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Pollution based on Biological

Indicators

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Authors and Institution

Leicht, Miriam (KIT)

Fuchs, Stephan (KIT)

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Project Coordination:

Main Coordinator:	Assistant Coordinators	
Prof. Dr. Nico Goldscheider Institute of Applied Geosciences, Karlsruhe Institute of Technology Adenauerring 20b 76131 Karlsruhe Germany Phone: +49 (0) 721 608 45465 Fax: +49 (0) 721 606 279	Prof. Dr. Martin Sauter Department of Applied Geology Göttingen University Goldschmidtstrasse 3 37077 Göttingen Germany Phone: +49 (0)551 39 79 11 Fax: +49 (0)551 39 93 79	Dr. Stefan Geyer & Dr. Roland Mueller Helmholtz Centre for Environmental Research (UFZ) Permoserstr. 15 04318 Leipzig Germany Phone: +49 (0)341 235 30 00 Fax: +49 (0)341 235 2885

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1. INTRODUCTION

In arid zones, such as Jordan, water is one of the scarcest resources and the people living there have to face problems usually connected to the lack of water. As water shortage has become of permanent nature, access to irrigation water was and is a major factor and meeting water demands is a challenge.

Jordan, with a total area of about 88.780 km² (Bender, 1968), is known to be one of the most water scarce countries in the world as only 8.5% of its total area receives more than 200 mm of annual rainfall (Hilal et al., 2010). Population growth is considered to be the main parameter influencing future water demand and with a population of 6,594,080 (June 2014 est.) Jordan has reached a water crisis (Department of Statistics). Together with high periodic influxes of refugees as well as the fact that Jordan shares most of its surface water resources with neighboring countries, the gap between water supply and demand became imbalanced. At present, the water demand exceeds the renewable freshwater, which is estimated at about 850 MCM per year, consisting primarily of surface and ground water resources, by more than 20%. In the near future, the water crisis will become more and more serious as due to population growth, urbanization, industrialization and agricultural irrigation the water problem will increase.

The water scarcity leads to limited surface and groundwater resources, which, due to the increasing industrialization and urbanization are being over-exploited and contaminated through inadequate treatment or illegal disposal of waste. The construction of industrial plants near potable supplies as well as the over- and misuse of pesticides, insecticides, fungicides and fertilizers are among the factors that cause the pollution of the limited ground and surface water resources (Hilal et al., 2010). These conditions have led to several approaches of the Jordanian Government to both reduce the demands as well as to increase the supply with water.

The "German Federal Ministry for Education and Research" (BMBF) has set up a program for the "Integrated Water Resources Management" (IWRM) in regions with water shortages, such as Jordan, to support the country in this sensible topic. SMART II, focusing on "Sustainable Management of Available Water Resources with Innovative Technologies" in the lower Jordan Valley, is one of those projects, this work is embedded in.

This document reports the work conducted while monitoring surface water pollution based on biological indicators as part of Work package 5, Deliverable D 502 of SMART II with the title "Monitoring of surface water pollution based on biological indicators."

The objectives of this Deliverable are:

- a) to use biological methods to describe the quality and pollution of surface water bodies in a selected area in Jordan
- b) to show an easy approach of how to measure the water quality
- c) provide useful information to be adopted in future monitoring programs in the Middle East Region

The study was conducted within a 2 years survey in the area between As Samra Wastewater Treatment Plant (WWTP) and King Talal Dam (KTD), Jordan in order to:

- 1) determine the water quality in Zarqa River
- 2) examine the macro invertebrate community
- 3) examine the ecological condition of the water in KTD
- 4) examine the heavy metal contamination

The overall goal of this work is to provide a guideline of how to monitor surface water pollution. Biological indicators were used to describe the quality and pollution of surface water bodies.

This study should function as a feasibility study in a selected area in Jordan. It will and cannot give a final conclusion but it might be useful for further studies in the region.

In the future, a classification of the surface water quality of rivers, lakes, coastal and transitional waters should be carried out. Following the European Water Framework Directive (WFD) (European Council, 2000) a major goal is to achieve a good status for all surface waters in both good chemical as well as good ecological status (European Council, 2000).

By adapting those regulations to Jordanian Rivers and Wadis, an attempt to protect and keep the Jordanian aquatic system healthy is being developed.

Regarding the macrozoobenthos study, an overall monitoring in Jordan needs to be carried out. Up to date, not all of the invertebrates are classified and thus are sometimes difficult to specify. Literature from neighboring countries and the Mediterranean were used to classify the invertebrates when no other literature was available.

2. Background and Motivation

2.1. Water resources, demand and deficit

At present, the water demand in Jordan exceeds the renewable freshwater, which is estimated at about 850 MCM per year, consisting primarily of surface and ground water resources, by more than 20% (Table 1).

Following Myszograj et al. (2011), in 2010 the renewable water resources were estimated to be about 1203 m³, including ground water (277 million m³ distributed among 12 basins), usable surface water (234 million m³ distributed among 15 catchments basins) and treated wastewater 177 million m³. In addition, 140 million m³/year of ground water is estimated to be available from fossil aquifers.

Table 1: Sources of water usage in Jordan in 1997, * estimated figures (modified after EMWISL 2008)

Source	Municipal	Industrial	Irrigation	Livestock	Total use
Surface Water	58,071	1,893	264,486	4,000	328,450
Jordan Rift Valley	38,441	1,893	194,486	0,000	234,820
Springs	19,630	0,000	* 30,000	0,000	49,630
Base and Flood	0,000	0,000	* 40,000	* 4,000	44,000
Ground water	177,557	35,343	266,189	7,118	486,207
Renewable	168,679	31,552	207,119	6,001	413,351
Nonrenewable	8,878	3,791	59,070	1,117	72,856
Treated Waste Water	0,000	0,000	61,000	0,000	61,000
Registered	0,000	0,000	57,300	0,000	57,300
Not registered	0,000	0,000	3,700	0,000	3,700
Total	235,628	37,236	591,675	11,118	875,657

2.2. Jordanian Standard

The Jordanian Standard 893/2002 is dealing with “Water-Reclaimed Domestic Wastewater” and determines the standard regulations and guidelines that are required for water reuse in present and future. This Standard specifies the conditions that reclaimed domestic wastewater discharged from wastewater treatment plants should meet in order to be discharged or used. Reclaimed wastewater can be discharged to streams, wadis or water bodies or reused when its quality complies with the properties and criteria. Reclaimed water has to be prevented from leaking into the ground water and it is not allowed to dilute by mixing reclaimed water before being discharged from wastewater treatment plants with pure water intentionally to comply with the requirement set in this standard (MWI, Ulimat, A.A., 2012).

Following the Jordanian Standard it is prohibited to use reclaimed water for irrigating vegetables that will be eaten raw. Further, when using reclaimed water for irrigating fruit trees, irrigation must be stopped two weeks prior to fruits harvesting and any falling fruits in contact with the soil must be removed (MWI, Ulimat, A.A., 2012).

Jordanian wastewater quality standards 893/2006 are shown in Table 2.

Table 2: Reclaimed domestic wastewater Standard 893/2006 (modified after Uleimat, A., 2012)

Discharge to Waterbodies and Wadis		Artificial Recharge		Irrigation			
Group A	[mg/l]	Group A	[mg/l]	[mg/l]	C	B	A
BOD ₅	60	BOD ₅	15	30	300	200	30
COD	150	COD	50	100	500	500	100
DO	>	DO	>2	>2			>2
TSS	60	TSS	50	15	300	200	50
pH	(6-9)	pH	(6-9)	(6-9)	(6-9)	(6-9)	(6-9)
NO ₃	70	NO ₃	30	45			30
T-N	70	T-N	30	70	70	45	45
E.coli	1000	E.coli	<1,1	<1,1		1000	100
Intestinal Helminthe Eggs	<1	Intestinal Helminthe Eggs	<1	<1	<1	<1	<1
FOG	8	FOG	8	2	8	8	8
Group B	[mg/l]		[mg/l]	[mg/l]	A	B	C
Phenol	<0,002	Phenol	<0,002	Phenol	<0,002		
MBAS	25	MBAS	25	MBAS	100(15)		
TDS	1500	TDS	1500	TDS	1500		
T-PO ₄	15	T-PO ₄	15	T-PO ₄	30		
Cl	350	Cl	350	Cl	400		
SO ₄	300	SO ₄	300	SO ₄	500		
HCO ₃	400	HCO ₃	400	HCO ₃	400		
Na	200	Na	200	Na	230		
Mg	100	Mg	100	Mg	100		
Ca	200	Ca	200	Ca	230		
SAR	6	SAR	6	SAR	9		
Al	2	Al	2	Al	5		

As	0,05	As	0,05	As	0,1
Be	0,1	Be	0,1	Be	0,1
Cu	0,2	Cu	0,2	Cu	0,2
F	1,50	F	1,50	F	1,5
Fe	5	Fe	5	Fe	5
Li	2,50	Li	2,50	Li	2,5 (0,075)
Mn	0,2	Mn	0,2	Mn	0,2
Mo	0,01	Mo	0,01	Mo	0,01
Ni	0,2	Ni	0,2	Ni	0,2
Pb	0,2	Pb	0,2	Pb	5
Se	0,05	Se	0,05	Se	0,05
Cd	0,01	Cd	0,01	Cd	0,01
Zn	5	Zn	5	Zn	5
Cr	0,02	Cr	0,02	Cr	0,1
Hg	0,002	Hg	0,002	Hg	0,002
V	0,1	V	0,1	V	0,1
COD	0,05	COD	0,05	COD	0,05
B	1	B	1	B	1
CN	0,1	CN	0,1	CN	0,1

3. SELECTION OF THE PROJECT AREA

The complete study comprises the area from the outlet of As Samra WWTP, following along Zarqa River and ending in KTD, where the Royal Botanic Garden (RBG) is located (Figure 2).

Treated wastewater from the As Samra WWTP flows through the Zarqa River and KTD to the Jordan Valley (JV) where it is reused indirectly for irrigation.

And as thus this water is used for irrigation purposes in the JV, also King Abdullah Canal (KAC) and the JV should be taken into consideration, but within this study there was unfortunately not enough time (Figure 1). The whole, comprising also the area upstream As Samra WWTP as well as KAC and JV will be considered within the Ph.D. thesis of Miriam Leicht.

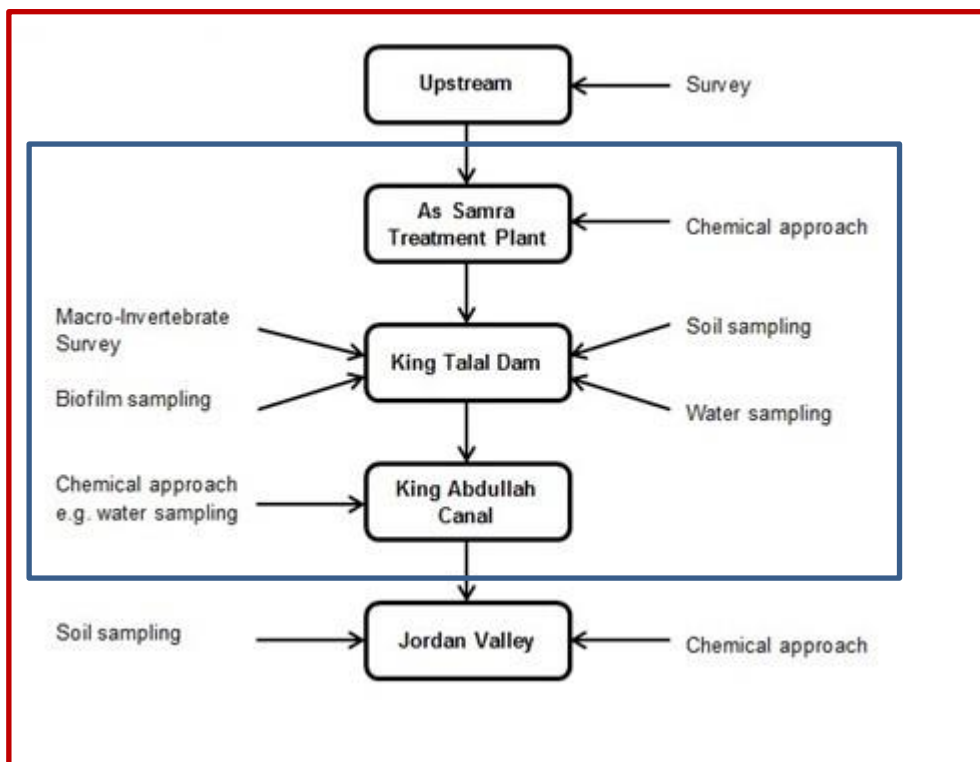


Figure 1: Objective target of the study (blue: study area comprised within D502, red: study area comprised within Ph.D. thesis of Miriam Leicht)

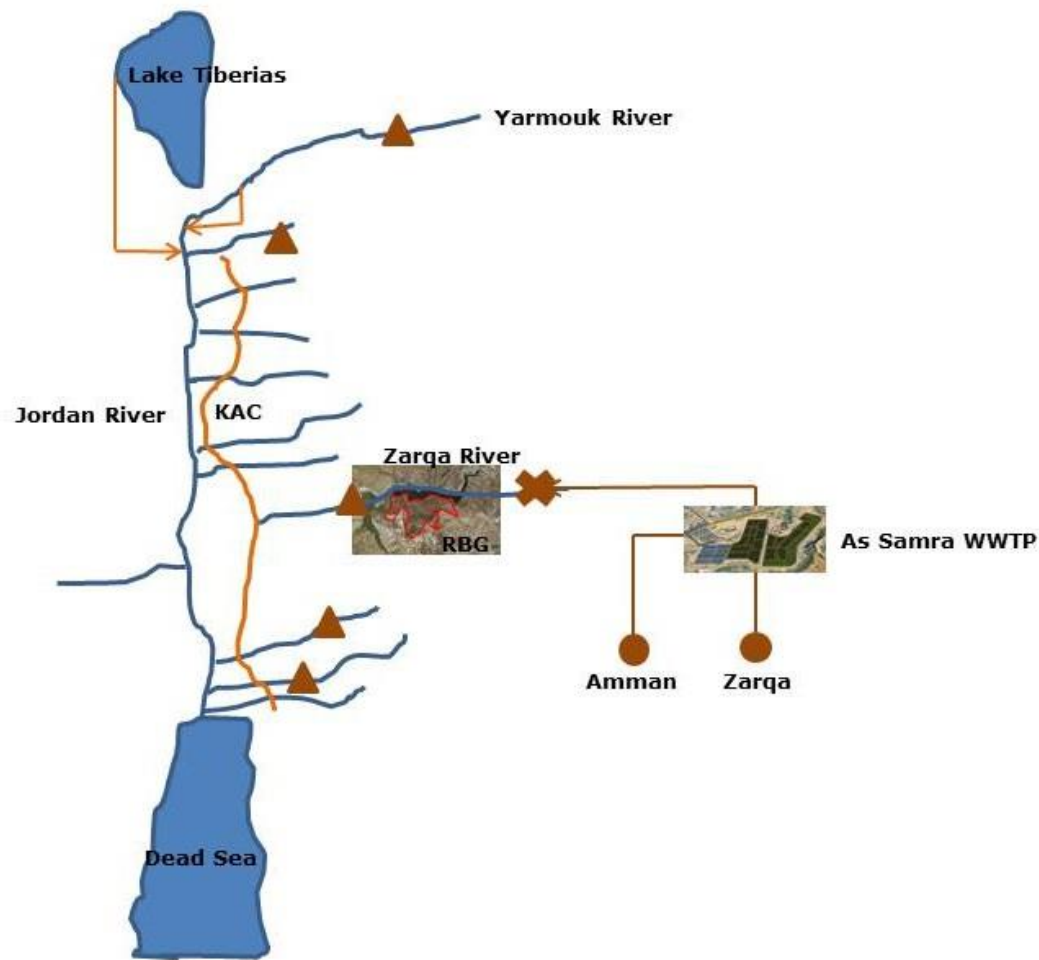


Figure 2: Location of As Samra, Zarqa River, KTD and RBG (modified after Al-Omari et al., 2012 and Google Earth)

3.1. As-Samra Wastewater Treatment Plant

The treatment plant which is leading its treated wastewater into the KTD reservoir is As Samra WWTP. Figure 3 shows the location of the As-Samra WWTP which is located in Zarqa area and which is the largest wastewater treatment facility in Jordan. It was built to replace the old As-Samra Wastewater Stabilization Ponds (WSP) (Kamel, A., 2008). The effluents of the WSP were not able to meet the Jordanian domestic wastewater discharge standards (Table 2) and thus the renewal of the plant started in 2003 and was finished in August 2008 (Water Technology Net, 2012). Table 3 shows the raw water quality and effluent water and sludge quality of As Samra WWTP, which all meet the required Standards. The plant now consists of a primary settling tank, eight aeration tanks and eight secondary settling tanks, four anaerobic sludge digesters, biogas and hydro-powered generators, and an odor control system (Kamel, A., 2008).



Figure 3: Location of As Samra WWTP (modified after Degrémont, 2008 and Google Earth)

Figure 4a shows the chlorination tank at As Samra WWTP and 4b the Outlet. As Samra WWTP receives its inflow from the Zarqa river basin, in which both Greater Amman and Zarqa are located (~ 2.2 million people), and thus treats an average daily inflow of 267.000 cubic meters.



Figure 4: (a) Chlorination tank and (b) Outlet at As Samra WWTP (Source: Pictures taken by author)

Table 3: Raw water quality and effluent water and sludge quality of As Samra WWTP (modified after MWI)

Raw Water Quality		Effluent Water and Sludge Quality	
BOD ₅	652 mg/l	BOD ₅	30 mg/l
COD	1,449 mg/l	TSS	30 mg/l
TSS	551 mg/l	TN	30 mg/l
VSS	440 mg/l	pH	6
TN	130 mg/l	DO	> 2 mg/l
Grease	30 m3/d	Fat, Oil & Grease	< 8 mg/l
H ₂ S	40 mg/l	Dry Solids	30%
Nematodes	5 eggs/l	Nematodes	< 1 egg/l
F-Coliforms	10 ⁸ MPN/100 ml	F-Coliforms	< 1000 MPN/100 ml

3.2. Zarqa River

The Zarqa River, second largest tributary of the lower Jordan River, rises from a spring named Ain Ghazal near Amman and flows through a deep and broad valley into the Jordan



river. The Zarqa River (Figure 5) is perennial, but with a very low base flow of about 2 to 3 MCM/month during summer and 5 to 8 MCM/month during the winter months. The area of the Zarqa River watershed has two main branches: Amman-Zarqa which drains the Eastern Escarpment of the Jordan Rift Valley and parts of the Jordan Highland, and Wadi Dhuliel draining the Jordan Highland and Plateau. Zarqa River is flowing through populated and industrialized areas, where more than 52% of Jordan's industrial plants are located. During the dry summer months the water of Zarqa often has a brownish color as its water composes mostly of treated domestic and

Figure 5: Zarqa River, Jordan (Source: Pictures taken by author)

industrial waste-water and thus degrades its water quality. Often foam can be found on its surface due to the large amounts of organic matter (Al Eisawi D.M.H, 2005). Additional sources of pollutants might be the illegal dumping of industrial waste.

The rehabilitation of the Zarqa River is a top priority for the Jordanian Ministry of the Environment and with the construction of treatment plants, such as As-Samra, the situation can be handled much better (Medwet, 06.2014).

Table 4: Heavy metal content of As Samra Outlet and KTD Inlet in comparison to Jordanian Standards (893/2006)

Parameter	Max. limit allowed [mg/l]*	As Samra Outlet [mg/l]**	King Talal Dam Inlet [mg/l]**
		19.09.2010	11.09.2011
Cu	0,2	<0,02	<0,02
Fe	5	0,056	0,0447
Pb	0,2	<0,09	<0,09
Cd	0,01	<0,005	<0,005
Zn	5	0,018	<0,016

* Jordanian Standards (893/2006) for reclaimed domestic wastewater to be discharged to Wadis and water bodies (Table x)

** Data modified after JVA

3.3. Royal Botanic Garden

Within the project area, the “The Royal Botanic Garden of Jordan (RBG)” is located north of Amman, in a protected area. The RBG is located in Tell Ar-Rumman, overlooking King Talal Dam (KTD) (Figure 6 & 7). The RBG, a non-profit organization, founded in 2005, conserves the flora and biodiversity of Jordan by propagating and displaying native plants, rehabilitating habitats at the whole-systems level, conducting research, demonstrating sustainable practices and sharing information (RBG, 2012).



Figure 6: Royal Botanic Garden (RBG) in Tell Ar-Rumman, Al Balqa Governorate in Jordan (modified after Hugo Bugg Landscapes)

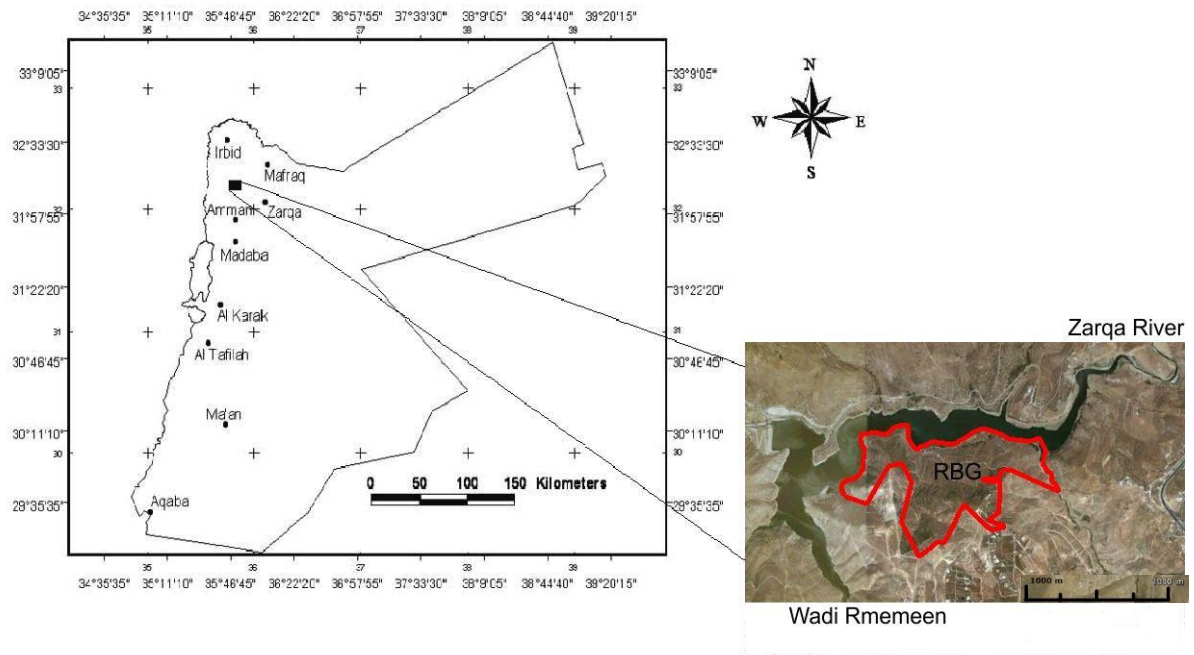


Figure 7: Study area (modified after Royal Botanic Garden and Google Earth)

The RBG covers ~180 hectares with more than 300 m of elevation change and is used as a demonstration site showcasing sustainable water management and energy strategies (Royal Botanic Garden, 2012). Every strategy used at the RBG should be replicable by the average Jordanian.

Although an independent non-profit organization, the RBG is part of the Biodiversity Strategy and Action Plan prepared by Jordan's Ministry of Environment, to implement the 1992 "Convention on Biological Diversity", ratified by the Kingdom in 1993.

The work of the RBG is divided into four main components: Scientific research, Biodiversity conservation, sustainable living and education (Royal Botanic Garden, 2012).

The location of the RBG shows several advantages regarding the implementation of this study as it provides:

1. a protected environment to place samplers for monitoring
2. easy access to laboratories (RBG, Jordan University, Royal Scientific Society (RSS))
3. inflow of treated wastewater from As Samra Treatment Plant
4. use of the KTD surface water for irrigation purposes in the Jordan Valley (JV)
5. demonstration site in Jordan showcasing sustainable water management

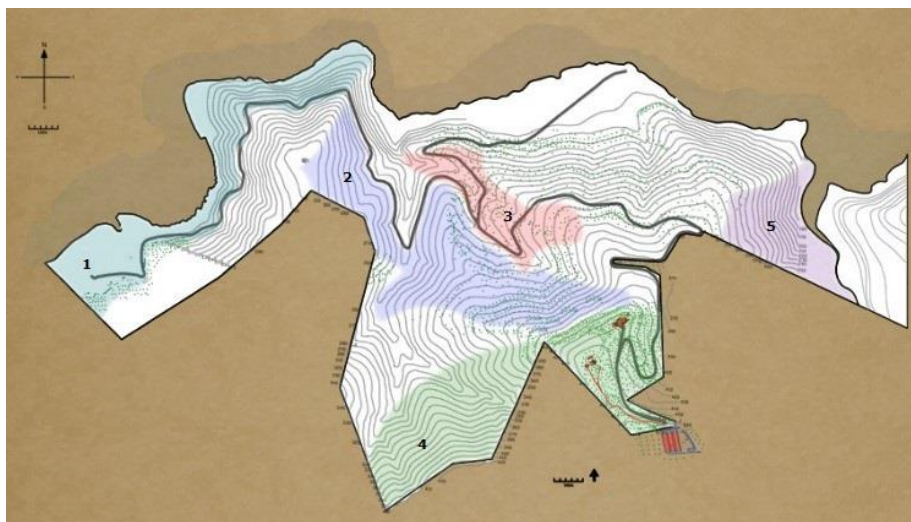


Figure 8: Location of five habitats that are re-created in the RBG (www.royalbotanicgarden.org)

Figure 8 shows a map of the RBG pointing out the location of the five Jordanian habitats that the RBG is re-creating in Tell Ar-Rumman:

1. Jordan Valley Habitat
2. Pine Forest Habitat
3. Juniper Forest Habitat
4. Deciduous Oak Forest Habitat
5. Freshwater Habitat

3.4. King Talal Dam

The KTD, an earth filled dam, constructed between 1972 and 1978, created Jordan's largest artificial above groundwater reservoir with a capacity of 85 MCM (Figure 9a and Table 5) (Hilal et al., 2010). The reservoir is located in the northern highlands, about 35 km north of Amman, across the Zarqa River. The previous purpose of the KTD was to supply water for municipal use in the Amman region, but due to the high pollution levels in the lake, the surface water cannot be used for human consumption and thus is used for irrigation purposes in the JV (Fandi, K.G. et al., 2009). The reservoir is highly polluted by garbage disposal, untreated sewage overflow and illegal dumping of industrial waste, which is leading to raising salinity, chemical and metal levels (Fandi, K.G. et al., 2009) (Figure 9b and 10a&b). As more than 60 industries are located in the catchment area of Amman-Zarqa, an increasing emission of industrial effluents also affected the reservoir (Gideon, R, 1991). In addition, groundwater salinization and agricultural residues have influenced the surface water of the dam and lead to a high eutrophication (Fandi, K.G. et al., 2009).



Figure 9: a) KTD with reservoir and b) Pollution on the shore of the KTD reservoir (Source: Pictures taken by author)

The treated wastewater KTD reservoir receives from As Samra WWTP contributes to about 50% of the total water reaching the dam, whilst its annual inflow is about 113 MCM (Hilal et al., 2010). Wadi Rmemeen drainage represents the second important source of water for the reservoir and receives its water mainly from Al Baqa'a treatment plant and some springs (RSS, 2005). As Samra WWTP effluent, as well as the industrial wastewater discharged into the dam via the Zarqa River, has a relatively high concentration of heavy metals, phosphorus and ammonia which affect the water quality of the KTD (Al-Jassabi et al., 2006) and thus also limits the use of its water for irrigation purposes (Hilal et al. 2010). Hilal et al. as well as several other reports show that the water as well as the sediments in the reservoir are polluted due to many anthropogenic and natural sources, including nutrients, heavy metals and show extensive blooms in the summer season due to the cyanobacteria *Microcystis aeruginosa* (Numayer, 1999).



Figure 10: Dead fish in the KTD reservoir and pollution at KTD shoreline and (b) pollution in the reservoir (Source: Pictures taken by author)

Table 5: KTD – basic information (Data obtained from Jordan Valley Authority)

King Talal Dam	
Catchments of dam (km ²)	3700
Purpose of dam	Irrigation + Electrical Generation
Spillway capacity (m ³ /sec)	4500
Sediment load (MCM/yr)	14,5 MCM up to now
Evaporation (MCM/yr)	4,3
Seepage (MCM/yr)	2,8
Seepage (l/sec)	60 - 100
Average inflow	2,6
Average outflow	3,5
Carry over (Turn over) MCM	25
Avarage Rainfall (mm/yr)	250

(*): Million Cubic Meters

4. Monitoring Methods

4.1. Introduction

Biological methods are highly recommended to describe the quality and pollution of surface water bodies and are an excellent instrument to evaluate the overall ecological quality. Their advantage is the allowance of an integrated assessment of surface water quality, considering several parameters such as organic load, discharge, bottom substrates and pollutants. To offer all necessary information regarding water quality, physical and chemical measurements should be conducted in addition to biological parameters. As the aquatic environment can be affected by both natural and anthropogenic influences and organisms living in a water body are sensitive due to any changes in their environment, the response of an organism to those changes can be used to determine the water quality regarding its ability for aquatic organisms living there (Friedrich, G. et al., 1992). Following Friedrich, G. et al. (1992) there are, in general, five main types of biological assessment of water bodies, listed as followed:

(1) Ecological methods

- Analysis of the biological communities (biocenosis) of the water body
- Analysis of the biocenosis on artificial substrates placed in a water body
- Presence or absence of specific species

(2) Physiological and biochemical methods

- Oxygen production and consumption
- Respiration and growth of organisms suspended in the water
- Studies of the effects on enzymes

(3) The use of organisms in controlled environments

- Assessment of the toxic effects of samples on organisms under defined laboratory conditions
- Assessing the effects on defined organisms of waters and effluents *in situ*

(4) Biological accumulation

- Studies of the bioaccumulation of substances by organisms living in the environment
- Studies of the bioaccumulation of substances by organisms deliberately exposed in the environment

(5) Histological and morphological methods

- Observation of histological and morphological changes

Within the scope of this project, two biological methods were tested and applied in the study area, focusing on the area of Zarqa River and KTD Reservoir and two methods to verify the biological findings (Figure 11):

- Macro-invertebrate survey to evaluate the overall ecological status (1)
- Biofilm monitoring for the assessment of water pollution e.g. heavy metals (4)
- Soil sampling to verify the data of the biofilm monitoring
- Water sampling (chemical methods to verify the data)



Biofilm sampling



Macro-invertebrate survey



Soil sampling



Water sampling

Figure 11: Methods of fieldwork monitoring

4.2. Biofilm monitoring

Biological monitoring is used to determine the condition of the environment by using living organisms. Compared to physical or chemical monitoring, biological monitoring shows several advantages, such as an overall ecological integrity (physical, chemical and biological) as well as an integrated measure of environmental conditions by integrating stresses over time. With a Macro-invertebrate survey, organisms are being used to determine the water.

The method of biofilm monitoring is based on aquatic biofilms and is used to monitor surface water pollution. Biofilms have the ability to adsorb and incorporate material, they can be found at any surface exposed to water and they represent a microbial community with various inhabitants such as sessile bacteria, protozoa, fungi and algae (Fuchs, 1996). They are, according to their structure, able to incorporate contaminants, to grow rapidly and they also offer an easy sampling possibility (Fuchs et al., 1996). Thus these aquatic microbial communities can be used as a pollutant-monitor (Fuchs et al., 1996).

4.3. Water and Soil sampling

In addition to the biological methods, chemical and physical parameters like oxygen, temperature, conductivity, COD, Nitrogen, Hydrogen carbonate, Carbon trioxide, Iron, Nitrate, Sulfate and Total Phosphorous have been analyzed to support the biological findings.

Soil samples have been tested for Fe, Pb, Cu, Zn and Cd and were analyzed at the laboratory of the Karlsruhe Institute of Technology (KIT, Institute for Water and River Basin Management, Department of Aquatic Environmental Engineering).

4.4. Advantages and disadvantages of biological methods

“Biological assessment can be defined as the systematic use of biological responses to evaluate changes in the environment with the intent to use this information in a quality control program” (Matthews et al., 1982).

As this definition is often used when biological assessment refers to field studies on plankton, macro invertebrate or fish community in a river to evaluate biological water quality it can be defined as a form of ecosystem monitoring (De Zwart, 1994).

If an aquatic system is damaged, it can sometimes be clearly visible such as in change of color or odor or the occurrence of dead fish. But sometimes it might not be that easy to see. In that case, aquatic organisms are a good choice as they show several advantages (Friedrich, G. et al., 1992). They integrate effects on the environment they have settled throughout their lifetime and thus are able to reflect if a situation gets worse way faster. Thus it's possible to give an assessment of the past and present state of the environment

(Friedrich, G. et al., 1992). Dependent on the organism, it's possible to track back between one or two weeks up to several years. For example bacteria can reflect the water quality of one or two weeks prior to their sampling and analysis, whereas insect larvae, worms, snails, and other macroinvertebrate organisms can reflect more than a month and possibly several years (Friedrich, G. et al. (1992).

The main advantages of macro invertebrate sampling are that it is a quick and cheap method, little equipment is necessary and a large area can be surveyed very intensively in a short time (Table 6).

Table 6: Advantages and disadvantages of the major methods for freshwater quality assessment (modified after Friedrich, G. et al., 1992)

Organisms	Advantages	Disadvantages
Bacteria	• Routine methodology well developed • Rapid response to changes, including pollution • Indicators of fecal pollution • Ease of sampling	• Cells may not have originated from sampling point • Populations recover rapidly from intermittent pollution • Special equipment necessary
Protozoa	• Saprobic values well known • Rapid responses to changes • Ease of sampling	• Good taxonomic ability required • Cells may not have originated from sampling point • Indicator species also tend to occur in normal environments
Algae	• Pollution tolerances well documented • Useful indicators of eutrophication and increases in turbidity	• Taxonomic expertise required Not useful for severe organic or fecal pollution
Macro Invertebrates	• Diversity of forms and habits • Many sedentary species can indicate effects at site of sampling • Whole communities can respond to change Long-lived species can indicate integrated pollution effects over time • Qualitative sampling easy • Simple sampling equipment • Good taxonomic keys	• Quantitative sampling difficult • Substrate type important when sampling • Species may drift in moving waters • Knowledge of life cycles necessary to interpret absence of species • Some groups difficult to identify
Fish	• Methods well developed • Immediate physiological effects • Ease of identification	• Species may migrate to avoid pollution

5.2. Saprobian Index by Kolkwitz & Marsson

The Saprobian Index is based on the observation that the biocoenosis of a water body varies in a predictable way with the organic load. Some organisms react more resistant to organic water pollution while others can only survive unpolluted or slightly polluted water as their range of tolerance differs.

Some species are more common in organic polluted waters than others. These observations can be explained by the biology of the organisms, as, for example, some organisms need oxygen rich waters and will die with decreasing oxygen content while others require a high supply of nutrients but may also be able to tolerate very low oxygen levels (Friedrich, G. et al., 1992). The occurrence and frequency of those organisms which react to organic pollution can be used to determine the grade of pollution if the tolerance ranges for each species are known.

With the Saprobian Index, each indicator is assigned an index value which is based on the observation of several polluted and unpolluted water bodies and is derived empirically and not based on laboratory tests.

The Saprobian index is the “average of the index values of all indicator species occurring in a specific area, weighted by the frequency of occurrence, arises into a numerical value for an investigated sample site” (Friedrich, G. et al., 1992). The occurring species are used as instruments for the organic load. “For the determination of the water quality class, the Saprobian index of the examined surface water area will be compared to a standard list of indices, based solely on presence or absence of taxa”. In that way a classification of the watercourse in water quality classes can be made (Friedrich, G. et al., 1992).

Figure 12 gives an example of the classification, the Saprobian system is based on. It shows that all organisms have specific environmental demands and will only settle down if a spot meets all their demands. Downstream of a heavy pollution caused by the discharge of untreated wastewater in the surface water body, a change in biota occurs. Directly after the inlet point a rapid decay of organic material occurs which will consume all oxygen that's available in the water and thus leads to a significant change in freshwater community. In class number 5, only organisms which can stand very low oxygen concentration or very high organic pollution will survive.

Due to self-purification the community will recover and a change in the ecosystem can be observed, principally in the components of the biotic communities. Organisms have specific environmental demands and will only settle down if a spot meets all their demands. Thus, indicator species, living almost only in one of the four zones are used to determine the zones by comparing the collected species of a sampling point with the list of indicator species for the four zones.

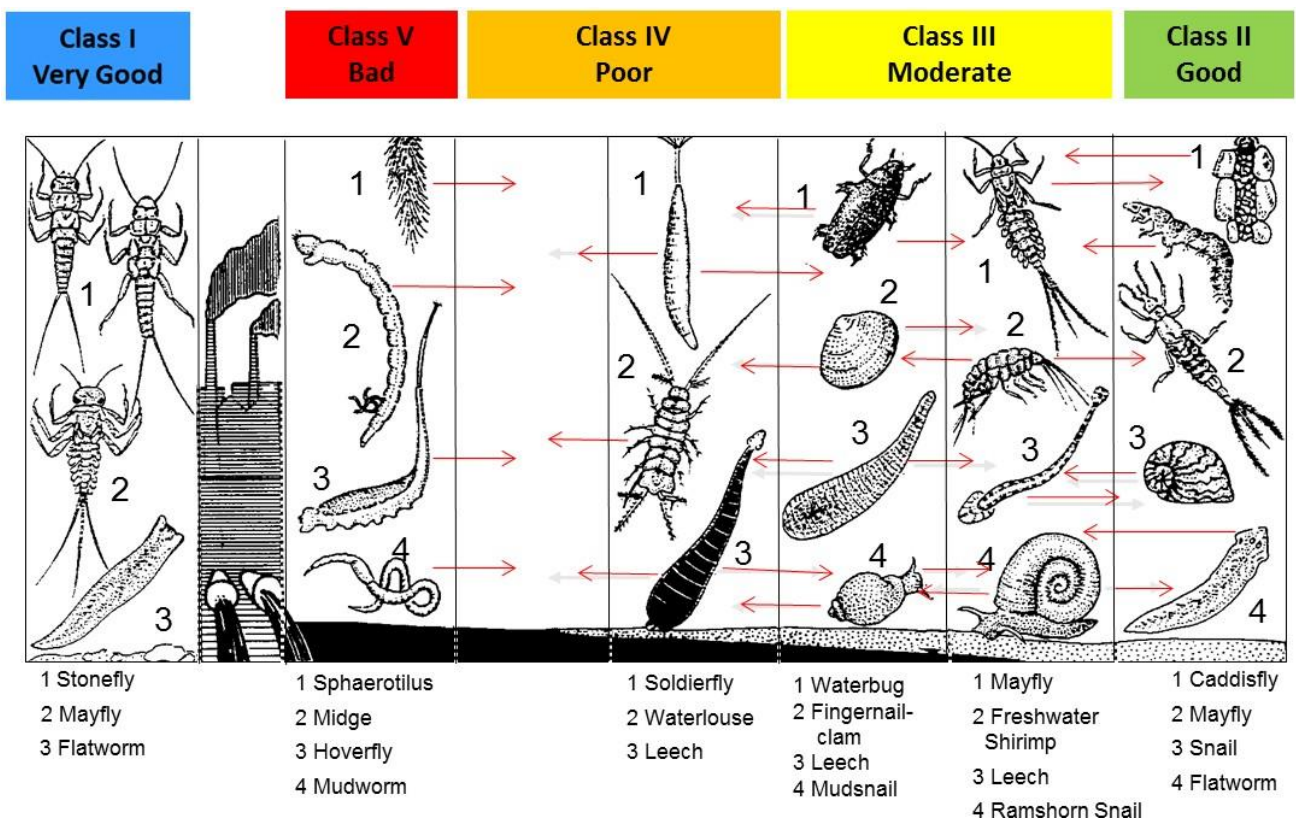


Figure 12: Water quality and Saprobien system – self-purification in flowing waters (modified after Barndt et al., 1996)

Already in 1960, Hynes et al. published a paper to “The Biology of Polluted Waters” which clearly shows, that the inflow of sewage into a water body has an enormous effect on different aquatic organisms (Figure 13).

After an inlet of sewage, there’s a rapid decline in oxygen and an increase in nutrient content. If the pH rises over 8.5, an increase in unionized ammonia can be recognized, which is fish toxic. Following the biological decomposition of domestic sewage, Phosphate also becomes available. These changes of the chemical composition of the water result in significant changes in the structure of the biota as some organisms can for example tolerate reduced oxygen concentrations while others are dependent on high oxygen concentrations.

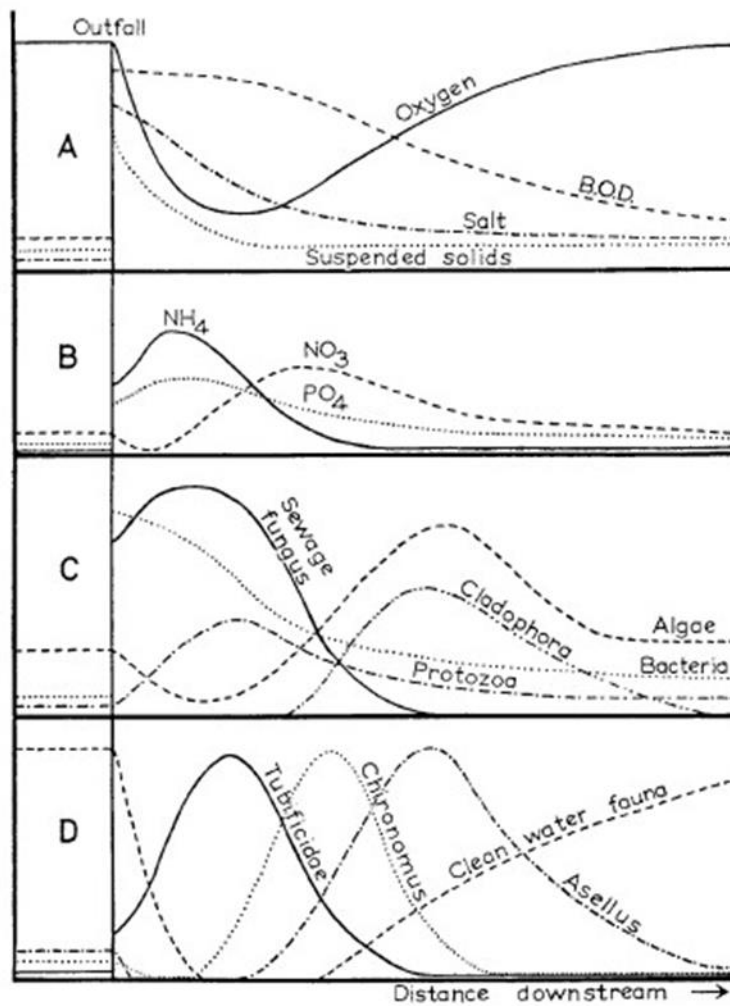


Figure 13: Effects on water quality and associated biota downstream of a sewage outlet. A and B. Physical and chemical changes; C. Changes in micro-organism populations; D. Changes in invertebrate populations (After Hynes, 1960)

5.3. Self-Purification

Following Friedrich, G. et al. (1992), the System is based on four zones of self-purification which are characterized by indicator species, chemical condition and the general nature of the bottom of the water body and the water itself (Table 8):

- the polysaprobic zone
- the α -mesosaprobic zone
- the β -mesosaprobic zone
- the oligosaprobic zone

Table 8: The four zones of gradual self-purification (modified after Friedrich, G. et al., 1992)

Zone	Polysaprobic zone	α-mesosaprobic zone	β-mesosaprobic zone	Oligosaprobic zone
Pollution grade	Extremely severe pollution	Severe pollution	Moderate pollution	No/ slightly pollution
Indicator species	- Absence of most autotrophic organisms - Dominance of bacteria - Various blue-green algae, rhizopods, zoo-flagellates and ciliated protozoa - Only few invertebrates having the blood pigment, hemoglobin will survive	- Mainly “sewage fungus” - Common in waters containing wastes rich in carbohydrates, such as sewage - The mass of organisms can become detached from the bottom and then drift in the water column as dirty-grey masses	- Rich submerged vegetation - Abundant macrozoobenthos particularly Mollusca, Insecta, Hirudinae and Entomostraca	Sensitive species such as aquatic mosses, planaria and insect larvae can be found
Chemical conditions	- Rapid degradation - Predominantly anaerobic conditions - Hydrogen sulphide (H₂S), ammonia (NH₃) and carbon dioxide (CO₂) as end products of degradation	- Amino acids are present - Free oxygen causes a decline in reduction processes	- Aerobic conditions - Protein degradation products such as amino acids, fatty acids and ammonia are found in low concentrations only	Oxygen saturation is common
Bottom	Often silty bottom (black sludge) and black undersides of stones			Formation of inorganic or stable organic residues
Color	Dirty grey in color, highly turbid	Dark grey	Transparent or slightly turbid	Not colored
Odor	Faecal or rotten smell	Smells rotten due to H₂S	No odor	No odor
Fish	Not present		Coarse fish	Salmonid species

6. FIELD STUDY – MACRO INVERTEBRATES

Benthic macro invertebrates usually occur in all kind of freshwater environments. They usually settle down in a specific environment which fits to their needs and are likely to be exposed to environmental changes due to pollution or stress. Their life span is quite long and if an environmental impact occurs, it is likely that the community will not recover that fast and the stress will be detected.

The main object of this work was to survey the common aquatic insects of Wadi Tel Ar-Rumman located in the area of the KTD and RBG and reference sites of Zarqa River (Figure 14).

This data can be used to study the water quality in the area and the nearby aquatic water bodies.

As Samra
WWTP

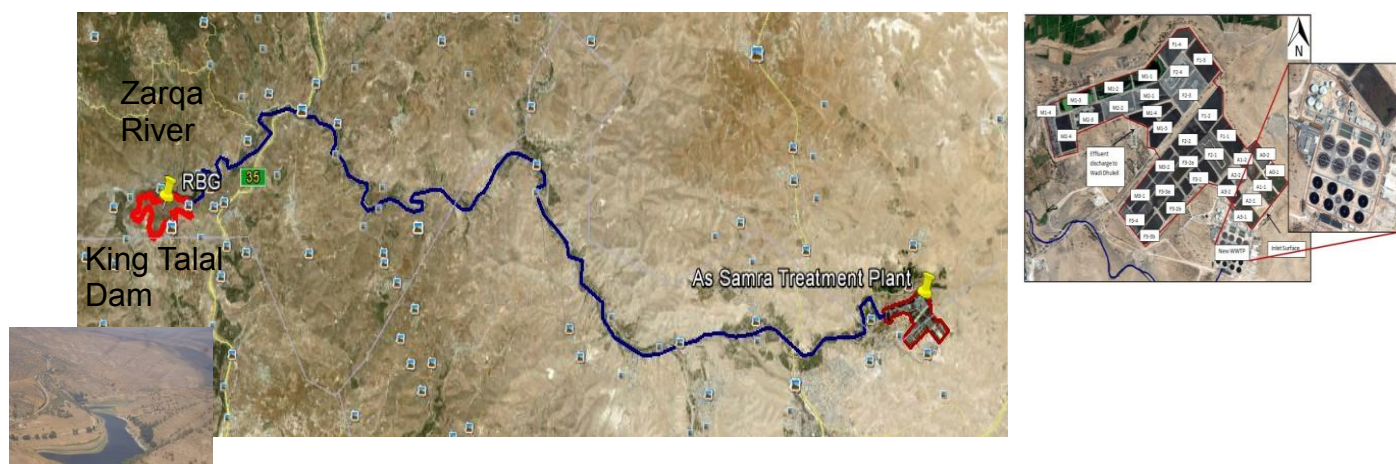


Figure 14: Area of Macroinvertebrate Sample Locations between As Samra WWTP Outlet and King Talal Dam (modified after google maps)

6.1. Macroinvertebrate Sample Locations

The samples were taken around the area of the KTD, mainly within the protected area of the RBG and the Zarqa River (Figure 14 + 15). Several samples were taken at each location to ensure the representativeness of the biological community in each stream. The sampling campaign was necessary to identify the impact of the pollution in the surface water. The fauna in flowing water is usually more sensitive to pollution impacts than standing or slow flowing water. During this campaign it was tried to sample in flowing waters even if most of the locations were in slow flowing areas.

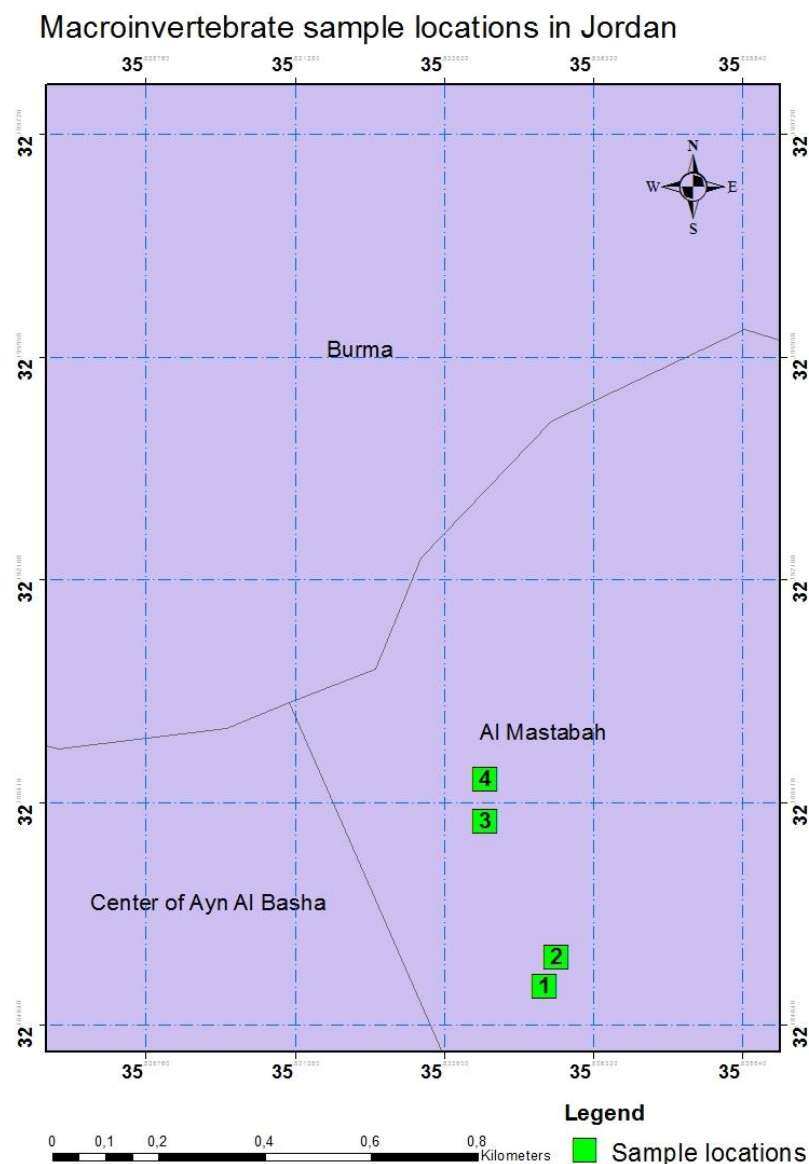


Figure 15: Macroinvertebrate sample locations in Jordan

6.2. Material and Methods

Biweekly field trips were conducted to sample aquatic insects in Wadi Tel Ar-Rumman from January 2012 to March 2013 (Figure 16). Insects were sampled using an aquatic net from collection sites selected along the stream. The main locations and coordinates of each sampling site are shown in Figure 15. Water temperature, pH, conductivity and oxygen content were recorded in addition to support the biological findings. In addition to the sites at Wadi Tel Ar-Rumman, sampling sites were selected at Zarqa River representing totally different environmental condition.

To collect benthic macroinvertebrates, equipment as listed in table 10, is necessary.



Figure 16: Collection of macroinvertebrates in Wadi Tel Ar-Rumman

Sampling always starts with the completion of a form which describes the location, e.g. coordinates, time, date, name, substrate, etc. The samples are taken with a sweep-net or a surber. Sweep-net sampling is conducted by striking the net in the open water area.

To include species, which are attached to stones, algae etc., different kinds of aquatic vegetation and substrata need to be added to the sample. The pool bottom is sampled by scraping in a vegetation free area. The soil is washed from the net and larger macro-invertebrates are collected manually.

The content of the net was placed in a plastic bag or plastic container and then taken to the laboratory for picking, sorting and counting the collected insects. The samples were preserved in 75% alcohol and transferred into small vials (Figure 17).

Insects will be identified to order, family and, if possible to the genus or species according to



Figure 17: Sample preserved in a vial showing an Ephemeroptera

the availability of references. Labels containing data about the site, date and identification were printed for the samples. The collected insects were briefly described, photographed and the necessary illustrations helping in identification of the specimen were added.

Afterwards the macro invertebrates were being identified under a stereo microscope (Figure 18) with the help of main identification keys as listed in table 9.

With a stereo microscope having a magnification range between 7 x to 30 x, organisms may be identified to taxonomic level such as family or genus (NYSDEC Stream Biomonitoring Unit, 2013). Identifying specimens to the species level is sometimes difficult or impossible because (NYSDEC Stream Biomonitoring Unit, 2013):

- Larvae often differ widely to the appearance of mature specimens
- Damaged specimens may be missing e.g. gills that are important to identification
- Some species have variable color patterns and do not look as on images in identification keys
- Species identification keys are not available for some groups

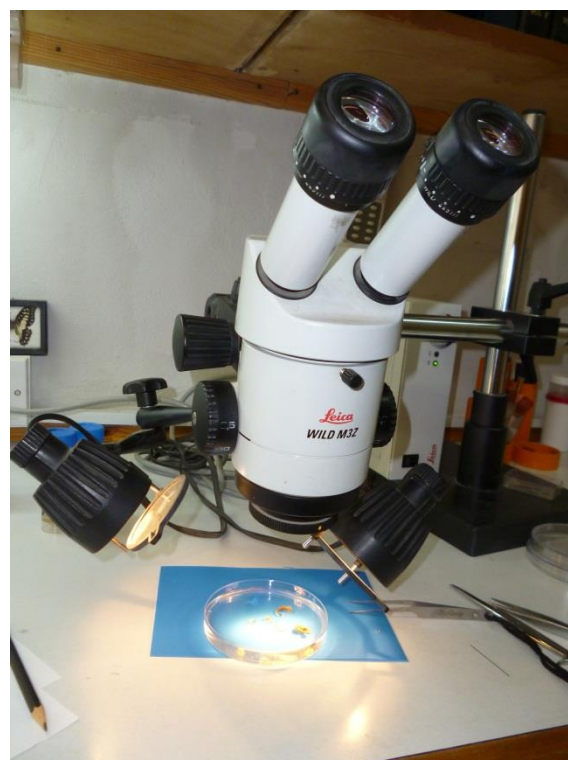


Figure 18: Stereo microscope used to identify the species

Table 9: List of literature used as key identification

General	Nagel (1989), Tachet et al. (1984), Schmedtje et al. (1992), Barndt et al. (1996)
Coleoptera	Bouchard, R.W. (2004)
Mollusca	Glöer et al. (2000)
Ostracoda	IRGO (2013)
Chironomidae	UMMZ (2011)
Hemiptera	Fauna Europa (2012)
Ephemeroptera	Sauter, W. (1992)

Table 10: Equipment to collect benthic macroinvertebrates and water samples

General	Water	Macroinvertebrates
Gloves	Sensors: PH, conductivity, temperature, oxygen	Buckets with cover
Form/ Field sheets	Measuring cylinder (plastic): 1000 and 2000 ml	Vials with snap caps for the macro invertebrate samples
Notebook with forms	Measuring cylinder (plastic): 500 and 1000 ml	Distilled water
Camera	Pipettes/Pipette tips	Tweezers
Pencils/ Black markers (waterproof)		Plastic pipettes
Labels for bottles		Sweep net
Plastic trays		75% Ethanol
Magnifying glass		Petri dishes
GPS (Geographical Positioning Satellite) to track the position of the sampling site		Macroinvertebrate Identification Chart
		Stereo microscope

7. INSECT BIODIVERSITY IN WADI AR-RUMMAN

7.1. Introduction to the species

Members of several insect orders live an aquatic life. Some may be indicators of water quality. The following is a brief introduction to each of these orders followed by the available literature of previous research conducted in the sampling region in Jordan (Figure 19 and Table 11).

1. Odonata



<https://thelifeofyourtime.files.wordpress.com>

2. Trichoptera



<http://blancowateratlas.files.wordpress.com>

3. Ephemeroptera



<http://bugguide.net>

4. Diptera



<http://www.aquatax.ca/diptera/>

5. Hemiptera



<http://tolweb.org/Corixidae/10931>

6. Coleoptera



<http://www.mdfrc.org.au>

Figure 19: Overview of the Species found in Wadi Rumman and Zarqa River

Table 11: Species found in Wadi Rumman (WR) and Zarga River (ZR) and identification keys

		Location	Identification key
Odonata			Nagel, P. (1989), Schmedtje et al., 1992, Bouchard, R.W., 2004
	Libellulidae	WR	M.Kiany und K. Minaei, 2009
	Euphaeidae	WR	A.F.S.L. Lok, 2009
	Coenagrionidae	WR	Angelo B.M. Machado, 2012
	Platycnemidae	WR/ZR	R.A. Dow, 2010
	Calopterygidae	WR	Christopher Anderson, 2011
	Gomphidae	WR	Julie A. Craves, 2002
Trichoptera			Nagel, P. 1989, Schmedtje et al., 1992, Bouchard, R.2004
	Hydropsychidae	WR	Leandro Goncalves Oliveira, 1996
	Hydroptilidae	WR	Allan Paulo Moreira Santos, 2011
Ephemeroptera			Nagel, P. 1989, Schmedtje et al., 1992, Bouchard, R.2004
	Baetidae	WR/ZR	Sauter (1992)
	Caenidae	WR/ZR	Sauter (1992)
Diptera			Nagel, P. 1989, Schmedtje et al., 1992, Bouchard, R.2004
	Simuliidae	WR/ZR	Bass J, 1998
	Ceratopogonidae	WR	Y. Braverman, 1994
	Chironomidae	WR/ZR	Vergon J.-P.,1993
	Tabanidae	WR/ZR	Rafael E. Cardenas, 2009
	Tipulidae	WR	G. Theischinger, 1996
	Psychodidae	WR	Freddy Bravo, 2011
	Empididae	WR	Dominique Duviard, 1983
	Ephydriidae	WR/ZR	Waynen. Mathis 1981
	Dixidae	WR	Papp,L., 2007
	Dolichopodidae	WR	Toyohei Saigusa, 1984
	Muscidae	WR	Marcia Souto Couri, 2010
	Stratiomyidae	WR	Maurice T. James, 1960
Hemiptera			Nagel, P. 1989, Schmedtje et al., 1992, Bouchard, R.2004
	Corixidae	WR	Savage (1989)
	Veliidae	WR	Savage (1989)
	Notonectidae	WR	Savage (1989)
Coleoptera			Nagel, P. 1989, Schmedtje et al., 1992, Bouchard, R.2004
	Hydrophilidae	WR/ZR	Hebauer F., 1998

7.2. Ephemeroptera

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Ephemeroptera (Mayflies)

They are living in freshwater and can be found mainly in streams, rivers, ponds and lakes. They Mayfly nymphs can be found in cool, fast flowing waters under stones or among plants in slow streams (Walsh, A. 2005).

They are usually brownish and have gills on both sides of the thorax which can be oval, leaf-like or fringed, six large hooked legs, antennae and, most characteristic, 3 long tails. The 3 tails also gave them their name “3-tails”, even it is important to take care while sampling not to damage a tail as a two tailed specimen can be a mayfly just missing one tail (Walsh, A. 2005). They are nymphs for up to 3 years and are living only about 1 to 5 days as adults to mate and lay eggs.

Ephemeroptera are aquatic insects and a good indicator for water quality as they are sensitive to various forms of pollution (Elliott *et al.*, 1988).

The nymphs prefer cool water, because it retains more oxygen than warm water as they are sensitive to low levels of oxygen in the water. Mayfly nymphs are also sensitive to chemical pollution in the water, the flow rate of the water and shade (Islandwood, 1008)

Occurrence in the sampling region (Table 12)

Malzacher (1992) recorded five species of Caenidae from Palestine: *Caenis macrura*, *Caenis gilbonensis* sp.n., *Caenis antoniae* sp.n., *Caenis parabrevipes* sp.n., *Caenis robusta* and Sartori (1986 & 1992) recorded: *Baetis nubecularis*, *Heptageniidae*, *Ephemerellidae*, *Leptophlebiidae* and *Palingeniidae* (<http://www.insecta.bio.spbu.ru/z/Eph-spp/ref-Malzacher.htm>).

Table 12: Occurrence of Ephemeroptera in the sampling region

Order	Family	Location
Ephemeroptera		
	Baetidae	WR/ZR
	Caenidae	WR/ZR

7.2.1 Family Baetidae

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Ephemeroptera (Mayflies)
Suborder: Schistonota
Superfamily: Baetoidea
Family: Baetidae

Baetidae larvae can be found in different aquatic habitats from pools to fast flowing streams (Clifford, H. 1991).

They prefer cold, unpolluted, alkaline waters but usually inhabit almost every microhabitat in the stream except for silt beds (Troutnut, 2013).

The Baetidae is the largest family of mayflies, with over 900 described species and 100 genera globally (Webb et al., 2011). Baetidae nymphs are also called "small minnow mayflies", as they tend to swim like a small fish or drift in current. They are brownish as adults with blue or transparent wings and black as nymphs (Brown, W., 2008). Compared to other mayflies they are small in size at all stages of living.

Following Buss et al. (2006), the family Baetidae is relatively tolerant and quite pollution resistant but prefer unpolluted, cold waters.

7.2.2 Family Caenidae

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Ephemeroptera (Mayflies)
Suborder: Pannota
Superfamily: Ephemerelloidea
Family: Caenidae

Caenidae are poor swimmers and usually crawl on the riverbed or attach to aquatic plants. They can be found in silty and sandy areas of slow moving streams and debris-laden regions of ponds and lakes (Clifford, 1991)

Compared to most other Ephemeroptera they are relatively small in size (up to 6 mm). They are pinkish to brownish, have antennae which are longer than their head and thorax and abdomen are flattened. Gills are present on the abdominal segments 1-6. The first gills are monofilamentous and the second ones form a covering over the other gills (operculate) and are rectangular and fringed with fine hairs. Gills 3 to 6 show multifid tracheal filaments (MDFRC, 2009).

Caenid nymphs are more pollution resistant than other families of Ephemeroptera and can be found in e.g. eutrophic lakes suggesting a tolerance to nutrient enrichment. They don't inhabit saline waters (MDFRC, 2009).

7.3. Odonata

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Subclass: Pterygota
Infraclass: Palaeoptera (disputed)
Superorder: Odonatoptera

The Odonata includes two suborders, Dragonflies (Anisoptera) and Damselflies (Zygoptera). The larvae are aquatic insects and live underwater, breathing through gills. Damselfly larvae have gills in the form of three long appendages extending from the tail end of their abdomen while dragonflies lack these appendages, and have internal rectal gills (CSIRO, 2004). Both adult and larval stages are predaceous, and mostly prey upon other invertebrate species (CSIRO, 2004).

As adults they are large in size (30 up to 150mm). Adult damselflies are smaller while the dragonflies are usually larger in size. They can be differentiated by the forewing and hindwing, which are, for damselflies similar in shape while for dragonflies they are different in shape, with the base of the hindwing being wider than that of the forewing.

Dragonflies larvae are sensitive to pollution, depending on the species while damselfly larvae are more tolerant of nutrient pollution and can survive in polluted waters (Axler, R.C.,

2009). Damselfly Nymphs are sensitive to habitat disturbance, because they need vegetation in the waterways where they live (Islandwood, 2008).

In general, following Kefford *et al.* (2003), Odonata are more tolerant to salinity than many other aquatic macroinvertebrates, but within the group, a wide range of tolerance occurs (Bailey *et al.*, 2002).

Occurrence in the sampling region (Table 13)

In Jordan, 46 species of Odonata are recorded. The Zygoptera of Jordan comprises 15 species while the Anisoptera comprises 31 species (Katbeh-Bader *et al.* 2004). From Al Azraq Oasis, 13 species of Odonata were recorded (Katbeh-Bader *et al.* 2002).

Table 13: Occurrence of Odonata in the sampling region

		Location	Suborder
Odonata			
	Euphaeidae	WR	Damselflies
	Coenagrionidae	WR	Damselflies
	Platycnemididae	WR/ZR	Damselflies
	Calopterygidae	WR	Damselflies
	Gomphidae	WR	Dragonflies
	Libellulidae	WR	Dragonflies

7.3.1 Euphaeidae

Kingdom: Animalia (Animals)
 Phylum: Arthropoda (Arthropods)
 Class: Insecta (Insects)
 Order: Odonata (Dragonflies and Damselflies)
 Suborder: Zygoptera (Damselflies)
 Superfamily: Calopterygiodea
 Family: Euphaeidae

Euphaeidae larvae have, in addition to the common three gills at the tip of the abdomen, seven pairs of supplementary gills along the abdomen.

7.3.2 Family Coenagrionidae

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Odonata (Dragonflies and Damselflies)
Suborder: Zygoptera (Damselflies)
Superfamily: Coenagrionoidea
Family: Coenagrionidae

This Zygoptera can be found in different habitats in standing as well as flowing waters, even they are most common in margins of lakes and wetlands.

7.3.3 Platycnemididae

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Odonata (Dragonflies and Damselflies)
Suborder: Zygoptera (Damselflies)
Family: Platycnemididae

Most of the species live along rivers, although a few species breed in standing waters too.

7.3.4 Calopterygidae

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Odonata (Dragonflies and Damselflies)
Suborder: Zygoptera (Damselflies)
Family: Calopterygidae

The larval stage of these damselflies is completely aquatic. They can be found burrowed in substrate in still or slow moving waters. They show three leaf-like gills at the end of the abdomen, which, together with a large lower lip covering the mouth parts and the majority of

the insect's head when viewed ventrally (from the belly-side), makes them easier to identify (UWEX, 2007).

7.3.5 Gomphidae

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Odonata (Dragonflies and Damselflies)
Suborder: Anisoptera
Family: Gomphidae

The larvae are between 30 – 45 mm in length and bury themselves in silt or sand at the bottom of lakes and ponds. The tip of the abdomen remains above the substrate so the insect can continue to obtain dissolved oxygen from the water.

7.3.6 Libellulidae

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Class: Insecta (Insects)
Order: Odonata (Dragonflies and Damselflies)
Suborder: Anisoptera (Dragonflies)
Family: Libellulidae (Skimmers)

The Dragonflies of the family Libellulidae are usually common in ponds and lakes and seldom in streams and rivers. The larvae are often hidden in the sediment either due to their camouflaged color or a thin layer of sediment on their body. Libellulid dragonflies can be very tolerant to low levels of dissolved oxygen and can be found in warm lakes and ponds with high amounts of nutrients (Bouchard, R.W., 2004).

7.4. Trichoptera

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Superorder: Amphiesmenoptera
Order: Trichoptera

Trichoptera is the largest order of insects in which every member is truly aquatic (Bouchard, R.W., 2004).

They can be identified by their short antennae, the sclerotized head and plate on thoracic segment one (sometimes also on two and three), a soft abdomen, three pairs of segmented legs and an abdomen that terminates in a pair of prolegs bearing hooks (Bouchard, R.W., 2004).

Because of their sensitivity to water pollution, the presence or absence of caddisfly larvae is used as an indicator of water quality (JRANK, 2013).

Occurrence in the sampling region (Table 14)

In 1992 Botosaneanu studied the systematics and distribution of the Trichoptera of the Sinai (Egypt), Israel, Jordan, Lebanon and Syria west of the Euphrates River. He provided a key to the families of Trichoptera in the Levant, and individual family of the Rhyacophilidae, Glossomatidae, Hydroptilidae, Philopotamidae, Hydropsychidae, Polycentropodidae, Ecnomidae, Psychomyiidae, Brachycentridae, Limnephilidae, Leptoceridae, Sericostomatidae and Beraeidae which were all found in the region.

Table 14: Occurrence of Trichoptera in the sampling region

		Location
Trichoptera		
	Hydropsychidae	WR
	Hydroptilidae	WR

7.4.1 Hydropsychidae

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Trichoptera
Suborder: Annulipalpia
Superfamily: Hydropsychoidea

The Hydropsychidae larvae can be found in freshwater of rivers and streams. They construct retreats composed of plants and minerals, which are attached to rocks. At the open end of their retreat they spin a net to catch algae and detritus. That's why they prefer flowing water in order to catch food with their net. Some genera are sensitive to certain contaminants or pollutants, suffer declines in growth and/or survival. Larval populations thrive at sites impacted by moderate organic enrichment (MDFRC, 2009).

7.4.2 Hydroptilidae

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Trichoptera
Suborder: Spicipalpia
Superfamily: Hydroptiloidea
Family: Hydroptilidae
Stephens, 1836

The larvae occur in still and flowing, fresh and brackish waters, usually on the upper surface of rocks. Sometimes they are attached to algae or macrophytes (MDFRC, 2009).

7.5. Diptera

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Superorder: Panorpida
Order: Diptera

Diptera are only aquatic during larval stage, but adults are terrestrial. The larvae inhabit a wide range of aquatic habitats and some taxa are very pollution tolerant and can live in highly polluted waters.

The majority, however, would have elongated, wormlike bodies, with eyes and legs absent. The bodies are soft, naked, or covered with bristles or scales. Some larvae are able to swim with rapid wriggling motion, others would simply crawl around.

They have diverse responses to pollution. Some species live in the cleanest habitats while others endure the worst imaginable water quality like raw sewage or acid mine drainage (Voshell, 2009).

Occurrence in the sampling region (Table 15)

In Palestine, Austen (1937) recorded 128 species and Zaitzev (1995, 1996, 1997, 1998, 1999) added new records raising the number of species of Bombyliidae to 229. Of these, 153 species are not yet recorded in Jordan. And there are 41 species recorded from Jordan not yet recorded in Palestine. From Arabia, 137 species were recorded (Greathead 1980, 1988) many of them are not known to occur in Jordan so far. In particular more species of the subfamily Phthiriinae are expected to occur in Jordan, since only one species is recorded in this study while 8 species have been recorded from Palestine (Katbeh-Bader, Arabyat, 2004).

Table 15: Occurrence of Diptera in the sampling region

		Location
Diptera		
	Simuliidae	WR/ZR
	Ceratopogonidae	WR
	Chironomidae	WR/ZR
	Tabanidae	WR/ZR
	Tipulidae	WR
	Psychodidae	WR
	Empididae	WR
	Ephydriidae	WR/ZR
	Dixidae	WR
	Dolichopodidae	WR
	Muscidae	WR
	Syrphomyiidae	WR

7.6. Hemiptera

Kingdom: Animalia
 Phylum: Arthropoda
 Class: Insecta
 Infraclass: Neoptera
 Superorder: Paraneoptera
 Order: Hemiptera, Linnaeus, 1758

Only about 10% of all species Hemiptera are associated with water. Adult and nymphal aquatic hemipterans are on a variety of aquatic insects, crustaceans and small fishes. Most hemipterans are either lentic or slow water lotic forms. Not all but some hemipterans have indicator value because their life does not depend entirely on water quality (Joshi, P. 2012).

Occurrence in the sampling region (Table 16)

Twenty-two species of Psylloidea are recorded for the first time from Jordan. This raises the number of Psylloidea known from Jordan to 33 species (Katbeh-Bader *et al.*, 1997).

Table 16: Occurrence of Hemiptera in the sampling region

		Location
Hemiptera		
	Corixidae	WR
	Veliidae	WR
	Notonectidae	WR

7.7. Coleoptera

Kingdom: Animalia
 Phylum: Arthropoda
 Class: Insecta
 Subclass: Pterygota
 Infraclass: Neoptera
 Superorder: Endopterygota
 Order: Coleoptera, Linnaeus, 1758

Table 17 shows the occurrence of Coleoptera in the sampling region.

Table 17: Occurrence of Coleoptera in the sampling region

		Location
Coleoptera		
	Hydrophilidae	WR/ZR

7.8. Chironomus

Kingdom: Animalia
 Phylum: Arthropoda
 Class: Insecta
 Order: Diptera
 Suborder: Nematocera
 Infraorder: Culicomorpha
 Superfamily: Chironomidea
 Family: Chironomidae
 Subfamily: Chironominae
 Tribe: Chironomini
 Genus: Chironomus



Figure 20: Chironomus collected at KTD reservoir

Chironomids, commonly known as midges, are mosquito-like insects whose larvae live in the sediments of all types of aquatic habitats. The large red Chironomus or bloodworm can be an important freshwater indicator (<http://lakes.chebucto.org/>).

The larvae of some Chironomids are very sensitive to specific forms of pollution, whereas others are quite tolerant. The larvae often feed on dead plant and thus are often exposed to contaminants contained in the organic matter. As chironomids live in a wide variety of habitats they are very useful indicators.

Pollution-tolerant chironomids are often indicative of poor water quality (characterized by low dissolved oxygen and high nutrient concentrations). These species can survive in water with very low oxygen levels because it contains red pigment (haemoglobin), which helps to absorb oxygen.

In the sampling region it was found at King Talal Reservoir. In 1937 Bodenheimer listed 35 species from Palestine. Following Saether, O. A. (1979), "the ratio of chironomids to oligochaetes and the distribution patterns of single species have proven useful in pin-pointing localized areas of pollution".

8. RESULTS OF THE MACROINVERTEBRATE SURVEY

Aquatic insects were sampled from selected sites along the project area and identified to order, family and, if possible, to the genus or species.

A total of 6 orders and 26 families were found, whereas the families are:

- Diptera
- Ephemeroptera
- Hemiptera
- Odonata
- Trichoptera
- Coleoptera

The organisms were given values from 0 to 10 according to the organism's tolerance to the water quality.

The Index of Biotic (IBI) is a metric based on the concept that certain groups of aquatic organisms are sensitive to pollution while others are more tolerant. It allows a standardized comparison of sites along a stream, or multiple streams, across geographic areas and through time. The IBI was originally developed for fish species (Karr 1981) but researchers have created many different forms, modifications, and applications of the IBI (Weigel and Robertson 2007).

The Field Biotic Index (FBI) (Hilsenhoff 1988), which weighs pollution tolerance values of each taxonomic group, will be calculated.

In general, higher taxonomic richness (number of species) indicates better water quality. (Table 18).

Organisms rated with 1 or 2 are intolerant organisms which will not survive waters with poor conditions while organisms rated with values 9 or 10 are tolerant and will survive in waters of poor quality (Table 19).

The tolerance values of the organisms found range from 2 (Dixidae) to 9 (Libellulidae). In KTD Reservoir as well as in Zarqa River, the tolerance values ranged from 4 to 9, with a high percentage around a tolerance value of 6 and no species with a low pollution tolerance.

This is an indicator for a moderate to polluted water quality as organisms which settle here have a higher tolerance to pollution. Within the area of the RBG (Wadi Tell Ar Rumann), species with a tolerance value of 2 were found indicating good to moderate water quality, even if some species also showed a value of 6.

Based on the results of Wadi Tell Ar Rumann, no indicators for organic pollution have been identified, whereas Al Zarqa River shows a reduced invertebrate community indicating the organic loading of the water.

Table 18: Interpretation of FBI Scores (after Hilsenhoff, 1988)

FBI	Water quality	Degree of organic pollution
0,00-3,50	excellent	No apparent organic pollution
3,51-4,50	very good	Possible slight organic pollution
4,51-5,50	good	some organic pollution
5,51-6,50	fair	fairly significant organic pollution
6,51-7,50	fairly poor	significant organic pollution
7,51-8,50	poor	very significant organic pollution
8,51-10,00	very poor	severe organic pollution

Table 19: Water Pollution Sensitivity

Odonata		FBI	Poll	More tolerant to salinity	Source
Dragonfly	Libellulidae	9	5	Sensitive to pollution, tolerant to low levels of dissolved oxygen, can be found in warm lakes with high amount of nutrients	Rapid Field Assessment of Organic Pollution with a Family-Level Biotic Index William L. Hilsenhoff
Damselfly	Euphaeidae			More tolerant, can survive in polluted waters	
Damselfly	Coenagrionidae	9	6,5	More tolerant, can survive in polluted waters	
Damselfly	Platycnemididae			More tolerant, can survive in polluted waters	
Damselfly	Calopterygidae	5	5	More tolerant, can survive in polluted waters	
Dragonfly	Gomphidae	1	1	Sensitive to pollution	
Trichoptera				Sensitive to water pollution	
	Hydropsychidae	4	5	Intolerant	Effectiveness of macroinvertebrate based biotic indexes in Assessing Steam water qualitz in Szcamore creek, Rebecca e. Goldstein
	Hydroptilidae	4	6	Intolerant	Effectiveness of macroinvertebrate based biotic indexes in Assessing Steam water qualitz in Szcamore creek, Rebecca e. Goldstein
Ephemerotera				Sensitive to various forms of pollution	
	Baetidae	4	4	Relatively tolerant	
	Caenidae	7	7	Tolerant to nutrient enrichment	
Diptera				Divers	
	Simuliidae	6	6	Larvae quite tolerant toward fluctuations, notably pH and saline concntration	Rapid Field Assessment & Biotic index calculation worksheet & Blackflies (Simuliidae) Moshki, Academy of sciences of the USSR
	Ceratopogonidae	6	6		Rapid Field Assessment&Lab9: index of biotic integrity

	Chironomidae	8	8	Moderately tolerant of nutrient pollution.	Effectiveness of macroinvertebrate based biotic indexes in Assessing Steam water qualitz in Szcamore creek, Rebecca e. Goldstein& http://www.lakesuperiorstreams.org/understanding/bugs_diptera.html
	Tabanidae	6	6	Moderately tolerant of nutrient pollution.	Rapid Field Assessment& Lab9: index of biotic integrity & http://www.lakesuperiorstreams.org/understanding/bugs_diptera.html
	Tipulidae	3	3	Intolerant or moderately intolerant of nutrient pollution, good water quality indicators.	Biotic index calculation worksheet & Effectiveness of macroinvertebrate based biotic indexes in Assessing Steam water qualitz in Szcamore creek, Rebecca e. Goldstein& http://www.lakesuperiorstreams.org/understanding/bugs_diptera.html
	Psychodidae		10		Lab9: index of biotic integrity
	Empididae	6	6		Rapid Field Assessment& Lab9: index of biotic integrity
	Ephydriidae	6	6		Rapid Field Assessment& Lab9: index of biotic integrity
	Dixidae		1		Taxa Tolerance values
	Dolichopodidae	4	4		Rapid Field Assessment& Lab9: index of biotic integrity
	Muscidae	6	6		Rapid Field Assessment& Lab9: index of biotic integrity
	Srtratiomyidae		7		Taxa Tolerance values
Hemiptera			9		Biotic index calculation worksheet
	Corixidae		5	Very tolerant of pollution.	Taxa Tolerance values& http://www.lakesuperiorstreams.org/understanding/bugs_hemiptera.html
	Veliidae		6	Because short legged water striders don't actually live in the water, they are not very useful indicators of water quality.	http://www.lakesuperiorstreams.org/understanding/bugs_hemiptera.html
	Notonectidae		5		http://www.gov.mb.ca/waterstewardship/iwmp/icelandic_river/docume

					ntation/invertebrates_eastinterlake.pdf
Coleoptera					
	Hydrophilidae		4,6		Biotic index calculation worksheet

FBI = Family biotic index for use at the family level of taxonomy

0-1 intolerant

2-4 moderately intolerant

5-7 tolerant

8-10 very tolerant

Poll Pollution tolerance = Hilsonhoff's IBI

9. BIOFILM MONITORING

9.1. Method of biofilm monitoring

The method of biofilm monitoring is based on aquatic biofilms and is used to monitor surface water pollution. Biofilms have the ability to adsorb and incorporate material, they can be found at any surface exposed to water and they represent a microbial community with various inhabitants such as sessile bacteria, protozoa, fungi and algae (Fuchs, 1996). They are, according to their structure, able to incorporate contaminants, to grow rapidly and they also offer an easy sampling possibility (Fuchs et al., 1996). Thus these aquatic microbial communities can be used as a pollutant-monitor (Fuchs et al., 1996). Due to their low cost, easy handling and low site specific requirements, the method allows a high spatial resolution of monitoring. Furthermore, the analysis of the biofilm will deliver reliable and time integrated results on sources and state of surface water pollution. The biofilm samplers which are used have a total surface area of 1m² and are exposed at different sites within the surface water system for about 14 days, depending on the organic load of the water.

During this time a biofilm grows on the surface of the collector and incorporates any particulate and dissolved pollution passing through. Afterwards the biofilm can be harvested easily and transferred to a lab for the subsequent analysis of specific pollutants (e.g. heavy metals, organic volatile compounds etc...as necessary) (Figure 21).

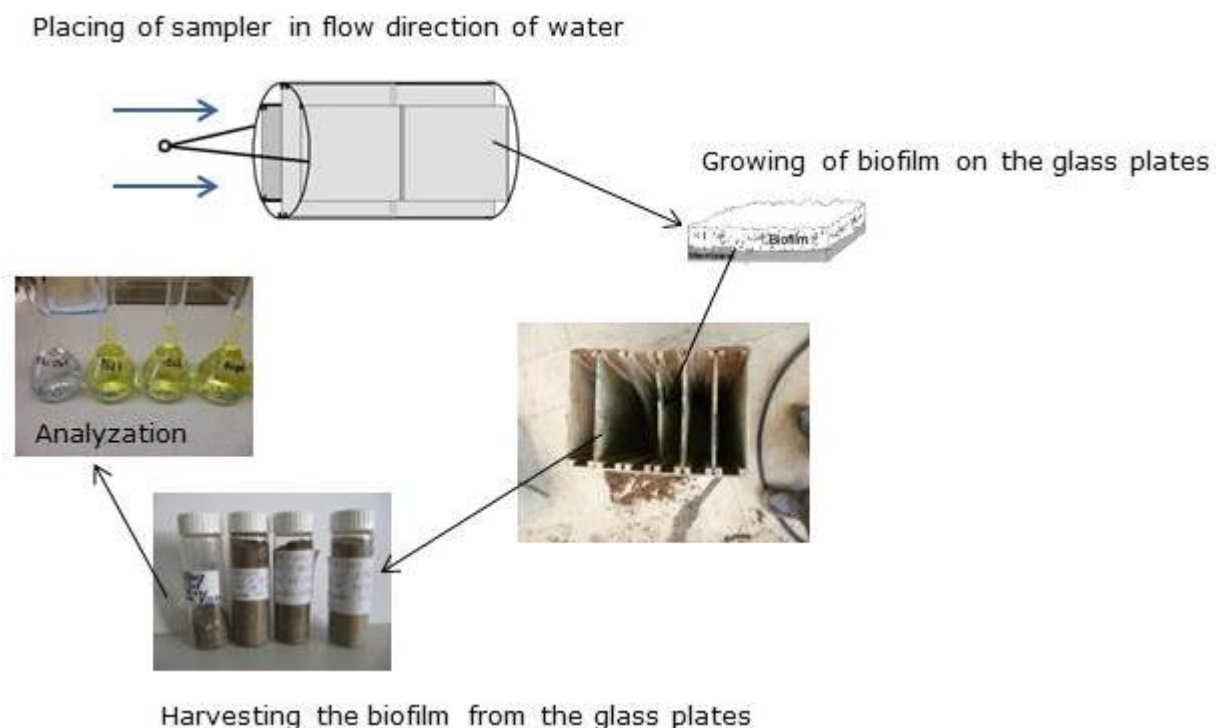


Figure 21: Steps of Biofilm monitoring (modified after Flemming, H.C., 1999)

9.2. Biofilm

Biofilm forms when bacteria stick to a surface in a moist environment by excreting a slimy substance, creating thick layers or remain thin, dependent on environmental conditions.

They can be found not only in ponds and streams but on almost all surfaces with sufficient nutriment and water (Figure 22).

A biofilm community can be formed by a single bacterial species, but usually biofilms consist of a high variety of species of bacteria, fungi, algae, yeasts, protozoa, other microorganisms, debris and corrosion products. They stick together by “EPS”, "extracellular polymeric substances", sugary molecular strands, which are produced by the cells (Montana State University).

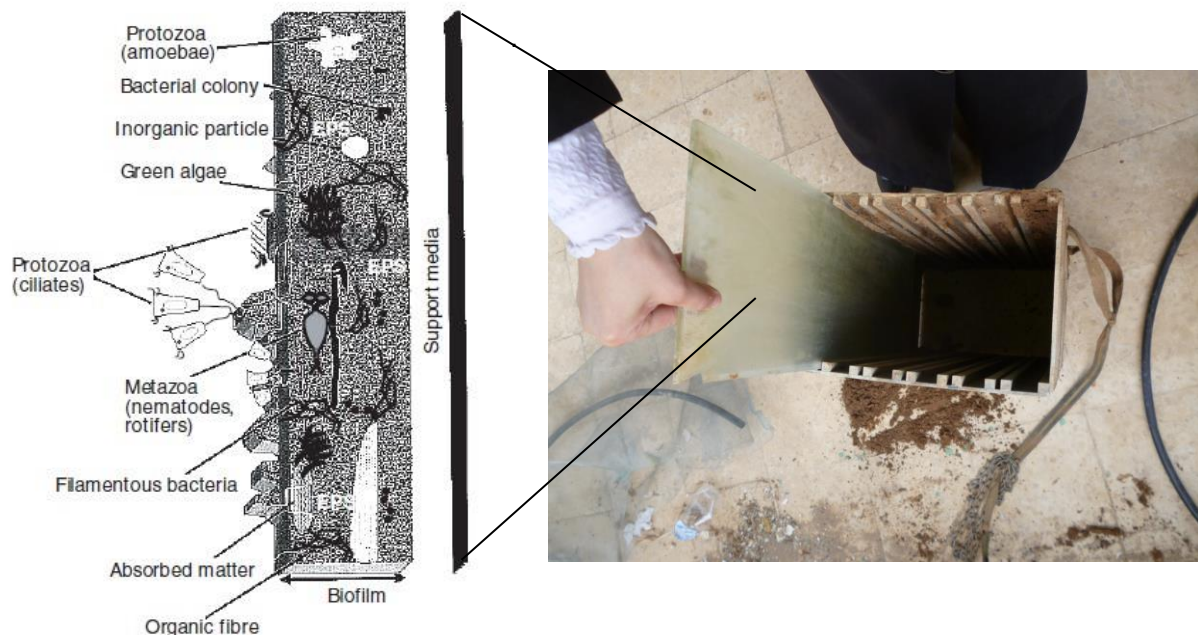


Figure 22: Composition of a biofilm (Martín-Cereceda, 2002) and biofilm on the sampler

9.3. Construction of the samplers

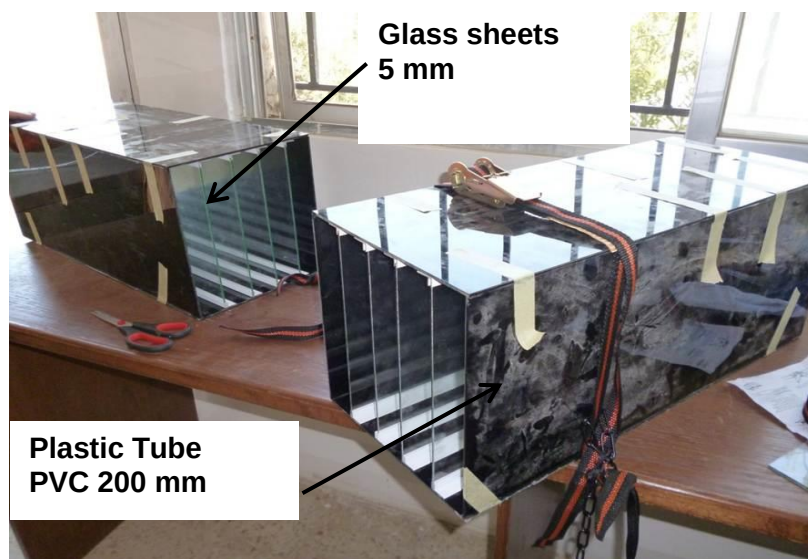


Figure 23: Biofilm samplers used at the RBG

For the construction of the biofilm samplers, a PVC tube with a total length of 60 cm and a side span of 25 x 25 cm was used (Figure 23). For the attachment of the biofilm, glass plates with a total surface area of 1m² were inserted into the sampler.



Figure 24: Scheme of a biofilm sampler

The biofilm samplers were then placed at different sites within the surface water system under water in streaming direction for about 14 days (Figure 24). During this time a biofilm grew on the surface of the collector and incorporated any particulate and dissolved pollution passing through.

Unfortunately several samplers got stolen or destroyed during the measuring period.

9.4. Sampling

The biofilm samplers were exposed at different sites within the surface water system in flow direction for about 14 by a student trainee from the University of Jordan (Figure 25).

By leaving the samplers exposed to water for 14 days, the developing biofilm will tell the “story” of the last 2 weeks as it collects and incorporates any particulate and dissolved pollution passing through. After 2 weeks, the samples were being collected and harvested and stored at the lab of the RBG. Afterwards the biofilm was transferred to a lab for the subsequent analysis of five heavy metals: Iron, Lead, Copper, Zinc and Cadmium. For the subsequent analysis of specific pollutants, e.g. heavy metals, organic volatile compounds etc. they were shipped to Germany.

For measuring, 2 different atomic absorption spectrometers were used: Perkin Elmer - AAS 1100 B, used for determinations in the mg L⁻¹ range and a Perkin Elmer AAS SimAA 6000, measuring in the range of µm. Using those measurements, a geochemical index (I_{geo}) was calculated according to Müller`s (1981) formula (Muzungaire, L., 2012).

The samplers can be reused after harvesting by adding stearin acid as a culture medium on the glass plates and put them back in the sampler.

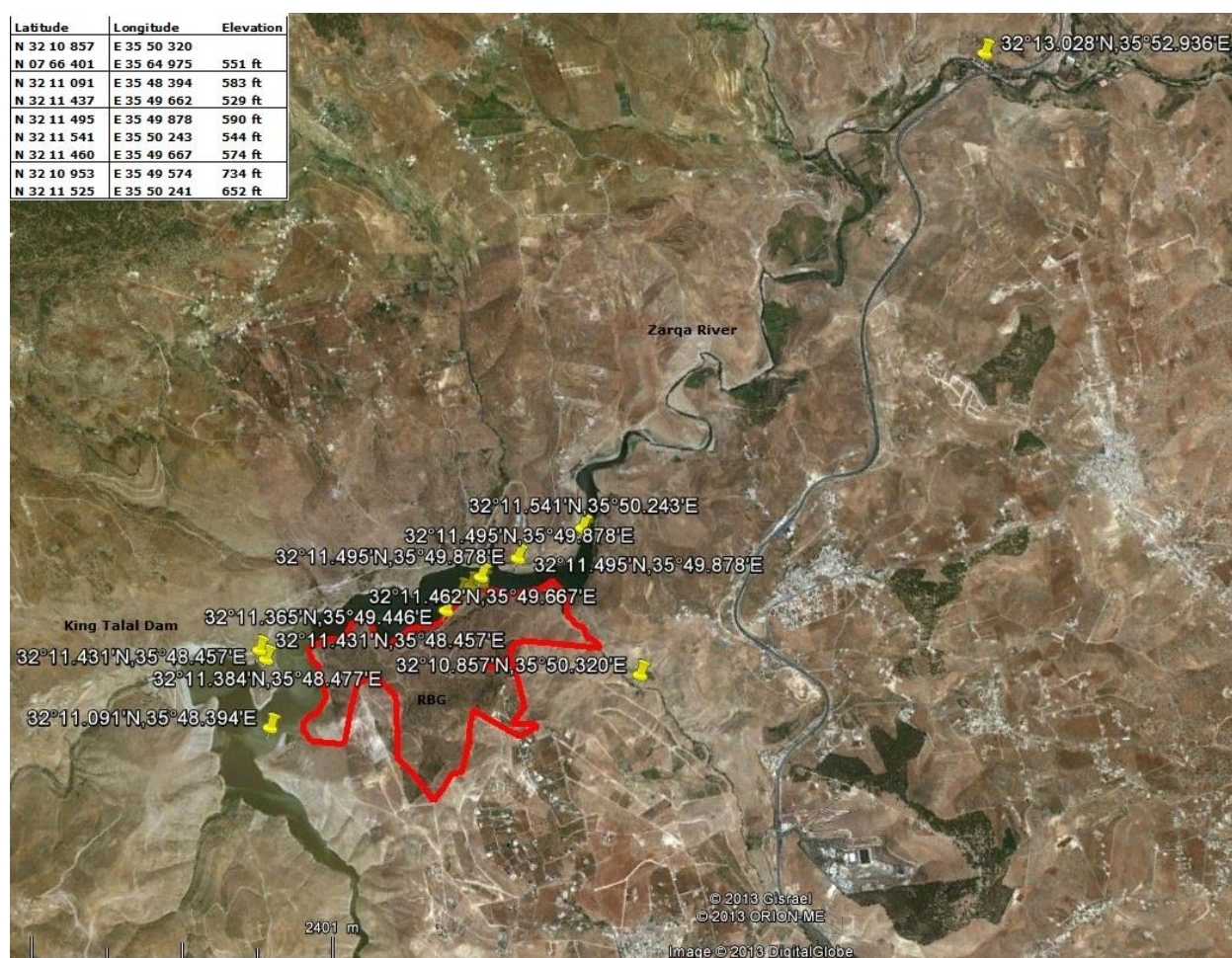


Figure 25: Location of the biofilm samplers

9.5. Laboratory methods

At the Karlsruhe Institute of Technology (KIT), Institute for Water and River Basin Management, Department of Aquatic Environmental Engineering, the samples were measured for five heavy metals (Figure 26):

- Iron (Fe)
- Lead (Pb)
- Copper (Cu)
- Zinc (Zn)
- Cadmium (Cd)

To measure the samples, they first got dried at 105°C for about 2 hours. Afterwards they got weighed between 0,5 and 3,0 g. For heavy metal disintegration they got spiked with hydrochloric acid or nitric acid and had to cook at 300°C for minimum 1 hour (Figure 27). After the cooking they got filtered to separate any coarse particles. For the measuring, 2 different atomic absorption spectrometers were available: Perkin Elmer - AAS 1100 B, used for determinations in the mg L⁻¹ range and a Perkin Elmer AAS SimAA 6000, measuring in the range of µg.

The AAS 1100 B (Figure 28a) is a flame atomizer, where the sample solution is aspirated by a pneumatic nebulizer, transformed into an aerosol, which is introduced into a spray chamber, where it is mixed with the flame gases and conditioned in a way that only the finest aerosol droplets (< 10 µm) enter the flame.

The processes in a flame include the following stages:

- Drying – the solvent is evaporated and the dry sample nano-particles remain
- Vaporization (transfer to the gaseous phase) – the solid particles are converted into gaseous molecules
- Atomization – the molecules are dissociated into free atoms
- Ionization – depending on the ionization potential of the analyzed atoms and the energy available in a particular flame, atoms might be in part converted to gaseous ions



Figure 26: Scratched biofilm



Figure 27: Biofilm samples prepared for AAS

The AAS SimAA 6000 is a Graphite (Figure 28b) furnace atomic absorber, where a small aliquot (usually less than 100 microliters (μL) and typically 20 μL) is placed, either manually or through an automated sampler, into the opening in the graphite tube. The sample is vaporized in the heated graphite tube; the amount of light energy absorbed in the vapor is proportional to atomic concentrations (EPA, 2010).



Figure 28: a) Perkin Elmer - AAS 1100 B



b) Perkin Elmer AAS SimAA 6000

9.6. Results of the biofilm sampling

Among the inorganic contaminants of the KTD water, heavy metals are important due to their toxicity and accumulative behavior.

Even as some of the metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients in plants and microorganisms, many other metals like Cd, Cr and Pb are proved detrimental beyond a certain limit which is very much narrow for some elements like Cd (0.01 mg l⁻¹), Pb (0.10 mg l⁻¹) and Cu (0.050 mg l⁻¹). Therefore, monitoring these metals is important for safety assessment of the environment and human health in particular.

The Iron content in comparison to Lead, Copper, Zinc and Cadmium is really high. Measured values were in the range of mg/kg while Cadmium was almost not detectable (µg/kg). The following table shows the results of the sampling campaign (Table 20).

Table 20: Results of the biofilm sampling campaign

Date	Latitude	Longitude	Elevation	Sample ID	Fe	Pb	Cu	Zn	Cd
					mg/Kg	mg/Kg	mg/Kg	mg/Kg	µg/Kg
02.02.2012	N 32 10 857	E 35 50 320	-	1483	15295	7,51	9,27	46,52	270
01.05.2012	N 07 66 401	E 35 64 975	551 ft	1471	21165	10,7	9,23	79,47	410
01.05.2012	N 07 66 321	E 35 64 980	551 ft	1532	21908	5,98	6,64	57,31	100
03.05.2012	N 07 64 983	E 35 64 475	643 ft	1541	10843	3,24	1,83	27,21	40
22.05.2012	N 32 11 365	E 35 49 446	523 ft	1478	18151	4,8	4,23	46,59	160
22.05.2012	N 32 11 091	E 35 48 394	583 ft	1531	16364	5,01	3,42	27,75	110
23.05.2012	N 32 11 437	E 35 49 662	529 ft	1469	26121	8,7	8,57	56,71	250
23.05.2012	N 32 11 437	E 35 49 662	529 ft	1527	26256	8,75	9,01	54,03	220
05.06.2012	N 32 11 431	E 35 48 457	534 ft	1474	19931	9,72	9,57	84,79	720
05.06.2012	N 32 11 431	E 35 48 457	534 ft	1539	21690	10,21	9,41	97,91	630
05.06.2012	N 32 11 384	E 35 48 477	527 ft	1529	20168	9,86	11,52	88,81	310
05.06.2012	N 32 11 384	E 35 48 477	527 ft	1472	19298	8,5	9,3	76,45	280
05.06.2012	N 32 11 384	E 35 48 477	527 ft	1477	16322	7,0	8,22	54,67	250
05.06.2012	N 32 11 462	E 35 49 666	569 ft	1473	23519	6,71	7,62	42,83	250
05.06.2012	N 32 11 462	E 35 49 666	569 ft	1528	22831	7,29	7,44	53,87	260
24.06.2012	N 32 11 462	E 35 49 667	619 ft	1476	21432	9,09	4,8	58,89	470
24.06.2012	N 32 11 462	E 35 49 667	619 ft	1537	21450	8,55	4,80	55,99	390
24.06.2012	N 32 11 462	E 35 49 667	619 ft	1536	22667	11,01	5,63	70,66	540
24.06.2012	N 32 11 462	E 35 49 667	619 ft	1541a	19749	8,66	4,81	62,07	400
25.06.2012	N 32 11 495	E 35 49 878	590 ft	1479	12572	7,16	7,54	76,85	680
25.06.2012	N 32 11 495	E 35 49 878	590 ft	1482	12624	7,56	6,25	58,89	600

25.06.2012	N 32 11 495	E 35 49 878	590 ft	1530	19860	9,71	8,09	87,48	660
25.06.2012	N 32 11 495	E 35 49 878	590 ft	1535	19962	10,97	6,87	79,73	660
25.06.2012	N 32 11 541	E 35 50 243	544 ft	1533	24701	6,87	7,53	51,53	380
25.06.2012	N 32 11 541	E 35 50 243	544 ft	1534	21651	6,61	7,32	55,36	340
25.06.2012	N 32 11 541	E 35 50 243	544 ft	1540	23034	6,61	4,94	53,17	340
15.07.2012	N 32 11 460	E 35 49 667	574 ft	1481	19745	4,63	6,67	30,93	150
15.07.2012	N 32 11 422	E 35 49 546	567 ft	1480	19827	13,4	5,93	26,91	120
01.08.2012	N 32 11 524	E 35 50 243	672 ft	1470	16834	7,2	6,49	66,61	770
01.08.2012	N 32 10 953	E 35 49 574	734 ft	1538	18024	5,52	4,84	47,39	390
10.09.2012	N 32 11 525	E 35 50 241	652 ft	1475	16052	6,9	5,37	26,64	190

For a better understanding, the results were transferred into the geoaccumulation index (Igeo).

9.7. Distribution of Heavy Metals according to Igeo Classes

The geoaccumulation index (Igeo) was calculated in x stations in the area of Zarqa River and KTD. The sediment pollution was investigated by following the concentration of five heavy metals (Fe, Pb, Cu, Zn, Cd).

Inductively coupled plasma mass spectroscopy (ICPMS) was used for analysis.

9.8. Index of Geoaccumulation

To establish pollution status of the Zarqa River and KTD reservoir, a geochemical index (Igeo) was calculated according to Müller's (1981) formula (Muzungaire, L., 2012):

$$I_{geo} = \log_2 C_n \cdot 1.5 B_n^{-1}$$

Where:

C_n = trace element concentration in the sediment at the particular station,

B_n = geochemical background of the element given by Turekian and Wedepohl (1961).

Table 21 shows the I_{geo} classes with respect to sediment quality (Müller, 1981).

Table 21: I_{geo} classes with respect to sediment quality (Müller, 1981)

I_{geo}	I_{geo} Class	Pollution intensity
0 - 0	0	Undetected
0 - 1	1	Unpolluted
1 - 2	2	Unpolluted to moderately polluted
2 - 3	3	Moderately polluted
3 - 4	4	Moderately to highly polluted
4 - 5	5	Highly polluted
>5	>5	Very highly polluted

I_{geo} classes with respect to sediment quality (Müller's (1981) are indicated in table 27 (Appendix). The distribution of the elements in the Earth's crust (Expressed in parts per million) which are necessary to calculate the I_{geo} index (modified after Turekian and Wedepohl (1961)) are indicated in table 26 (Appendix).

9.9. Results of Geoaccumulation

Table 22 shows the mean values of the geochemical index of Zarqa River and KTD reservoir of the sampling campaign from February to September 2012. Pb and Cu are both within the first class, thus showing no pollution at all. Zn and Cd show a moderate pollution, whilst the water is highly polluted with Iron (I_{geo} class 5). The relatively high contents of Cd are probably due to the use of fertilizers and pesticides in agricultural activities along the Zarqa river. Fe, Cu, and Zn are components of pipes, wires and tires in motor vehicles and are released into the roadside environment as a result of mechanical abrasion (Qasem M. et al., 2005). Rainwater can wash those abrasions into the nearby water body. Environmental impact assessment studies carried out on the end-of-life vehicle stores reveal that Pb, Cd, Zn, and Cu are the major inorganic contaminants and engine oil and break fluids are the major organic contaminants. Lead is added to gasoline to prevent engine knock and thus cars become a major source of lead to the environment (Qasem M. et al., 2005).

Table 22: Mean values of geochemical index of Zarqa River and KTD reservoir

Metal	I_{geo} value	I_{geo} class	Pollution intensity
Iron	4,29	5	Highly polluted
Lead	0,88	1	Unpolluted
Copper	0,81	1	Unpolluted
Zinc	1,74	2	Unpolluted to moderately polluted
Cadmium	2,48	3	Moderately polluted

10. CHEMICAL SAMPLING

10.1. Water sampling parameters

To be able to compare the biological findings with chemical analyses, water samples have been taken at Zarqa River, KTD and at the RBG (Figure 28).

After taking the water samples, they were immediately transported to the laboratories of the Royal Scientific Society (RSS) where they got analyzed for (Annex III):

- Nitrogen ($\text{NH}_4\text{-N}$)
- Hydrogencarbonate (HCO_3)
- Carbon trioxide (CO_3)
- Iron (Fe)
- Chemical Oxygen Demand (COD^{**})
- Nitrate (NO_3)
- Sulfate (SO_4)
- Total Phosphorous (T-P^{**})

$\text{NH}_4\text{-N}$: Ammonia measurement is an important water quality parameter which is used to indicate water pollution. Even in low concentrations it is toxic to fish and aquatic organisms.

The danger ammonia poses for fish depends on the water's temperature and pH, along with the dissolved oxygen and carbon dioxide levels. The higher the pH and the warmer the temperature, the more toxic the ammonia. (Source: <http://www.h2ou.com/h2wtrqual.htm>).

HCO_3^- : Alkalinity is a measure of the acid-neutralizing capacity of water.

Alkalinity in most natural waters is due to the presence of carbonate (CO_3), bicarbonate (HCO_3^-), and hydroxyl (OH^-) anions. But also borates, phosphates, silicates and other bases contribute to alkalinity, if present. Alkalinity is usually reported as equivalents of calcium carbonate (CaCO_3). (Wilson, P.C., U.F.A., SL332)

Fe: At normal levels, iron is not deadly to aquatic animals, but at higher levels, when iron does not dissolve in water, fish and other creatures cannot process all the iron they take in from water. The iron can build up in animals' internal organs. Higher levels of iron in fish and aquatic plants also have negative effects on the people or creatures consuming them.

(http://www.ehow.com/list_6778733_effects-iron-water-aquatic-life.html)

COD: High COD levels decrease the amount of dissolved oxygen available for aquatic organisms. Low dissolved oxygen causes reduced cell functioning, disrupts circulatory fluid balance in aquatic species and can result in death of individual organisms as well as large "dead zones". Hypoxic water can also release pollutants stored in sediment (Source: <http://www.stormwaterx.com/Resources/IndustrialPollutants/COD.aspx>).

NO₃: The presence of normal levels of nitrates usually does not have a direct effect on aquatic insects or fish. However, excess levels of nitrates in water can create conditions that make it difficult for aquatic insects or fish to survive. Algae and other plants use nitrates as a source of food. If algae have an unlimited source of nitrates, their growth is unchecked.

Large amounts of algae can cause extreme fluctuations in dissolved oxygen. Photosynthesis by algae and other plants can generate oxygen during the day. However, at night, dissolved oxygen may decrease to very low levels as a result of large numbers of oxygen consuming bacteria feeding on dead or decaying algae and other plants. High concentrations of nutrients, especially phosphates and nitrates, can lead to Eutrophication (excessive growth of algae). As the algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water of available oxygen, causing the death of other organisms, such as fish.

SO₄: Sulphate is one of the least toxic anions.

T-P:. High concentrations of nutrients, especially phosphates and nitrates, can lead to Eutrophication (excessive growth of algae). Phosphates are not toxic to people or animals unless they are present in very high levels (Source: <http://www.water-research.net/Watershed/phosphates.htm>).

10.2. Water sample locations



Figure 29: Water sample location

While taking the samples, several things have to be taken care of:

- Samples should be taken minimum 20 cm above the sediment surface
- Avoiding sediment re-suspension
- The equipment used for sampling should be cleaned properly between two sampling points to avoid contamination between the two sites
- Avoiding of exposure to direct sunlight while sampling and transporting the samples
- The samples should be kept cool and dark and processed immediately upon arrival in the laboratory

10.3. Results of water sampling

Table 23 shows the results of the water sample analyzation (analyzed by RSS) compared to literature data from Al-Zu'bi, 2007, Uleimat, A., 2007, MWI 2012.

The Iron content of the water at King Talal Dam Inlet was 0,0447 mg/l. The maximum limit allowed regarding the Jordanian Standards (893/2006) is 5 mg/l. The water samples were taken at 3 different stations show a differing Iron content from 1,30 mg/l at Zarqa river, 0,490 mg/l at King Talal Dam reservoir and 1,55 mg/l at King Talal Dam reservoir within the area of the RBG. Still, the maximum limit of 5 mg/l is not reached. COD exceeded the upper limit at all sample stations whilst all other parameters are within or below the limit of the Jordanian Standard and thus show no limit for using the water for irrigation purposes.

Table 23: Results of the water sample analyzation (analyzed by RSS (Annex), Al-Zu'bi, 2007, Uleimat, A., 2007, MWI 2012)

Parameter	Sample number			Jordanian Standard 893/2006	Al-Zu'bi, 2007	MWI
	Sample 1 KTD at RBG [mg/l] 2012	Sample 2 KTD [mg/l] 2012	Sample 3 Zarqa River [mg/l] 2012		KTD [mg/l]	11/2012
NH ₄ -N	> 3,7	> 3,7	> 3,7	-	-	0,77
HCO ₃	349	338	275	400	135 - 464	329,40
CO ₃	0	0	0	-	7,5 - 22,5	-
Fe	1,55	0,49	1,3	1,5	<5,0	0,15
COD**	18,4	34,6	26,8	0,05	-	-
NO ₃	15,3	39	70,4	70	6,3 - 41,38	-
SO ₄	193	236	195	300	19,2 - 253	37,67
T-P**	0,257	3,13	6,78	15	-	-

10.4. Sediment sampling

The two main types of metal input to the soil system are:

- Mineral rock weathering
- Anthropogenic sources

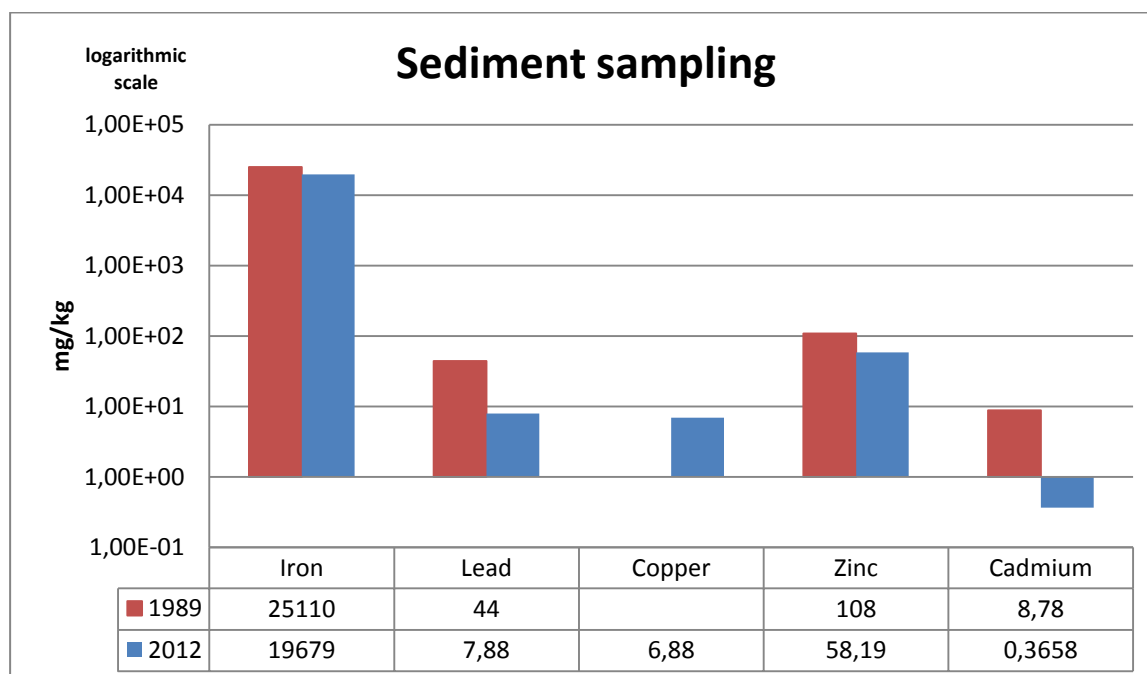
Figure 23 shows the heavy metal content of sediment samples at KTD in 1989 in comparison to sediment samples of KTD in 2013.

High quantities of certain metals are being released into the environment by anthropogenic activities, primarily within industrial processes, manufacturing and the disposal of industrial and domestic waste materials (Qasem, M. et al., 2005). Heavy metals are threat to soil quality due to their persistence after entering the soil and metals as Iron, Mercury, Arsenic, Lead, Zinc, Cadmium, Chromium, Nickel and Copper are common in soils but can't be degraded (Ghrefat, Habes A., et al., 2012).

During the sampling campaign soil samples were taken at the same sites as the biofilm samples and measured for Iron, Lead, Copper, Zinc and Cadmium.

The results indicate that the amount of heavy medals in the soil decreased in comparison to the values of 1989.

Table 24: Heavy metal content of sediment samples at KTD in 1989 in comparison to sediment samples of KTD in 2013



Fe, Cu, and Zn are components of pipes, wires and tires in motor vehicles and are released into the roadside environment as a result of mechanical abrasion (Qasem M. et al., 2005). Rainwater than wash those abrasions into the nearby water body.

11. INTERPRETATION AND RESULTS

Many studies had been conducted to investigate the heavy metal contamination of soil, water and plants. Unusually high quantities of metals are usually being released into the environment by anthropogenic activities, primarily associated with industrial process, disposal of industrial and domestic waste and agricultural activities (fertilization,...).

(Ross, 1996).

If streets are located close to a water body, the abrasion from brake pads and tires as well as leaded and unleaded petrol, diesel oil and exhaust pipes will be washed into the water with the next rain runoff.

Pb added to gasoline is preventing engine knock, Fe, Cu, and Zn are essential components of many pipes, wires and tires in motor vehicles and are released into the roadside environment as a result of mechanical abrasion. A high content of Cd is probably due to the use of fertilizers and pesticides in agricultural activities alongside a waterbody.

In general it can be said, that Fe, Pb, Cu, Zn and Cd are mostly of anthropogenic origin and may origin from similar pollution sources such as agricultural and industrial activities.

The water samples that have been taken within the campaign show a differing Iron content from 1.30 mg/l at Zarqa river, 0.490 mg/l at KTD reservoir and 1.55 mg/l at KTD reservoir within the area of the RBG (Wadi Tell Ar Rumann). Still, the maximum limit of 5 mg/l (regarding the Jordanian Standard 893/2006) is not reached. COD exceeded the upper limit at all sample stations whilst all other parameters are within or below the limit of the Jordanian Standard and thus show no limit for using the water for irrigation purposes.

Regarding the sampling of aquatic insects, in KTD Reservoir as well as in Zarqa River, the tolerance values ranged from 4 to 9, with a high percentage around a tolerance value of 6 and no species with a low pollution tolerance. This is an indicator for a moderate to polluted water quality as organisms which settle here have a higher tolerance to pollution. Within the area of the RBG (Wadi Tell Ar Rumann), species with a tolerance value of 2 were found indicating good to moderate water quality, even if some species also showed a value of 6.

Based on the results of Wadi Tell Ar Rumann, no indicators for organic pollution have been identified, whereas Al Zarqa River shows a reduced invertebrate community indicating the organic loading of the water.

The variation is probably due to different agricultural activities at different times of the year as well as the differing input volume of industrial and sewage waste.

12. LITERATURE

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13. APPENDIX

I TAXA LIST

Table 25: Taxa list of the insects found at the sampling region

Taxonomy group	Order	Family	Genus	Species
Insecta	Diptera	Simuliidae		
		Ceratopogonidae		
		Tabanidae		
		Psychodidae		
		Empididae		
		Ephydriidae		
		Dixidae		
		Dolichopodidae		
		Muscidae		
		Stratiomyidae		
		Chironomidae	Chironomini	
			Corynoneura	
			Orthocladiinae	
			Rheosmittia	
			Stenochironomus	
			Tanypodinae	
			Tanytarsini	
		Tipulidae	Antocha	
			Dicranota	
			Hesperoconopa	
			Hexatoma	
			Leptotarsus	
			Pilaria	
			Tipula	
	Ephemeroptera	Baetidae	Acentrella	
			Baetis	
			Baetis brunnicolor	
			Baetis vagans	
			Plauditus	
			Caenis	
	Hemiptera	Corixidae		
	Odonata	Calopterygidae		
		Coenagrionidae	Argia	
		Libellulidae		
	Trichoptera	Hydropsychidae	Hydropsyche	
			Hydroptila	
			Oxyethira	
	Coleoptera	Hydrophilidae		
	Hemiptera	Veliidae		
		Corixidae		

II WATER SAMPLING



الجمعية العلمية الملكية
Royal Scientific Society

الرقم التمييزي للعينه: ٢٣١١٢/١٢/٠٣
رقم التقرير: ١٦٤٣/١٢/٠٣

الحديقة النباتية الملكية المحترمين

عمان/ت: ٠٧٧٦٤٨١٠٩١

نوع العينة: مياه عادمة صناعية
طريقة اخذ العينة: تم جمعها وإحضارها من قبلكم
تاريخ الاستلام: ٢٠١٢/١١/١١
تاريخ الفحص: ٢٠١٢/١١/٢١

القطاع: المختبرات
القسم: المختبرات البيئية
المختبر: مختبر التحليل الآلي البيئي

السادة

العنوان

إشارتنا رقم: ٣٣٤٣/١/٥٥/٣٣٠ (٠٣٠٢)
تاريخ: ٢٠١٢/١١/٢٢
إشارتكم رقم: -----
تاريخ: ----/--/--

لا ينسخ التقرير بشكل مجزأ إلا بأخذ موافقة خطية من الجهة المصدرة للشهادة

نتائج الفحص تمثل العينة المفحوصة فقط

أي كشط أو تعديل يلغي هذا التقرير

Test report is only valid with deviation-stamp and signature

Test report shall not be reproduced other than in full, except with the written approval of the issuing party

The test results relate only to the items tested

Any erasure or attrition in the report will invalid it

الفحص	النتيجة/ رمز العينة	الوحدة	طريقة الفحص*
NH ₄ -N	٣,٧>	٣,٧>	٣,٧>
HCO ₃	٣٤٩	٣٣٨	٢٧٥
CO ₃	٠	٠	٠
Fe	١,٥٥	٠,٤٩٠	١,٣٠
COD**	١٨,٤	٣٤,٦	٢٦,٨
NO ₃	١٥,٣	٣٩,٠	٧٠,٤
SO ₄	١٩٣	٢٣٦	١٩٥
T-P**	٠,٢٥٧	٣,١٣	٦,٧٨

*: Standard Methods for the Examination of Water & Wastewater, Online.
**: Test is not accredited by UKAS.

رئيس القسم: د. نسرين الحمود

FORM NO. RSSPMP1302 REV.(1)

مسؤول المختبر: إيمان الطعان

صفحة (١) من (١)

 المعرفة Knowledge

 المختبرات Testina

 الجودة Quality

 تنمية المجتمع Outreach

هاتف ٩٦٢٦ ٥٣٤٤٧٠١ فاكس ٩٦٢٦ ٥٣٤٤٨٠٦ ص.ب ١٤٣٨ عمان ١١٩٤١ الأردن
Tel: +962 6 5344701 Fax: +962 6 5344806 P.O Box 1438 Amman 11941 Jordan

Figure 30: Results of the water samples taken out by the Royal Scientific Society, Jordan (RSS). Royal Scientific Society, P.O.Box 1438, Amman 11941, The Hashemite Kingdom of Jordan

III DISTRIBUTION OF HEAVY METALS ACCORDING I_{GEO}-CLASSES

Table 26: Distribution of the elements in the Earth's crust (Expressed in parts per million) (modified after Turekian and Wedepohl (1961))

"Igneous" Rocks							Sedimentary Rocks		Deep-Sea Sediments	
Ultrabasic	Basaltic Rocks	Granitic Rocks		Syenites	Shales	Sandstones	Carbonates	Carbonate	Clay	
		High Calcium	Low Calcium							
Fe	94.300	86.500	29600	14.200	36700	47.200	9800	3800	9000	65.000
Cu	10	87	30	10	5	45	X	4	30	250
Zn	50	105	60	39	130	95	16	20	35	165
Cd	0X	0.22	0.13	0.13	0.13	0.3	0X	0.035	0X	0.4
Pb	1	6	15	19	12	[D]	7	9	9	80

Table 27: Index of Geoaccumulation

Latitude		Longitude		Fe		Pb		Cu		Zn		Cd	
				I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	µg/Kg
N 32 10 857		E 35 50 320		4,18	15295	0,88	7,51	0,97	9,27	1,67	46,52	2,43	270
N 07 66 401		E 35 64 975		4,33	21165	1,03	10,7	1,0	9,23	1,9	79,47	2,61	410
N 07 66 321		E 35 64 980		4,34	21908	0,78	5,98	0,82	6,64	1,76	57,31	2	100
N 07 64 983		E 35 64 475		4,04	10843	0,51	3,24	0,26	1,83	1,43	27,21	1,6	40
N 32 11 365		E 35 49 446		4,26	18151	0,68	4,8	0,6	4,23	1,67	46,59	2,20	160

Latitude	Longitude		Fe		Pb		Cu		Zn		Cd
		I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	μg/Kg
N 32 11 091	E 35 48 394	4,21	16364	0,70	5,01	0,53	3,42	1,44	27,75	2,04	110
N 32 11 437	E 35 49 662	4,42	26121	0,94	8,7	0,9	8,57	1,75	56,71	2,4	250
N 32 11 437	E 35 49 662	4,42	26256	0,94	8,75	0,95	9,01	1,73	54,03	2,34	220
N 32 11 431	E 35 48 457	4,3	19931	0,99	9,72	0,98	9,57	1,93	84,79	2,86	720
N 32 11 431	E 35 48 457	4,34	21690	1,01	10,21	0,97	9,41	1,99	97,91	2,8	630
N 32 11 384	E 35 48 477	4,3	20168	0,99	9,86	1,06	11,52	1,95	88,81	2,49	310
N 32 11 384	E 35 48 477	4,29	19298	0,93	8,5	1,0	9,3	1,88	76,45	2,45	280
N 32 11 384	E 35 48 477	4,21	16322	0,85	7,0	0,9	8,22	1,74	54,67	2,4	250
N 32 11 462	E 35 49 666	4,37	23519	0,83	6,71	0,88	7,62	1,63	42,83	2,4	250
N 32 11 46	E 35 49 666	4,36	22831	0,86	7,29	0,87	7,44	1,73	53,87	2,41	260
N 32 11 462	E 35 49 667	4,33	21432	0,96	9,09	0,68	4,8	1,77	58,89	2,67	470

Latitude	Longitude		Fe		Pb		Cu		Zn		Cd
		I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	μg/Kg
N 32 11 462	E 35 49 667	4,33	21450	0,93	8,55	0,68	4,80	1,75	55,99	2,59	390
N 32 11 462	E 35 49 667	4,36	22667	1,04	11,01	0,75	5,63	1,85	70,66	2,73	540
N 32 11 462	E 35 49 667	4,3	19749	0,94	8,66	0,68	4,81	1,79	62,07	2,6	400
N 32 11 495	E 35 49 878	4,1	12572	0,85	7,16	0,88	7,54	1,89	76,85	2,83	680
N 32 11 495	E 35 49 878	4,1	12624	0,88	7,56	0,8	6,25	1,77	58,89	2,78	600
N 32 11 495	E 35 49 878	4,3	19860	0,99	9,71	0,91	8,09	1,94	87,48	2,82	660
N 32 11 495	E 35 49 878	4,3	19962	1,04	10,97	0,84	6,87	1,9	79,73	2,82	660
N 32 11 541	E 35 50 243	4,4	24701	0,84	6,87	0,88	7,53	1,71	51,53	2,58	380
N 32 11 541	E 35 50 243	4,34	21651	0,82	6,61	0,86	7,32	1,74	55,36	2,53	340
N 32 11 541	E 35 50 243	4,36	23034	0,82	6,61	0,69	4,94	1,73	53,17	2,53	340
N32 11 460	E 35 49 667	4,3	19745	0,67	4,63	0,82	6,67	1,49	30,93	2,18	150

Latitude	Longitude		Fe		Pb		Cu		Zn		Cd
		I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	mg/Kg	I _{geo}	μg/Kg
N 32 11 422	E 35 49 546	4,3	19827	1,13	13,4	0,8	5,93	1,43	26,91	2,08	120
N 32 11 524	E 35 50 243	4,23	16834	0,86	7,2	0,8	6,49	1,82	66,61	2,89	770
N 32 10 953	E 35 49 574	4,26	18024	0,74	5,52	0,68	4,84	1,68	47,39	2,59	390
N 32 11 525	E 35 50 241	4,21	16052	0,84	6,9	0,7	5,37	1,43	26,64	2,28	190
Mean value		4,29		0,88		0,81		1,74		2,48	

Table 28: Pollution intensity

I _{geo}	I _{geo} Class	Pollution intensity
0 - 0	0	Undetected
0 - 1	1	Unpolluted
1 – 2	2	Unpolluted to moderately polluted
2 – 3	3	Moderately polluted
3 - 4	4	Moderately to highly polluted
4 - 5	5	Highly polluted
>5	>5	Very highly polluted

BIOINDICATORS

Monitoring of Surface Water Pollution in King Talal Dam and Reservoir Based on Biological Indicators

<http://royalbotanicgarden.org/page/bioindicators> (June, 2014)



An integrated assessment is being conducted on water quality in King Talal dam and reservoir, adjacent to the Royal Botanic Garden. To evaluate the water quality and degree of pollution, parameters such as organic load, discharge, bottom substrates and pollutants are being examined. A biological method known as biofilm monitoring is being used, to help

determine the overall ecological quality. An aquatic biofilm (i.e. a film such as "slime" that develops on surfaces in water) has the ability to adsorb and incorporate material from the surrounding water. Biofilms form on almost any surface exposed to water, and host a microbial community that contain species such as sessile bacteria, protozoa, fungi and algae (Fuchs, 1996). Depending on their structure, biofilms can incorporate contaminants and grow rapidly, thus offering an easy sampling possibility (Fuchs, 1996).

Since biofilm monitoring is low-cost, the equipment is easy to handle, and few specific requirements are needed at the test site, a high spatial resolution of monitoring is possible.



The analysis of biofilms from the reservoir will deliver reliable, time-integrated results on the sources and state of surface water pollution. Miriam Leicht, a PhD Student from the Karlsruhe Institute of Technology (KIT)/ Institute for Water and River Basin Management in Germany is performing her PhD research on biological indicators at the RBG site.



Biofilm samplers are being set up at different locations within the water system for 7 to 14 days, depending on the organic load of the water. During this time, a biofilm will grow on the surface of the collector and incorporate any particulate and dissolved pollution passing through the sampler. Afterwards, the biofilm can be easily harvested from the sampler and transferred to a lab for subsequent analysis of specific pollutants (heavy metals, organic volatile

compounds, etc.).

In addition to the pollutant monitoring described above, a biological method based on macroinvertebrate communities will be applied at the project area in Wadi Rumman. This method, which is well established throughout Europe, results in an assessment of the ecological status of local rivers and streams. Macroinvertebrates will be collected at different



spots where running water is found. The next step is to determine the main functional groups and indicator species. Then, the composition of the macroinvertebrate community, and the presence or absence of specific organisms, will give a further indication of the ecological quality of the stretch of water under consideration.

As this method has not been applied in Jordan up to now, reference data from investigations elsewhere in the Mediterranean region will have to be considered.

In addition, chemical and physical parameters like oxygen, temperature, conductivity, COD, NH₄-N, NO₃-N and total phosphorus will be analyzed to support the biological findings.

Upon completion, the results of this water quality study will be published and a link will be included on this page. For further information, please contact us at:

research@royalbotanicgarden.org

Literature:

- Fuchs, S., Haritopoulou, T. & Wilhelmi, M. (1996): Biofilms in Freshwater Ecosystems and their Use as a Pollutant Monitor. *Water Science and Technology*, Volume 34, No. 7-8, pp. 137-140, 1996.
- Description of Work Packages SMART II: "Sustainable Management of Available Water Resources with Innovative Technologies," 2010-2012.

