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Aquatic Macroinvertebrates as Bioindicators of Water Quality in Wadi Mujib and Wadi Shueib, Jordan

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ABSTRACT

This study investigates the utility of macroinvertebrate assemblages as bioindicators for the environmental health of freshwater bodies in Wadi Mujib and Wadi Shueib. Twelve sampling stations were strategically selected along these wadies, and water quality was evaluated in relation to the occurrences of aquatic macroinvertebrates and specific environmental variables. Results demonstrate that the presence of sensitive macroinvertebrates, including *Theodoxus*, *Melanopsis*, *Turbellaria*, and *Amphipoda*, is indicative of good and clean water quality. In contrast, the existence of *Physa acuta*, tubifex worms, Isopoda, and *Simuliidae* suggests organic pollution. These macroinvertebrate assemblages establish themselves as valuable indicators of water pollution. A clear correlation was observed between distinct macroinvertebrate groups and water quality, underscoring the potential of these organisms as effective bioindicators, particularly in semi-arid regions experiencing high population growth, expanding industrialization, and increased use of agrochemicals and pharmaceutical products. Although the study validates the use of macroinvertebrates as water quality indicators, it also emphasizes the need for future studies to include other taxonomic groups as potential bioindicators. The inclusion of such groups could potentially refine the use of macroinvertebrate assemblages for water quality assessment.

1. INTRODUCTION

Invertebrate fauna is recognized as a pivotal component of aquatic ecosystems, playing essential roles in food provision, organic matter decomposition, and nutrient cycling [1]. Notably, many macroinvertebrate species serve as sensitive indicators of environmental changes, including habitat degradation, pollutant presence, water salinity, pH, nutrient enrichment, temperature, heavy metal content, and more. The composition of macroinvertebrate communities varies significantly across different aquatic ecosystems.

These organisms, which spend all or part of their life cycle in water, are directly influenced by water quality. The occurrence, diversity, and abundance of these biotic communities are consistently affected, directly or indirectly, by variations in the chemical, physical, and biological characteristics of their habitat [2-4]. Some adapt and thrive in specific ecological conditions, while others occupy a broader range of habitats. Macroinvertebrates with habitat-specific lifestyles can provide valuable insights into the quality of aquatic bodies and serve as reliable biological indicators of water status.

The use of macroinvertebrates as bioindicators is advantageous; they represent a diverse and abundant group of animals found in nearly all water systems. They vary in their pollution tolerance, are easily observable and collectible, particularly in shallow water bodies such as those in Jordan [5-8]. In contrast to chemical and physical water analyses, macro-organisms offer a cost-effective and rapid technique to monitor changes in water quality.

Globally, numerous studies have validated the use of macroinvertebrates as biological indicators for various environmental factors, including acidification, eutrophication, habitat degradation, temperature, heavy metals, nitrates and phosphorus enrichment, and water salinity [9-12]. In Jordan, bio-monitoring of water quality using aquatic invertebrates commenced in the early eighties [13], with researchers correlating the hydrochemistry of water sources to their hydrobiological contents.

Early studies assigned pollution grades to various surface water sources, ranging from 1 (excellent water quality) to 10 (heavily polluted water) [13]. Subsequent research refined these findings and improved the methodology of water quality bioindicators [14-17]. These studies confirmed the utility of invertebrate assemblages as bioindicators of environmental changes in Jordan's freshwater systems, correlating to various environmental parameters such as salinity, pollution, and trace elements.

This study aims to establish a correlation between the diversity and composition of aquatic invertebrate communities and the physico-chemical parameters, such as alkalinity, hardness, nitrate NO_3^-, phosphate (PO_4^-), chloride (Cl^-), biological oxygen demand (BOD), chemical oxygen demand (COD), zinc (Zn), copper (Cu), lead (Pb), and others, in the surface water of the study area. The objective is to discern the water status, facilitate future comparisons, and shed light on the impacts of socio-economic development on water resources and the surviving organic communities in the study area.

2. STUDY AREA

The study covers 12 sampling stations distributed along Wadi Shueib and Wadi Mujib (Figure 1A). Wadi Shueib is located in north Jordan west and southwest of Salt City and drains an area of 178 km^2. Its base and flood flow in addition to the treated effluents of Salt and Fuheis-Mahis wastewater treatment plants are collected in Shueib Dam before the water enters the Jordan Valley area (Figure 1B). The catchment area is densely populated and includes the cities of Salt, Mahis, Fuheis, and many smaller villages. Wadi Mujib, a perennial river in its lower reaches, drains most of the area east of the Dead Sea of 6150 km^2 into the Dead Sea. The average mean annual precipitation over Shueib catchment is 300 mm/yr. and over Mujib catchment 200 mm/yr. Temperatures rise during the summer months to 35-40°C and fall in winter months to about zero°C. Both wadis originate in the highlands with an elevation of around 1000 masl and flow down towards the Dead Sea at an elevation of around 430 mbsl.

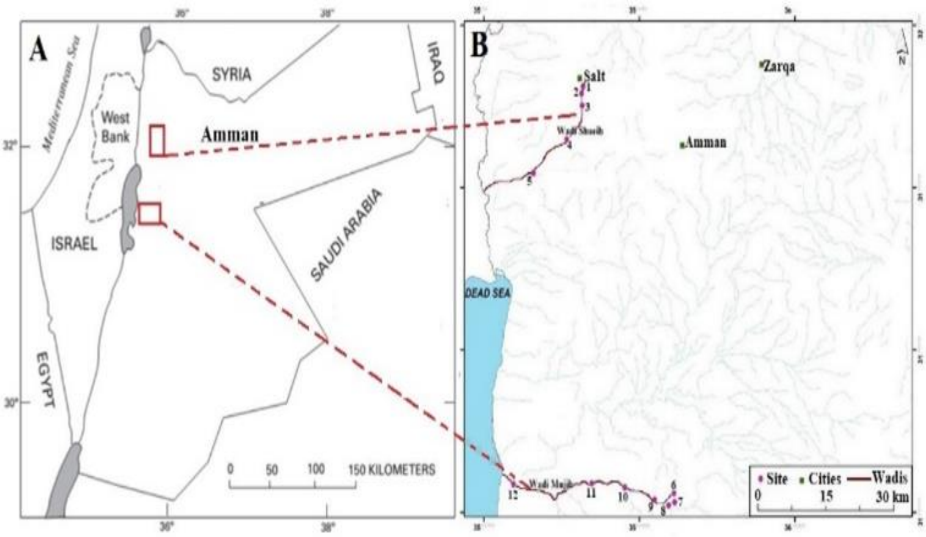

Figure 1. A. General map of the study area; B. Location of the selected sampling sites along Wadi Shuieb and Wadi Muijib

Macroinvertebrate assemblages were studied as indicators of water quality along Wadi Shueib and Wadi Mujib courses. These water courses show major quality changes along their short courses of around 25 km. They show several environmental conditions of freshwater system of stagnant to running water and clean to polluted water, especially organically polluted water. The results obtained from the sampled materials of macro invertebrates' assemblages of freshwater bodies fauna in accordance with data obtained from physico-chemical analyses of the water indicate a direct relation between the water quality and the composition of the surviving organisms' communities in the fresh water systems which can be well demonstrated on the examples of Wadi Shueib and Wadi Mujib.

3. METHDOLOGY

The method applied here is to use aquatic invertebrates in evaluating the quality of the fresh perennial water system of the two wadis. It also includes some stagnant water habitat along the wadis. The method examines the relations of the aquatic invertebrate abundances under various chemical and physical water quality parameters. Biological samples were collected together with water samples from 12 sampling sites along Wadi Mujib and Wadi Shueib courses. Within this framework, sites were chosen to represent different environmental conditions of fresh water including clean and polluted, running and still, fast and slow flowing, normal and mineralized waters, which were also sampled from study area. At each collection site, invertebrates and water samples were collected for laboratory analyses. The water analyses included: alkalinity, hardness, NO_3^-, PO_4^-, Cl^-, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and some heavy metals like Zinc (Zn), Copper (Cu), Lead (Pb), and Strontium (Sr). In the field water electric water conductivity, pH and temperature were measured using WTW-field equipment. Sampling of invertebrate was simple, not requiring advanced equipments, due to the shallow nature of sampled streams and rivers. The collecting devices consist of a mesh-screen and animals washed into beakers.

Water analyses were carried out according to the standard methods of the United States Geological Survey. Aquatic macro invertebrates were sampled during the period February to May (late winter to spring) from 2021 to 2022 using a sieve of 500 µm and benthos hand net. Those macroinvertebrates that cling to rocks, gravels, aquatic vegetation and often found under the rocks were manually collected by brushing them with the hand or with a fine brush. Sampled mayfly nymphs were stored in 80% ethanol and packed for analysed in the laboratory.

The freshly collected invertebrates were sorted and documented under a S6 D Leica stereomicroscope with magnification of 6.3–40x that is connected to a digital camera and Leica DM750 microscope. In the laboratory, macroinvertebrates were isolated and identified according to their place in the taxonomic system as far as possible. The material is deposited in the collections of the University of

Jordan and Museum of Zoology, Switzerland.

4. RESULTS

4.1 Physico-chemical characteristics

Beside the macro-invertebrates' samples, the physical and chemical properties of water at each site were evaluated such as Temperature (T), Potential of Hydrogen (pH), Electrical Conductivity (EC), Chlorides (Cl^-), Total Hardness (TH), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Iron (Fe), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and some heavy metals like Manganese (Mn), Copper (Cu), Lead (Pb), and Strontium (Sr). Our laboratory results of these analyses of fresh water are summarized in Tables 1-3.

Table 1. Composition of the water samples from studied sites

Site	EC (μS/cm)	Temp	pH	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	K (meq/l)	HCO_3 (meq/l)
1	630	17.3	7.49	4.432	1.059	0.899	0.044	3.98
2	835	18.5	7.63	4.627	1.655	2.13	0.366	4.01
3	685	18.6	7.47	3.95	1.53	0.55	0.1	4.9
4	775	18	8.45	3.987	1.479	1.979	0.197	2.59
5	680	17.3	8.43	3.337	1.747	1.532	0.199	2.49
6	925	17.3	7.7	3.67	2.261	2.825	0.247	1.57
7	933	17.3	7.66	3.73	2.351	2.514	0.247	1.57
8	932	17.3	7.7	3.69	2.402	2.963	0.247	1.57
9	950	17.3	7.73	3.81	2.69	3.244	0.2	1.57
10	920	17.9	8.1	5.182	3.83	4.789	0.19	1.57
11	890	18.7	7.3	3.9	3.57	3.23	0.18	4.56
12	986	17.48	6.59	5.26	2.75	10.31	0.654	3.4

Table 2. Chemical compositions of water samples

Site	CO_3 (meq/l)	Cl (meq/l)	SO_4 (meq/l)	NO_3 (meq/l)	PO_4 (mg/l)	COD (mg/L)	BOD (mg/L)
1	0	0.819	0.649	0.78	0.036	8.3	0
2	0	1.189	1.202	1.397	1.025	21.05	20
3	0	0.77	0.32	0.31	0.057	25.96	20
4	0.8	1.2	1.456	0.775	1.005	48.51	35
5	0.4	1.001	1.75	0.662	0.085	30.56	20
6	0	2.856	4.387	0.15	0.313	45.2	15.8
7	0	2.234	4.02	0.15	0.313	48.3	20
8	0	2.067	4.731	0.15	0.313	55.98	25
9	0	3.102	4.61	0.1	0.123	27.65	15
10	0	4.766	7.259	0.116	0.0132	20.19	15
11	0	3.85	1.66	0.03	0.128	4.27	0
12	0	6.59	8.343	0.693	0.03	4.1	27.8

Table 3. Chemical compositions of water samples (All measurements in ppm except F and Br in mg/l)

Site	Fe	Pb	Zn	Mo	Cu	Mn	Sr	Ba	Br	F	Habitat
1	0.016	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	0.43	Less than 0.01	0.275	0.703	Spring
2	0.021	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	0.109	0.503	Less than 0.01	0.293	0.24	Spring
3	0.017	Less than 0.01	0.03	Less than 0.01	Less than 0.01	Less than 0.01	0.59	Less than 0.01	0.205	0.244	Stream
4	0.022	Less than 0.01	0.043	Less than 0.01	Less than 0.01	Less than 0.01	1.085	Less than 0.01	0.448	0.19	Stream
5	0.041	Less than 0.01	0.05	Less than 0.01	Less than 0.01	Less than 0.01	1.041	Less than 0.01	0.373	0.373	Pond
6	0.021	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	0.044	11.36	Less than 0.01	1.506	0.691	Stream
7	0.021	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	0.044	11.36	Less than 0.01	1.506	0.691	Reservoirs
8	0.021	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	0.044	11.36	Less than 0.01	1.506	0.691	Pond
9	0.024	Less than 0.01	0.02	Less than 0.01	Less than 0.01	0.025	37.42	Less than 0.01	0.264	0.24	Pond
10	0.023	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	0.1	Less than 0.01	0.214	0.551	Stream
11	0.014	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	Less than 0.01	1.678	Less than 0.01	0.265	0.92	Stream
12	0.023	Less than 0.01	0.02	Less than 0.01	Less than 0.01	0.025	37.39	Less than 0.01	10.41	0.892	Stream

4.2 Field observations

Fieldwork investigations to study the area from the aspects of habitat, macroinvertebrate community, substrates, and other environmental conditions. were performed through field campaigns from the late winter to early spring time, between February and May. The substrates were mainly composed of fine to coarse clastic sediments and aquatic vegetation.

During the field campaign in 2021 and 2022, material of aquatic invertebrate assemblages was sampled and studied throughout these study sites. During the field trips different invertebrate groups were observed and collected mainly encompassing Ephemeroptera (Mayflies), Odonata (Dragonflies), Gastropods (snails), Annelida (Oligochaetes tubifex, leeches, turbellaria), Diptera (black fly Simuliidae, Chironomid midge), and others. Five sites were sampled and selected based on the alteration of macroinvertebrate assemblage along the Wadi Shueib. Running fresh water flow about 20 km from the highland of Salt city to Wadi Shueib Dam at the entrance of the wadi to the Jordan Valley.

Figure 2. Field photographs of Wadi Shueib. (A) Sampling site 1 with *theodoxus* and *melanopsis* snails; (B) Macroinvertebrate's collection Site 2; (C) Site 3, stream with well vegetated banks; (D) *Physa acuta* gastropods with their egg cases in Site 3; (E) Swift running freshwater Site 4; (F) Aquatic tubificid worms in muddy water (Site 4); (G) Blackfly (Diptera: *Simuliidae*) larvae in Site 4; (H) Small ponds of Site 5

The study began at Site 1, a spring water with a small weir to slow down the flow of the water over the stony substrate ground. Species of gastropods such as *theodoxus* and *melanopsis* were heavily present associated with amphipoda fauna (Figure 2A). In addition, *Dugesia* or *flatworms* (Turbellaria) occurred in this station. *Baetis monnerati* (Ephemeroptera) were also observed.

Down and not far from the Site 1, we found another large fresh water spring with slow running water in a concrete channel surrounded by trees. The gastropods *melanopsis* was still present, but in reduced numbers than found in Site 1. Notably, *theodoxus* species were not observed in this station but Ephemeroptera *Baetis monnerati* were found.

The local habitat experienced a disappearance of Amphipoda, whilst evidence of Isopoda's survival was found. Notably, the spring water in this location, densely surrounded by residential structures, serves as a popular site for recreational activities among locals, as depicted in Figure 2B.

At about 400 m downstream from Site 2, Site 3 was selected at a well vegetated stream part with fast flowing fresh water with a gravelly bottom in the middle and muddy substrates near the stream banks (Figure 2C). Alteration of invertebrate compositions were clearly observed here. For example, gastropod assemblages, disappearance of *theodoxus* and *melanopsis* and presence of *Physa acuta* (Figure 2D). Leech worms are commonly present here. Only Ephemeroptera *Caenis macrura* are abundant and exist associated with *Simuliidae* (black fly) and isopoda crustacean in this site.

Site 4 is located downstream of Salt waste water treatment plant (WWTP) and has fast flowing, browinsh, smelly and turbid water with large stony ground surrounded by huge reeds plants (*Phragmites australis*) (Figure 2E). Here the diversity and community composition has totally changed. Dense occurrence of *tubifex* worms belonging to Annelida (Oligochaetes) are found in mud rich in decomposing organic matter (Figure 2F).

Additionally, aquatic *Simuliidae* with leeches were noted on the stones in this site (Figure 2G). *Physa acuta* gastropods were noticeably reduced and mayflies were not documented in this site. Site 5 is located further downstream, near the Jordan Valley, before the water enters Shueib Dam. It consists of a small pond with stagnant water and muddy ground (Figure 2H). Only larvae of red chironomid midge or blood worms with their egg cases and *Podocopida* were found abundant in this muddy ground.

In Wadi Mujib, collection of samples started at the outlet of Wadi Mujib Dam downstream to its entrance into the Dead Sea, a total of 6 sites (Figure 3).

Site 6 is positioned at the outlet Wadi Mujib Dam with turbid swift running water where the only microorganisms found here are filamentous charophyte green algae and unicellular algae species (Figure 3A).

At Site 7, the wadi discharges fresh water and the wadi bottom is covered by algal mats (Figure 3B). Gastropod species of *Physa acuta* with their egg cases were noted. In the muddy bottom abundant *tubfix* worms were observed. Leech worms, *Simuliidae* larvae and frogs occur in this site.

Site 8 consists of a stagnant, smelly, turbid, muddy pool full of microorganisms and crowded by reeds (*Juncus rigidus* and *Phragmites australis*) with tamarix trees (Figure 3C, D). Here, the common and abundant macro invertebrate groups belong to gastropods *Physa acuta tubfix, Simuliidae*, *Culicidae* (Mosquitoes) and isopoda.

Site 9, showed slow moving to standing freshwater with dense emergent reeds and remarkably no algal mates (Figure 3E). In this site different macroinvertebrate assemblages were observed that start appearing together with mayfly *Baetis monnerati*, Dragonfly (Odonata), and *melanopsis* gastropods. Frogs and fish are also present.

Site 10 along the Wadi has moderate freshwater running over a stony substrates and algae assemblages, where *melanopsis* species are strongly represented associated with of mayfly species including *Baetis monnerati* and *Caenis macrura* (Figure 3F).

In Site 11, fast running water over a stony ground with algae covering the edges of the stream (Figure 3G). This site was crowded by *melanopsis* and, for the first time along Wadi Mujib, *theodoxus* species were found (Figure 3H). Aquatic mayfly *Baetis monnerati* and *Caenis antoniae* were observed too at the same site.

Finally, before the entrance of Wadi Mujib into the Dead Sea (Site 12), the river is fast flowing over a stony substrate. Occurances of *Melanopsis* are reduced and rarely found while *theodoxus* disappeared, *Baetis monnerati* mayfly declined, and aquatic *Simuliidae* and fish were noted in this site.

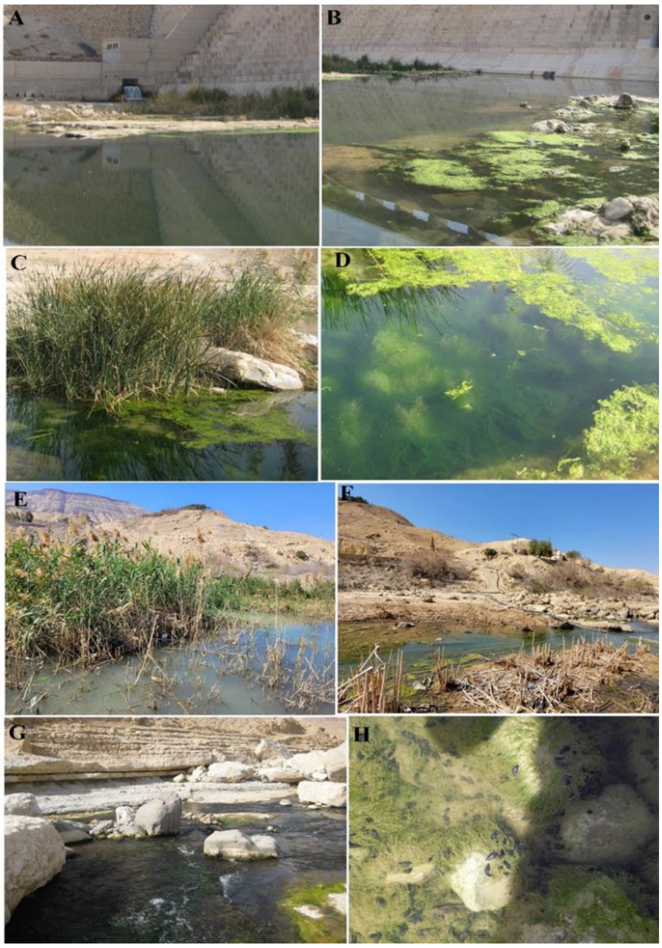

Figure 3. Field photographs of the study area in Wadi Mujib. (A) Site 6 at the outlet Wadi Mujib Dam. (B) Site 7 is covered by algal mats. (C) Site 8 consists of a stagnant, turbid water and surrounded by common reeds. (D) Different species of microorganisms were observed in Site 8. (E) Site 9 with absences of algae mates. (F) Fresh water stream (Site 10). (G) Fast running water over a stony ground with algae covering the edges of the stream. (H) The occurrences of *melanopsis* and *theodoxus* in Site 11

5. DISCUSSION

The presence or absence of aquatic organisms can provide important clues about the environmental health of the aquatic system in Jordan [14]. In the present investigation, a number of species of aquatic macroinvertebrates were found in the study area and can be utilized in characterizing the quality of its water. A summary of our own collections of macroinvertebrate groups in the selected sites with their classification shown in Table 3.

The transition from clean water to polluted water within the course of the same wadi is clearly shown on the example of Wadi Shueib. The dense occurrences of two species of gastropods including *theodoxus* and *melanopsis* in Site 1 indicate clean and clear water conditions. This water status is proven by the chemical analysis showing low salinity, and low pollution parameters such as NO_3, PO_4 and BOD5. Previous studies have suggested that the gastropods can be used effectively as biological indicators for water quality [18, 19]. In addition, local studies on bioindicators in Jordanian aquatic bodies, *theodoxus* and *melanopsis* were found intolerant to pollution [14]. Amphipoda inhabits only clean and clear water, which is not found in sites affected by pollution.

Literatures on the use of Amphipoda species as valuable biological indicators for environmental conditions concluded that generally this crustacean is intolerant to sewage pollution, but in the case of Jordan the use of this invertebrate group is limited because little is known about their taxonomy down to species level, which is important to identify the degree of sensitivity of each species [20, 21]. Further down along Wadi Shueib, the presence of *melanopsis* declines, first in site 2 and to disappear with pollution increase along this Wadi as observed in sites 3 and 4, with increasing NO_3, COD and BOD concentrations. *Theodoxus* gastropods have totally disappeared from the wadi, which shows their higher sensitivity to pollution than *melanopsis* species.

Moreover, in Station 3 with about 400 m distance from the Site 2 down in Wadi Shuieb, a creek with household sewage added from the surrounded houses are studied. Alteration of diversity and composition of invertebrate community were notably occurred in gastropod fauna by disappearing of the *theodoxus* and *melanopsis* and replacing by abundant of *Physa acuta* fauna. Leeches and Simuliidae larvae are present on stone. Regarding the bioindicator value of *physa acuta*, it is tolerant to sewage pollution and found live in sewage treatment plants [22-24].

Regarding Ephemeroptera insects, only two species of aquatic mayfly are documented *Baetis monnerati* (Sites 1, 2, 3) and *Caenis macrura* (Site 3). *Baetis monnerati* are the most common and most abundant species of aquatic mayfly throughout the country [17]. They were found in the majority of this study sites. No significant correlations were found between the presence or absence of *Baetis monnerati* and *Caenis macrura* and water quality, because we observed them in a wide range of habitats from very clean water to polluted water, but they can't survive in strongly polluted water as in site 4 where the creek becomes polluted by wastewater discharges from the sewage treatment plant of Salt. Oxygen degradation, high amount of organic sludge and higher concentrations of pollution parameters characterize the water of the wadi at this site. The elevated phosphorus concentration is reflected in the high growth and reproduction of sewage worm or *tubifex* worm (tubificids).

The presence of sewage worm or sludge worms is a certain indication that the water quality has degraded by sewage or other oxygen-consuming organic matter. Tubificid worms can tolerate water almost totally lacking in oxygen. The wide occurrence of *tubifex* has been shown to be a useful tool in the assessment of organic water pollution in Jordan. This and other studies' results have shown the positive correlations of the occurrence and abundance of macroinvertebrate assemblages consisting of *Physa acuta*, *tubfix* worms, aquatic Simuliidae and sewage pollution. They heavily occur close to waste water treatment plants outlets. They were also found in the eutrophic water in Wadi Mujib as showed in Site 7 and 8. The absence of this assemblage in site 6 could be due to the oxygenated swift water current because they preferred to live in slow-flowing or standing water habitats with lower oxygen concentration.

The opposite case of improving water quality from polluted to clean water was observed along the course of Wadi Mujib. The head water of Wadi Mujib is affected by rich autotrophic production of organic material. The presence of nutrient tolerant species (e.g., chrinomidea, tubifex and *Physa acuta* gastropods) associated with organic load (high nutrient concentrations, high algae growth and low dissolved oxygen) in Wadi Mujib Dam Lake are noted (Sites 7 and 8).

At a short distance downstream the dam, these pollution-tolerant organisms are replaced firstly by the pollution-intolerant organisms of *melanopsis* gastropods represented by two species; *Baetis monnerati* and *Caenis macrura* found in site 10 and downstream of it Their appearance is associated with the increase in oxygen supply resulting in a rich community of *melanopsis* and, notably appearing, theodoxus gastropods with aquatic mayfly species including *Baetis monnerati* and *Caenis antoniae*. *Caenis antoniae* indicate very good water quality which is found together with the sensitive pollution invertebrate species in Site 11. These species usually inhabit moderate to swift running water associated with higher oxygen concentrations and indicate clean and clear fresh water systems.

In general, the river has been cleaned by self-purification process, but with so many nutrients that the mud at the ground has turned black in places due to much anaerobic production. Downstream near the Dead Sea only *melanopsis*, *Baetis monnerati* and blackfly are observed, while the other invertebrates disappeared as a result of pollution originating from household sewage, animal husbandry and agrochemicals.

Degradation in water quality along Wadi Shueib is also mostly the result of human settlements in the catchment, wastewater treatment outflow, untreated household wastewater mixing with the stream water, and solid wastes disposal resulting from increasing urbanization and population growth, which have negative impact on diversity, composition of invertebrate community and accordingly on the water health, water quality and ecological conditions [25].

6. CONCLUSIONS

Macroinvertebrate assemblages were studied as indicators of water quality along Wadi Shueib and Wadi Mujib courses. These water courses show major quality changes along their short courses of around 25 km. They show several environmental conditions of freshwater system of stagnant to running water and clean to polluted water, especially organically polluted water. The results obtained from the sampled materials of macro invertebrates' assemblages of freshwater bodies fauna in accordance with data obtained from physico-chemical analyses of the water indicate a direct relation between the water quality and the composition of the surviving organisms' communities in the fresh water systems which can be well demonstrated on the examples of Wadi Shueib and Wadi Mujib.

Well-represented are *theodoxus*, *melanopsis*, turbellaria and amphipoda fauna associated with good water quality of low salinity and low concentrations of pollution parameters such as BOD5, COD, PO_4 and NO_3. The organic species are considered a sensitive group to pollution.

Abundances of the specific macroinvertebrate groups such as *Physa acuta*, tubfix worms, Isopoda and Simuliidae (black fly) are present close to sewage polluted water outlets indicating poor water quality. The use of other taxonomic groups of aquatic invertebrates (e.g., ostracods, beetles, caddisfly, diptera larvae) as biological indicators for water bodies in Jordan are limited, because of their survival in a wide range of environments with different species and their use on order level is not conclusive enough for identifying water quality.

The studied aquatic biota can be used effectively as bioindicators of water health especially, in a semi- arid country, such as Jordan with unpredictable seasonal rainfall, subject to the great scarcity of water and an ever-increasing demand from the rising human population, associated with great environmental problems. Agrochemicals such as those used in gardening and in agriculture can pollute water and sewage water entering water courses and cause their pollution as has been shown on the examples of Wadi Shueib and Wadi Mujib water courses.

Generally, human activities accompanied by population growth, increasing human settlements, use of agrochemicals, industrialization and production of wastes represent stressor factors with negative effects on the environment. In the semi-arid climate zone of the Globe, the scarcity of water resources does not allow for dilution of pollution and hence pollution threatens the biodiversity and cause declines and alterations in the invertebrate's composition in the scarce and limited quantities of water sources, as shown on the examples of Wadi Shueib and Wadi Mujib, discussed in this article. Therefore, it is of utmost importance to protect the water resources proactively from being polluted in order to keep aquatic systems healthy and before the need arises to deal with the entire water and environmental systems after being polluted.

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