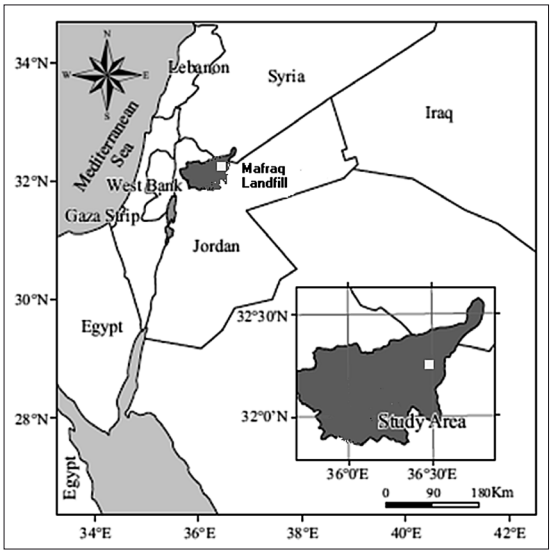

Figure 1. *Map of Jordan with the city of Mafraq and the landfill.*

ter has mainly been stressed by a rapid population expansion (Potter et al., 2009), but also other factors such as resource misallocation and conflicts with neighboring countries sharing the same resources have exacerbated the problem.

Studies estimate that about 30 % of Jordan's water resources occur as renewable groundwater (Octavio, 2008).The consumption of groundwater is nevertheless far exceeding its renewable capacity and can reach over 50 % of Jordan's total one (Ammary, 2007).

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.

In Jordan, landfilling of municipal solid waste has evolved over the past 15 years as recommended disposal method. Since 1950, waste disposal basically involved open dumping and burning without complying with the proper regulations, while at the beginning of the 1980s, awareness of the need to establish sanitary landfills increased (Abu Qdais, 2007). Until now, Jordan has relied only on landfills to store the waste (Aljaradin and Persson, 2011). Serious environmental problems are connected to this which could threaten human, ground water, surface water resources and soil still appearing. This study aims consequently at studying the interaction between the Mafraq landfill leachate and groundwater quality.

2 Background information

2.1 Location

The city of Mafraqs municipal landfill is located in the northern part of Jordan in the region of the Mafraq Governorate at about 70km of the capital city Amman, see figure 1 (long 36°12′30″E lat 32°25′10″N) (AlAnsari et al., 2005).

2.2 The Mafraq landfill

The landfill covers an area of approximately 18 ha and receives a total of 134 tons of waste per day from the city of Mafraq and 64 villages in the region (AlAnsari et al., 2005). The Mafraq landfill is represented by a photography taken during a field trip, see figure 2.

The different types of waste deposited on the landfill are residential, commercial, institutional and municipal. The waste is directly deposited on the surface ground. After disposal on the site a team of about 15–30 human scavengers are employed to sort the trash out into the following categories: plastic, cardboard/paper, metallic waste and aluminum waste. The remaining waste is then piled on by trucks for final deposition. The landfill is not considered to be sanitary for the following reasons (Aljaradin and Persson, 2010; Tadros, 2007).

- There is no daily covering with soil, it can take up to one year before covering by a few decimeters of soil takes place.
- The landfill is located on a basaltic aquifer with no impermeable layer preventing the leachate from entering the groundwater.
- There is no leachate recollection or treatment system.

2.3 The wells

Three water samples were taken during field trips, one from the Abdel Mute, one from the Abu Rabi and one from the Hammouda well. The wells were located at

Figure 2. *Photo of Mafraq landfill.*

around 2–5 km from the landfill and all of them were closed wells.

A total of 18 wells were analyzed on one or several occasions by Jordan's Water Authority. These wells are divided into three different groups, based upon their location in relation to the landfill, and the aquifers they mainly are tapping from.

3 Method

3.1 Leachate extraction

During the field trips to the Mafraq landfill no leachate was encountered; an alternative method was for that reason used in order to make a qualitative guess of the leachates chemical composition. Two soil samples were recollected, one "contaminated" sample taken from directly under the waste at the center of the landfill and one reference sample taken from just outside the landfill. Two hundred grams of the different soil samples were then mixed with 500 ml of distilled water. After about 12 h of sedimentation the water samples were roughly filtered and subsequently analyzed for main ions and various heavy metals.

3.2 Water samples

Water samples were recollected from three wells surrounding the Mafraq landfill, the Abu Rabi well, the Abdel Mute and the Hammouda well. The total dissolved solids (TDS), the electric conductivity (EC)and temperature were analyzed in situ whereas the pH, total organic carbon (TOC), the salts and heavy metals were analyzed at the Mutah University.

Eighteen wells were analyzed by Jordan's Water Authority. The different analyses of interest performed on the well waters were the main ions and heavy metal concentrations. In order to verify the accuracy of the chemical analyses performed a cation-anion balance calculation was carried out. A maximum error of 5 % was used in order to validate the good quality data. This data was then used in order to calculate TDS, EC, the sodium absorption ration (SAR) and the residual sodium carbonate (RSC). The total dissolved solid content was calculated as the sum of anions and cations

4 Results and discussion

4.1 Leachate Quality

The natural occurrence of ions and heavy metals in the soil underneath the landfill have been altered, nearly all chemical parameters are higher in the leachate sample then in the reference one. In that sense contamination of the landfill soil has been occurring. A possible explanation for the high heavy metal content could be that the human on site sorting is imprecise.

The difference in ion concentration in the reference sample and in the leachate could be explained by the decomposition of organic waste.

4.2 Water suitability for household purposes

Heavy Metals

An exceeding value of mercury, 0.17 mg/l compared to the guideline value of 0.006 mg/l, was found in the well number AL3375 of the Al Zatary well field. Mercury at such a concentration is toxic for human beings, ingestion could result in kidney damages.

Out of the 18 wells analyzed this well was one of the two wells in which the mercury concentration was at all measured. Mercury concentrations in groundwater are rarely expected to exceed 0.0005 mg/l (WHO, 2008). The mercury concentration measured is hence not likely to be a product of mineral weathering but of anthropogenic nature, such as fluorescents, batteries, barometers and thermometers. None of these components were found to be recycled at the landfill.

Ions

All ion concentrations analyzed at the Mutah University were in accordance with WHO guideline values except for the fluoride and the chloride concentrations.

The guideline value for fluoride is set to 1.5 mg/l whereas the Abdel Mute, Abu Rabi and Hammouda wells had fluoride values of 3.8, 11.1 and 14.2 mg/l correspondingly. Fluoride at such concentrations is likely to have several health effect related risks such as dental fluorosis and skeletal fluorosis. Fluoride levels in natural conditions rarely exceed a concentration of 10 mg/l in groundwater (WHO, 2008), even though it can reach higher concentrations locally.

The taste guideline value for chloride is set to 200–300 mg/l; the exceeding value found in the Abdel Mute well was of 334.3 mg/l. Such a concentration could contribute to give a salty taste to water.

The tests from the Jordanian Water Authority showed that the chloride concentration, the sodium and the hardness exceeded in some cases the guideline values. The chloride concentrations of nearly all private/isolated wells were comprised between the taste guideline of 200–300 mg/L. These wells could depending on the chloride ion association have or not waters with salty taste. Well number AL2329 had a chloride concentration of 631.056 mg/l and a sodium concentration of 286.534 mg/l whereas the taste limit for sodium is set to 200 mg/l. This water was very likely to have a strong salty taste.

Table 1. *Resuming table of the wells suitability for irrigation purposes. Restrictions on use: None, slight moderate, sever.*

Well field	SAR and EC	EC	RSC	Specific Ion toxicity			
				Cl		Na	
				surface irrigation	sprinkler irrigation	surface irrigation	sprinkler irrgation
Al Zatary							
Well 4							
Well 10							
Well 6							
Private/ Isolated							
Km 89							
Imadeddeen							
Km 93,5							
Al Aqeb							
Well 093							
Well K 094							
Well K 091,5							

Finally all wells from the different well fields, except for well Al1485 had hardness values exceeding the WHO standard of 100–200 mg/l. Well AL1486 on the other hand had a hardness below that standard with a value of 91.5. Too hard water might lead to major scale deposits especially when boiling the water and too soft water might be corrosive to water distribution pipes and unsuitable for washing purposes.

4.3 Water suitability for irrigation purposes

Resuming all the restrictions previously discussed is the table 1. From this table it can be read that six wells have at least three slight to moderate restrictions independently of the type of irrigation used. Well K094 has only one slight to moderate restriction on use (SAR and EC) and well 093 has two or three slight to moderate restrictions depending if surface or sprinkler irrigation is used. The Imadeddeen well has a slight to moderate restriction for the EC and in addition two possible severe restrictions if surface irrigation is used.

Assumptions and clarifications on the guidelines

The restrictions on use are approximate guidelines for a large spectrum of agricultural conditions and can vary greatly depending on them. They do not imply that the water is unsuitable for irrigation purposes only that they might affect the full production yield of certain crops negatively (Ayers, 1994).

5 Conclusion

The Mafraq landfill clearly doesn't fulfill the requirements to be classified as sanitary. The leachate is free to interact with the groundwater under the landfill. Furthermore the leachate analysis shows that contamination of the soil under the landfill is taking place.

The groundwater's from various wells were found to be unsuitable for household purposes. The most alarming problems for drinking purposes were found in three wells that classified as having too high fluorine concentration and one as having too high mercury concentration. These groundwater's may cause severe health damages to humans if indigested. One well had high content of both chlorine and sodium ions giving a salty taste to the water and thus making it unsuitable for drinking purposes. Nearly all wells had very hard waters making them unsuitable for domestic uses due to scale deposit problems. Note that the term unsuitable is highly subjective and only used because the concentrations exceed the guideline values.

The groundwater for all wells except for one was found to have slight to moderate restrictions on use for irrigation purposes. Special care about the choice of crop and irrigation management is needed in order to reach full yield potential. One well classified as having severe restrictions on use for surface irrigation because of its toxic chloride and sodium concentrations. Further studies are needed to evaluate the cropping techniques to use for full yield potential to be achieved.

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