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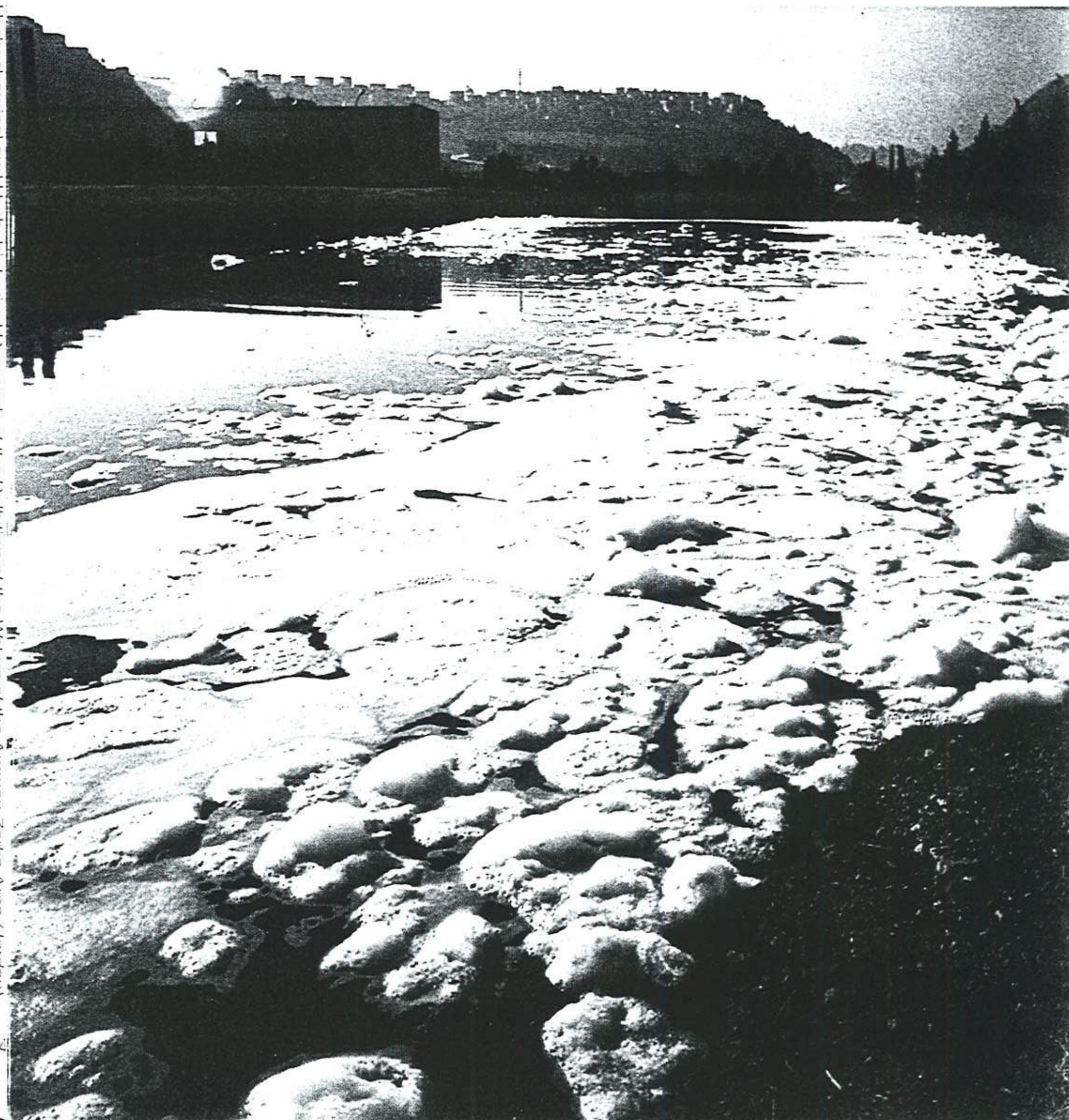
Hydrochemical and Hydrobiological Research of the Pollution of the Waters of the Amman Zerka Area (Jordan)

Klaus Bandel and Elias Salameh



Hydrochemical and Hydrobiological Research of the Pollution of the Waters of the Amman Zerka Area (Jordan)

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Abstract

The pollution of the Zerka River, the Wadi Shita, the Wadi Sir, and the Seel-Hisban has to a large extent reached a considerable and intolerable degree. 10 grades of pollution are differenciated on the basis of the composition of the aquatic macrofauna. Although the chemical and biological subdivisions of the degree of pollution are not always consistent with each other, they are closely correlated to each other. Both clearly indicate the human influence on the water system of the area studied. Recommendations are made for improvement and protection of the water quality.

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Introduction

The Amman-Zerka area is a semi-arid region receiving precipitation mainly from November to March. During the remainder of the year water precipitates only in the form of dew. The water resources in the area of this study are therefore limited and very valuable. Their development is greatly influenced by urban, industrial, and agricultural activities. Of the studies which have been carried out up to the present (see references), none has undertaken a detailed survey of the surface waters of the region with regard to their hydrobiological and hydrochemical properties. Owing to the rapid increase of industrialisation and rise of the population, particularly in this area, it is of imminent importance to establish a basic knowledge of the present effects of human activities on the water system. This should constitute the first step towards future control of the development of the water quality in the springs, creeks, ponds and rivers of the region.

The quality of the water is determined by its chemistry which is indicated by its faunal and floral content. This fact forms the basis of the present study which places its main emphasis on the gross chemistry of the water and the identification of the aquatic macrofauna. The field work, which constitutes a major part of this study, was carried out entirely by the authors themselves and not by untrained personel. The analytical work and the determination of the fauna was undertaken in the Department of Geology and Mineralogy of the University of Jordan.

Hydrological and Geological Data

The area studied lies in central Jordan and consists of a mountainous region ranging in elevation from sea level to 1100 metres above sea level. In the western parts of this area, close to the Jordan valley, the morphology is rugged and slopes are steep. In the east the landscape becomes more and more gentle and slopes are less steep.

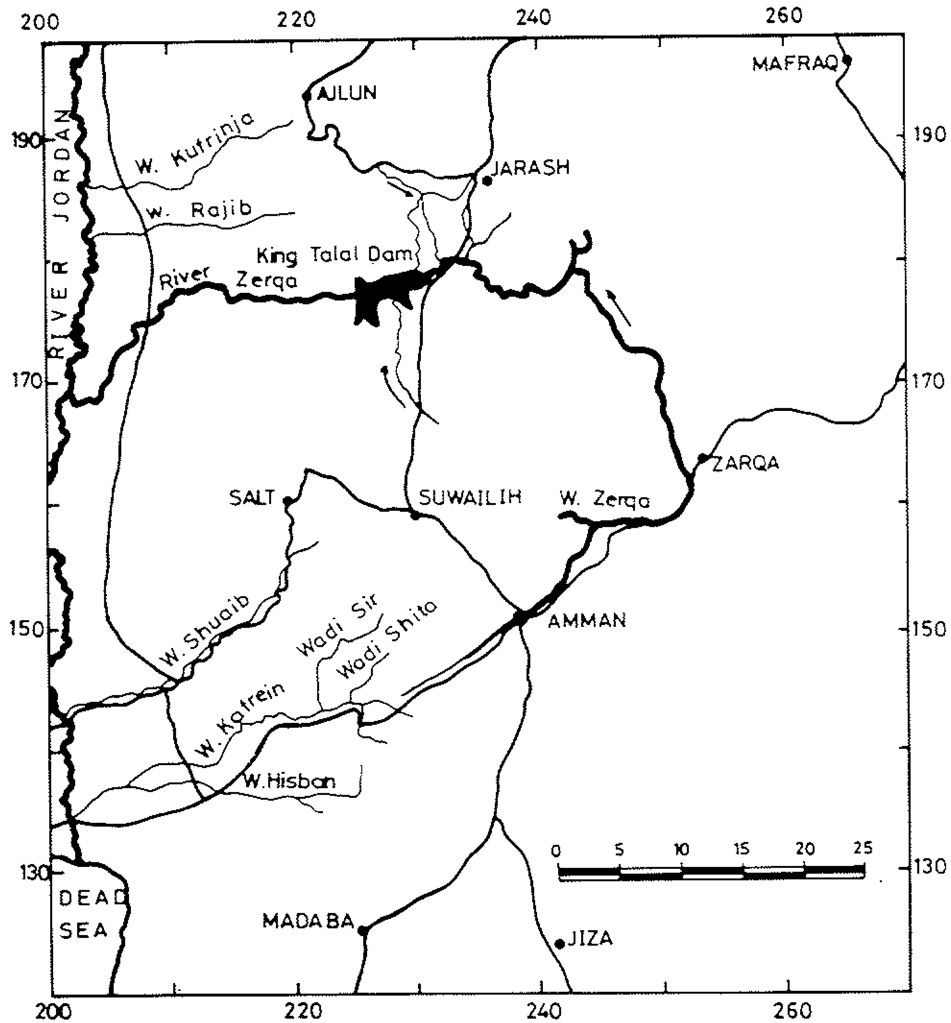


Figure 1: Map of the studied area indicating the water courses and major towns.

The area is drained mainly by the Zerka river. Only the western highlands drain directly to the Jordan valley via wadis with high gradient slopes. The Zerka river has its origin in Amman and flows towards the northeast passing the towns of Ruseifa and Zerka. Downstream of Zerka it turns into a northerly direction until reaching Sukhna where the wadi Duleil joins the valley. From here onward the valley takes a northwesterly course for about 20 km. Finally the river twists to the west until reaching the King Talal Dam Reservoir. Downstream of the dam, the wadi runs westerly until it joins the Jordan valley (fig. 1).
Geologically the area is a part of the uplifted East Jordanian Block. The rock units cut by the wadis consist mainly of Cretaceous sediments. These are, in their upper part, composed of limestones, marls, dolomites and cherts, while in their lower part they consist of sandstones and siltstones. The surface water either flows on exposed Cretaceous rocks or on gravel beds. The gravel is composed mainly of limestone and chert and to a lesser degree also of basalt. The courses of the wadis are largely determined by tectonic lines.

The utilized aquifers in the area of Upper Cretaceous age and are known as the "Upper aquifer" (locally called B1-2, A7) which is an unconfined limestone aquifer and the "Lower aquifer" (A4) which is a confined highly fractured, crystalline, dolomitic limestone. Both aquifers are separated by the so called A5-6 aquiclude. The waters in both aquifers are connected via faults.

In addition to these two Upper Cretaceous aquifers, the wadi fill deposits, which consist mainly of sandy gravels, build up a highly productive aquifer.

Hydrochemistry (General)

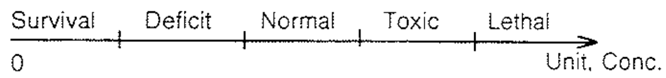
The chemical composition of a water is derived from many sources such as gases from the atmosphere, weathering and erosion of rocks and soils and activities of man.

The chemical constituents of a water are attributed to the influences of:

a) Geochemistry of the percolated rock units
b) Natural activities of man
c) Industrialisation and Urbanisation.

The use of a water for drinking, for industrial purposes or for irrigation is highly dependent upons its chemical composition.

The World Health Organization (WHO) has set standards regarding the uses of water with different chemical compositions. These standards are the results of long scientific research concerned with the hazards which may result from deterioration in the water quality. Such deterioration is expressed in the rapid increase of dissolved or suspended substances, which in small concentrations may be essential for the growth or the completion of the life cycle of an organism. The same essential substance, at higher concentrations, may become toxic, the essentiality, deficiency and toxicity of a substance can be represented on a continuous line:



Many substances dissolved in the water are essential for the development, metabolism and health of organisms. The intake of these substances in concentrations exceeding the WHO-standards may cause acute or chronic hazards, depending upon the rate of intake.

The importance of these standards will only become clear after a long period of intake. For example the heavy metals, which are not degradable in natural processes, are enriched in the organic and mineral substances and stored for a long time. They reach the human organism through the food chain, become enriched within the body and may cause chronic or acute hazards.

The following brief review presents the prevalent ions in water, their sources in the study area, the WHO-limits for the use as drinking water and the hazards resulting from the intake of ion concentrations exceeding the recommended WHO-standard limits.

Ion	WHO-Standards 1975 (ppm) 1	2	Sources in the Study area	Hazards resulting from concentrations exceeding WHO-Standards
Ca^{++}	75	200	Sedimentary rocks	Water hardness, precipitation in pipes and treatment plants, higher use of detergents
Mg^{++}	150	–	Sedimentary rocks	Water hardness, precipitation in pipes and treatment plants, higher use of detergents
Na^{+}, K^{+}	Salinity determinant		Sedimentary rocks, wastes of man, livestock	Salty water, taste problems
Cl^{-}	200	600	Sedimentary rocks,. wastes of man, livestock	Salty waters, taste problems
NO_3^{-}	45	–	Decay of plants, man activities, wastes of man, and livestock, leaching of fertilized soils, industrialisation greatly increases the NO_3^{-} content	Reduces the haemoglobin in infants
SO_4^{--}	200	400	Sedimentary rocks, industrialisation	Associated with water hardness
HCO_3^{-}	–	–	Atmosphere, soil-organisms	Associated with water hardness
Fe^{++}	0.1	1.0	Industry wastes, industrialisation, sedimentary rocks	Objectionable taste 0.3 ppm, helps in the growth of bacteria and damages the pipes

Ion	WHO-Standards 1975 (ppm) 1	2	Sources in the Study area	Hazards resulting from concentrations exceeding WHO-Standards
Mn^{++}	0.05	0.5	Industrial wastes, sedimentary rocks	Objectionable taste 0.15 ppm, helps in the growth of bacteria and damages the pipelines
Cu^{+}	0.05	1.5	Dumps or mill tailings, industrialisation	Objectionable taste 0.15 ppm, also in small concentrations it makes the biological degradation of treatment plants difficult for it is toxic to most organisms
Cd^{+}	0.01	–	Phosphate deposits, usually added industrially to the water (plating metal)	Itai-Itai illness, fragile bones, skeleton disorder, renal damage

Analytical Methods

pH	pH-Paper 0.1 range
Ca^{++},Mg^{++}	Titration with titriplex III Ca-Indicator 1–3 naphthalein carbonic acid Mg-Indicator eriochrom black
Na^{+}, K^{+}	Atomic absorption
Cl^{-}	Titration with $HgNO_3$, Indicator diphenol Carbazon
NO_3^{-}	Spectral photometer 206 mm Novone 1964
SO_4^{--}	Nephelometric 491 mm
HCO_3^{-}	Titration with 0.1 HCl
Fe^{++}, Mn^{++}, Cd^{++}, Cu^{++}	Atomic absorption after concentration

In figure 2 the degree of pollution for different constituents of the analysed water is shown, the adopted degrees of pollution in this classification are based upon their deviation from spring waters that are recharged and discharged in unpopulated or sparsely populated catchment areas.

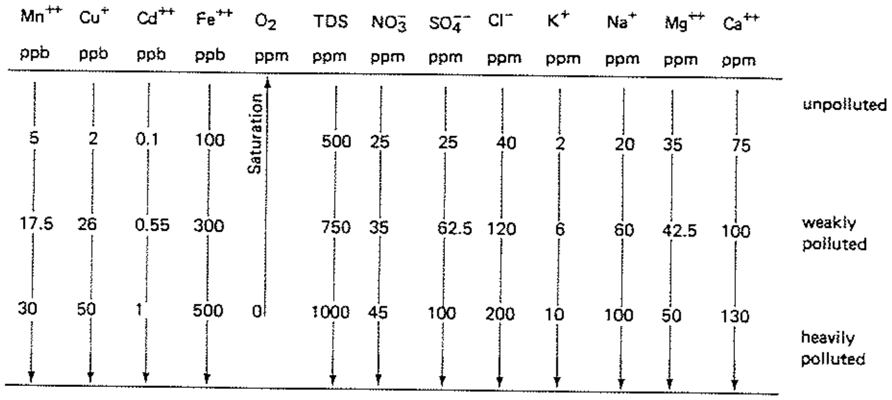


Figure 2: Diagram indicating pollution in relation to the different chemical constituents of the water in the studied area.

The influence of human population is expressed in an increase of the total dissolved solids (TDS) and of the different chemical constituents of the water. The industrial pollution is expressed in the additional increase of heavy metals.

Table I representing the chemical analysis of this study shows an increased amount of Ca^-, NO_3^-, SO_4^{--}, Na^+ which in most samples can be attributed directly to the influence of the human population.

Table I

Location	Ca^{++} ppm	Mg^{++} ppm	Na^+ ppm	K^+ ppm	Cl^- ppm	SO_4^{--} ppm	NO_3^- ppm	HCO_3^- ppm	TDS ppm	Fe^{++} ppb	Mn^{++} ppb	Cu^{++} ppb	Cd^{++} ppb	Grade
1	84	16.8	18.5	0.5	44	36.3	32.0	240	472	107	0.5	5.3	1	3
3	84	15.6	9.7	0.5	32	23.8	24.2	255	4448	30	0	1.8	1.3	1
4	58	24.3	12.56	2.2	32	13.4	21.0	244	407.5	104	4	1.5	0.5	2
6	82	16.3	16.8	0.5	36	24	16.8	265	457	28	0.2	1.6	0.4	1
10	76	28	19.2	1.1	40	53.3	44.5	244	506.1	128	1	2.0	0.4	5
11	72	37.3	12.5	0.6	32	34.5	32.5	300	521.4	35	0	2.3	0.5	3
12	72	29.2	13.5	0.8	36	36.3	33.8	270	491.6	61	1.1	2.6	0.1	4
14	76	31.5	18.00	1.4	48	56	44.7	240	515.6	129	0.6	2.2	0.2	7
16	62.2	30.0	23.1	2.2	60	18.3	37.0	240	472.8	621	16	2.5	0.2	6
20	112.0	30.0	148.7	4.1	240	20.7	100	342	997.5	4.2	1.2	9	0.4	10
29	114	20	165	25.3	336	67.1	35.5	317	1110	8	0.2	7	0.8	10
32	96	42.8	110.8	4.71	212	85.4	24.6	240	816.3	33	2.0	5	0.2	10
35	92	29	133	5.5	224	134.2	18.5	220	856.2	643	29	5	1	10
37	72	39	38.4	2.17	146	52.5	24.2	171	545.3	–	–	6	0.6	7
40	56	213	207.6	64.6	588	353.7	0	378	1861	22.5	1.2	6	0.6	–
44	136.8	65.7	118.7	14.5	310	146.4	8.8	342	1143	68	1.8	2.7	0.5	10
45	70	22.3	14.22	1.44	36	57	16.8	220	437.8	272	5	2.9	0.5	3
49	48	19.5	16.7	1.57	40	36.3	18.5	164	344.6	8.3	0.2	4	0.7	3
51	84	51.1	106.5	13.6	220	112.2	100	195	882.4	3.3	6.2	3.3	0.1	10

The increase observed in the content of the heavy metals is due to the current increase in industrialisation in the catchment area. This can be especially well demonstrated along the course of the Zerka River.

Aquatic Fauna (General)

In the framework of this study only the larger members of the aquatic fauna are taken into consideration. Animals of microscopic size have not been collected though they are of importance within the food chain. Similarly the flora of the discussed streams and ponds is described only in very general terms, though water plants are of fundamental importance to the animal life, because they produce food and oxygen and react with the water when they photosynthethize carbohydrates. In addition water plants need nitrates, phosphates, sulphates, carbonates, silicates and trace elements, which they extract mainly from the water. Plants also provide a good holdfast and hiding place for many species of fauna. They are also the base of the food chain in each ecosystem.

Thus we restricted our study to such animals that are visible with the naked eye on a sieve with 0.5 mm mesh. For their determination a microscope is usually required. Most encountered fauna, except the molluscs, were not determined to the species level but to higher taxionomic orders only. All the animals and animal groups discussed here are represented in a drawing of one example collected during our research, so that the interested non-specialist may determine the aquatic fauna to a degree that will allow him to check the results which are presented in this study, and to carry out similar studies for other areas.

Our study therefore does not present detailed work on the faunal assemblage of the springs, streams and ponds of the area under discussion but presents a general picture of the life present in the different environments and shows the reaction of the fauna to natural and unnatural influences on its ecosystem. The change in the community of animals and plants functioning in a non-living environment can clearly be traced with the scale of determination adopted by us. If, for example, one turns a stone in the creek just below the village of Wadi Shita one sees numerous animals attached to it, doing the same thing in a stream of similar size in the neighbouring valley just below Wadi Sir, no animals will be observed. In the latter case the fauna react very strongly to environmental factors that consist here of the oil pollution caused by the water pumping station at the upstream end of the Wadi Sir.

The environment of organisms living in fresh water depends on a number of factors such as light, temperature, chemical composition of the water and the amount of oxygen available in it. The most important adaptations of aquatic animals are concerned with the way in which they breathe, move and obtain their food. Each species has its own oxygen requirements and therefore reacts to changes in this one parameter in a specific way. The distribution of aquatic animals in small streams, an environment that constitutes most of the studied localities, is largely dependent upon the nature of the bottom of the stream bed. Stream bottoms supporting growths of aquatic plants are more productive than streams with bottoms devoid of vegetation. Animals of swift streams need specific modes to cling to the rocky bottom or have to show a great ability in their swimming mode. Vegetation due to the assimilation processes enriches the water with the oxygen needed by all animal life. A shortage of oxygen can prevail in water that contains a large amount of decaying animal and plant matter, as the process

of decomposition uses the oxygen present. This may be the case in pools of streams mainly near their end course before they disappear in their own gravel bed during much of the season. The streams discussed here, in general, are so swift that by the constant churning action of the current they are almost permanently saturated with oxygen.

The fauna encountered showed three types of fresh water worms. The Turbellaria are flat, long oval worms usually found on the underside of stones or on other hard substrates. Here the worms, up to 1 cm long, crawl rapidly with their ciliated foot. Flat worms are scavengers utilizing all kinds of organic material for food. They may also hunt for small sized animal prey or may feed on algae. A number of different species of Turbellaria are present in clean streams just below springs as well as in oxygen rich, somewhat polluted water.

The Oligochaeta (fig. 3) are segmented worms which have a pair of bristles on each segment live within the sediment as well as among water plants. Some species dwelling in muddy or sandy bottom substrate construct tubes of mucus-agglutinated sediment particles. They live head downwards in these tubes and wave the posterior portion of their bodies ceaselessly to extract oxygen from a wide area of water. In irrigation pits and canals these worms may form mass populations. The food of the fresh water Oligochaeta consists of products of decomposition of organic materials and of small animals and plants. A number of different species occur in clean water of springs as well as water quite enriched with natural pollutants but still under aerobic conditions.

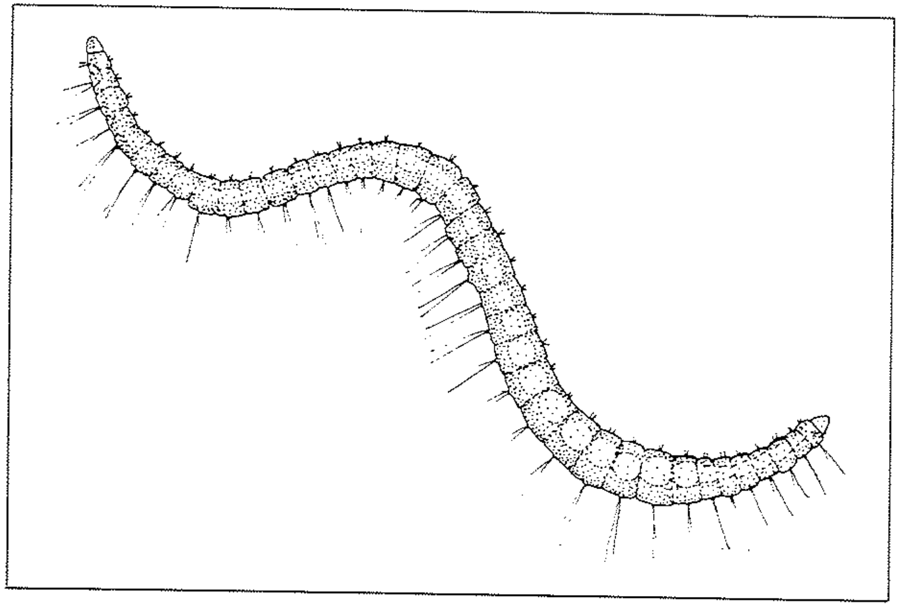


Figure 3: Oligochaete worm of approx. 5 mm length.

The Hirudinea or leeches (fig. 4) are elongated worms with flattened bodies without bristles, with fine rings, and with a sucker at either end. They are usually considerably larger than the Turbellaria and Oligochaeta and thus more conspicuous. The front sucker is also the mouth opening and is used for holding onto the prey and sucking in food which consists of animals. Leeches live among stones in clean to weakly polluted, oxygen-rich water. The cupola-shaped, transparent egg capsule is attached to the underside of stones. Egg capsules give evidence of the presence of adult individuals. If the latter are no longer found where capsules are present the water quality must have deteriorated not long before. This can for example be observed well in the Zerka river at the end of spring-time, when water deteriorates in quality rapidly as the dry season progresses.

All aquatic worms mentioned here breathe oxygen through much of their body surface. An oxygen rich water, therefore, is required as the living environment.

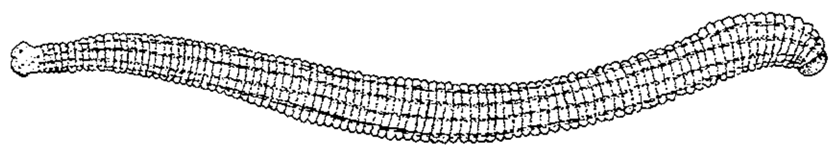


Figure 4: Leech (Hirudinea) of approx. 15 mm length.

Crustacea are present in the streams and ponds with some very characteristic forms. The Amphipoda (fig. 5) of the Gammaridae family are yellowish-brown fresh water shrimp with a bilaterally flattened body. This long body is curled in a bow, has 2 pairs of long antennae and 2 feelers on the under lip. Each of the 7 free thoracic segments shows a pair of legs. The 6 abdominal segments carry the three frontal pairs of swimming feet. These feet are in continuous movement and thus keep the gills supplied with fresh water. The three posterior segments have jumping legs. The food of the fresh water shrimps mainly consists of plant material, but also of decaying plants and animals. The amphipod crustaceans are characteristic of spring water, and only very clean creeks and streams.

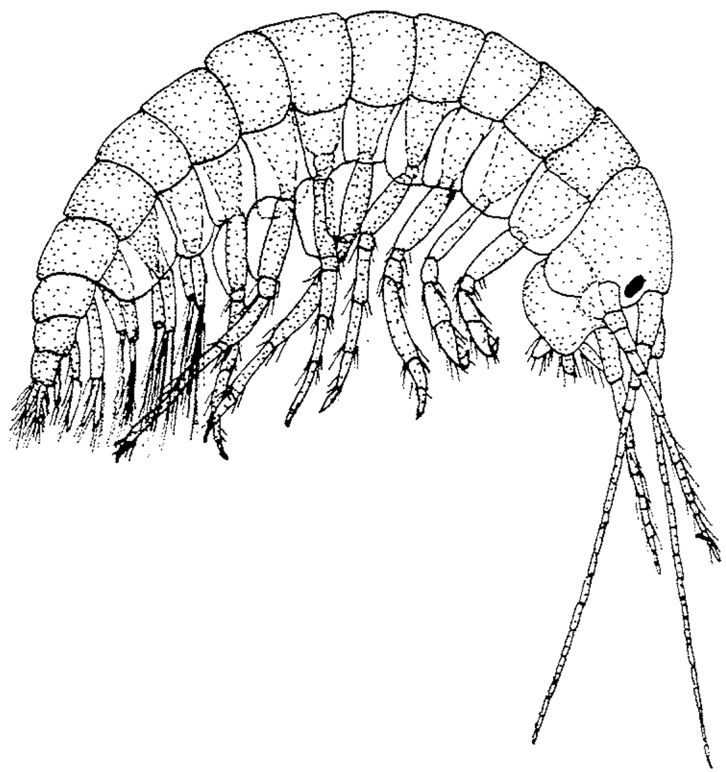


Figure 5: Fresh water shrimp (Amphipoda) of approx. 6 mm length.

The Isopoda with members of the Asellidae family (fig. 6) prefer water with some natural pollution that is stagnant or slow moving. Often streams rich in Amphipoda in their upper portion become rich in Isopoda further down or when channelled into irrigation canals. The long body of the fresh water isopod is of uniform width throughout. There is one pair of short and one pair of long antennae on the head. To each of the 7 thoracic segments a pair of walking limbs is attached. The abdominal rings are fused into one large plate with two forked abdominal legs. Isopods feed on decaying organic particles mainly of plant origin often derived from the faeces of large herbivores as for example that of donkeys. The gas exchange is carried out by the gills within the water only. While natural pollution is tolerated and even constitutes the preferred habitat of the fesh water isopod under aerobic conditions, chemical pollution results in a complete absence of crustaceans from the stream.

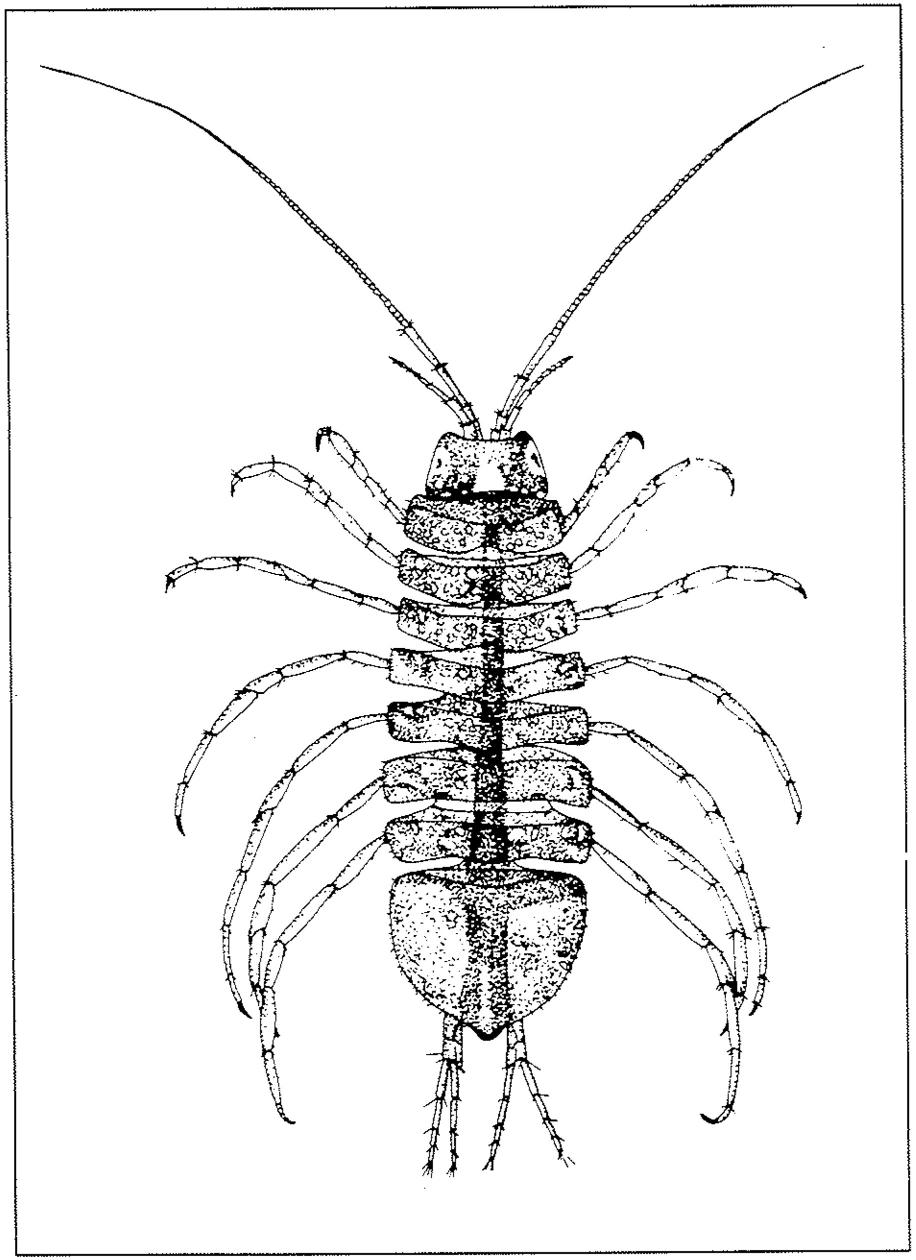


Figure 6: Isopod of approx. 8 mm length.

The Ostracoda (fig. 7) exchange gases through their skin. They have a hard exoskeleton consisting of two valves which are hinged to each other at one place only, similar to the two valves of a lamellibranch shell. The ostracod limbs are modified in various ways to create a current of water which flows over the soft body parts. Fresh water ostracods feed on decaying plant and animal material and prefer slow moving and stagnant water, an environment similar to that prefered by the isopods. Ostracods may often be found together with mass populations of reddish oligochaetes. The ostracod fauna of the slow moving streams and irrigation ditches is usually composed of several species.

Copepods and Cladocera, both small crustaceans, prefer standing water in which they move about with the aid of their long antennae. They acquire oxygen from the water with the help of gills and feed on minute planktonic orgnisms as well as organic material drifting our suspended in the water. Members of both crustacean groups produce eggs that can well withstand desiccation. They can thus reappear rapidly in dried out pools after these are refilled with water. Pollution is tolerated to quite some degree.

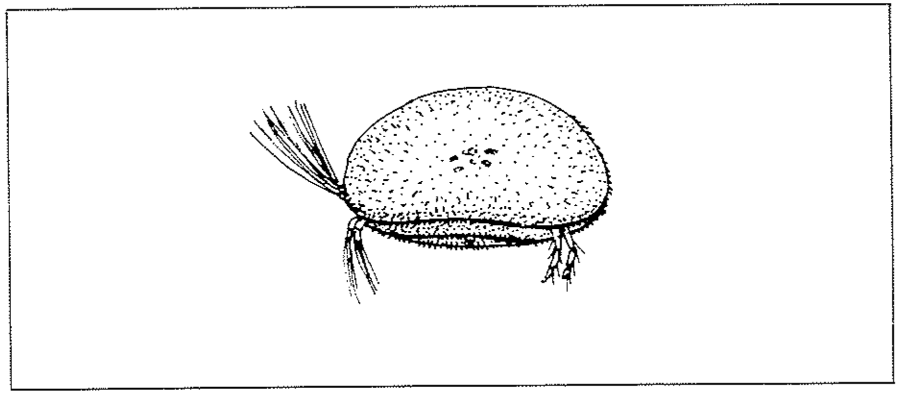


Figure 7: Ostracod of approx. 1.5 mm length.

Large brachyuran crabs (fig. 8) are present in almost all the aquatic environments visited during this study. The large, solid, back plate covers and protects most of the body. Two large, strong claws are present and 4 pairs of walking legs enable the crab to move at quite some speed in all directions. The rudimentary abdomen is wrapped under the cephalo-thorax. The crab constructs deep tunnel galleries into the stream banks just above the water surface as living burrows. The way of life of the crabs is amphibious. Breathing is carried out with gill booklets. The crabs can hold air bubbles between single leafs of the gill booklet and provided with oxygen in this manner, they can penetrate water which is poor in oxygen content. The brachyuran crabs are very resistant to pollution. Their food consists of plants of all types and different animal materials either fresh or in decay.

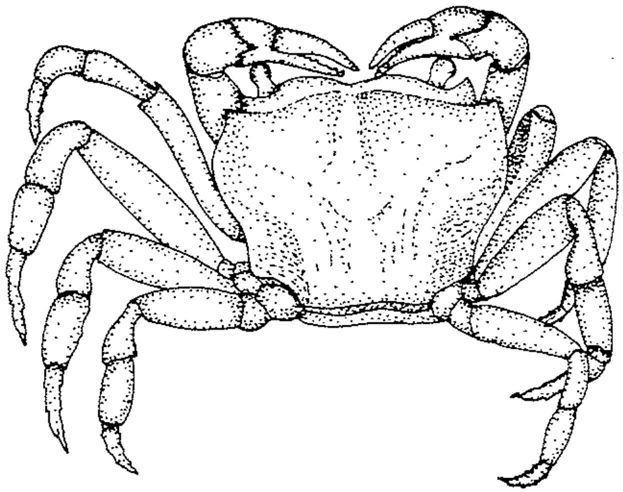


Figure 8: Brachyuran crab of approx. 50 mm width.

The spiders (Arachnoidea) are represented by the aquatic mites (Hydracarina, fig. 9) in clean to somewhat polluted water. The roundish oval body is unsegmented and 4 pairs

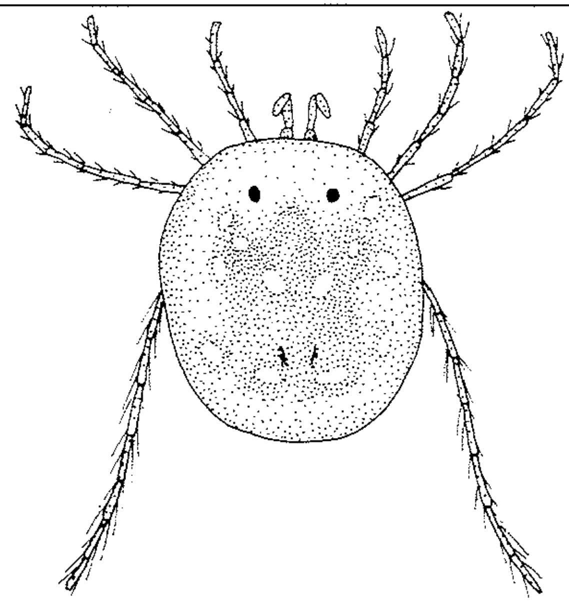


Figure 9: Aquatic mite (Hydracarina) of approx. 1.5 mm length.

of legs are joined to it. The mites, present in a number of different species, are animals of prey which hunt ostracodes, small insect larvae and other small aquatic animals. The oxygen for respiration is taken from the water itself.

The insects form the large bulk of aquatic creatures encountered in the ponds and streams of Jordan. Most insects are aquatic only as larvae. They inhabit every kind of fresh water environment.

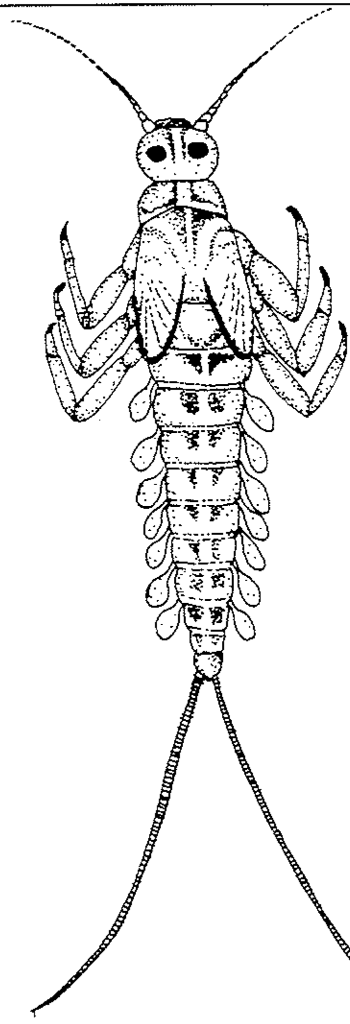


Figure 10: May-fly nymph (Ephemeroptera) of approx. 8 mm length.

The mayfly nymphs (Ephemeroptera, fig. 10) are most commonly found under rocks in flowing streams. They have a long body and head with 2 long antennae and 2 large eyes. The three pairs of legs end in claws. The 9 abdominal rings on each side are characterised by leaf-like or feather-like tracheal gills. At the end of the body are 2 or 3 long tails. The mayfly nymph may live for 1–4 years in the water until the adult develops which may live only for a very short time and only serves for reproduction and spreading. Many different species of mayflies exist and more environmental differentiation would probably be possible if they were studied in detail. Their food consists of plants.

The dragonfly and damselfly nymphs (Odonata, fig. 11) are large insect larvae which, like the Ephemeroptera, breathe by means of the gills although they have retained the air tubes of the land insects. These gills of the damselfly nymphs (Zygoptera) are in the form of three leaf-like structures at the end of the abdomen. The nymphs swim by body undulations, the gill functioning like the tail of a fish. They feed on various species of small aquatic animals which they catch with an adapted lower lip. Before the imago hatches from the nymph the latter crawls out of the water attaching itself solidly to a rock or a plant just above the surface of the water. The empty hulls of hatched larval exuviae remain at their place of attachment for some time and give evidence of the former occurrence of Odonata nymphs in the stream even after water conditions have deteriorated. This can be observed in the Zerka river below the highway bridge Amman Jerash, where the water improves in quality during the wet season making the growth of damselfly nymphs possible, whereas during the spring the water quality deteriorates and no more nymphs of the latter insect order can survive.

Caddisfly larvae (Trichoptera, fig. 12) are found only in clean streams rich in oxygen. They spin a funnel-shaped tube attached to the sides and the lower faces of a rock (fig. 13). This protective shelter, held together by silk webs, is rarely left by the larvae and is composed of agglutinated small pebbles and plant fragments. The opening of the tube faces upstream and one side of the aperture is extended. Here the wall is composed of a silk net thus forming a device like a fishing net. Floating matter of both animal and plant origin is caught in this net, seized by the larvae, and is eaten. The net-building caddisflies (Hydropsychidae) are confined to running water and will die within hours if placed into standing water. The larva is like a caterpillar with a well developed head and thoracic legs and a pair of hooklike appendages at the end of the abdomen. The abdominal segments bear filamentous gills. To pupate the larva forms an oval cocoon composed of agglutinated material like its living tube and attaches it to the lower side of rocks (fig. 14).

The Hemiptera (aquatic bugs, fig. 15) have a number of different representatives. These aquatic insects, called water boatmen and backswimmers, have elongated and oarlike hind legs. As do all aquatic bugs, they lack gills and obtain air from the surface of the water. They usually carry a bubble of air underwater, either on the surface of the body or under the wings. They swim rapidly but often cling to vegetation for long periods or rest just below the surface of the water. The aquatic bugs feed on other insects or on algae and minute aquatic organisms depending upon the species in question. They

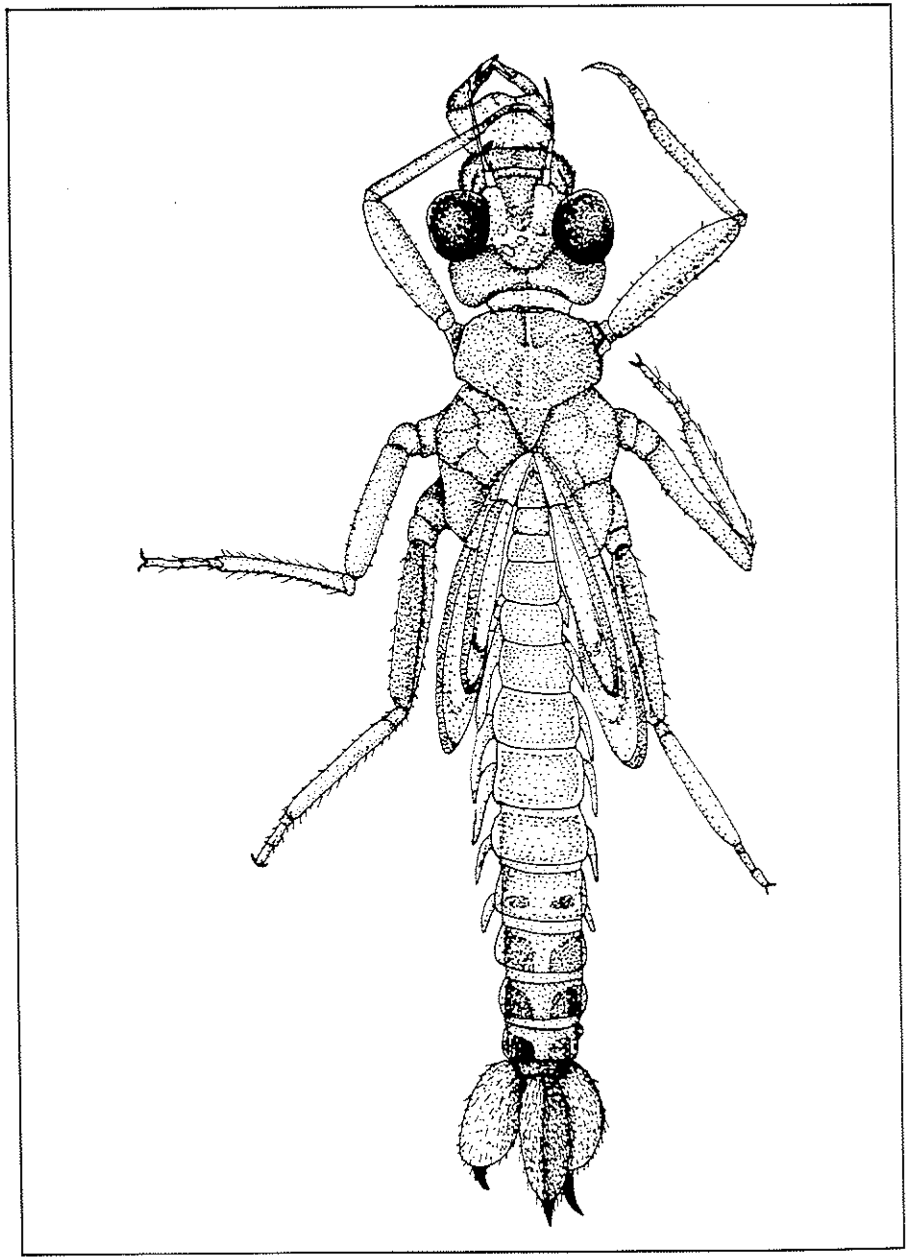


Figure 11: Damsel-fly nymph (Odonata) of approx. 35 mm length.

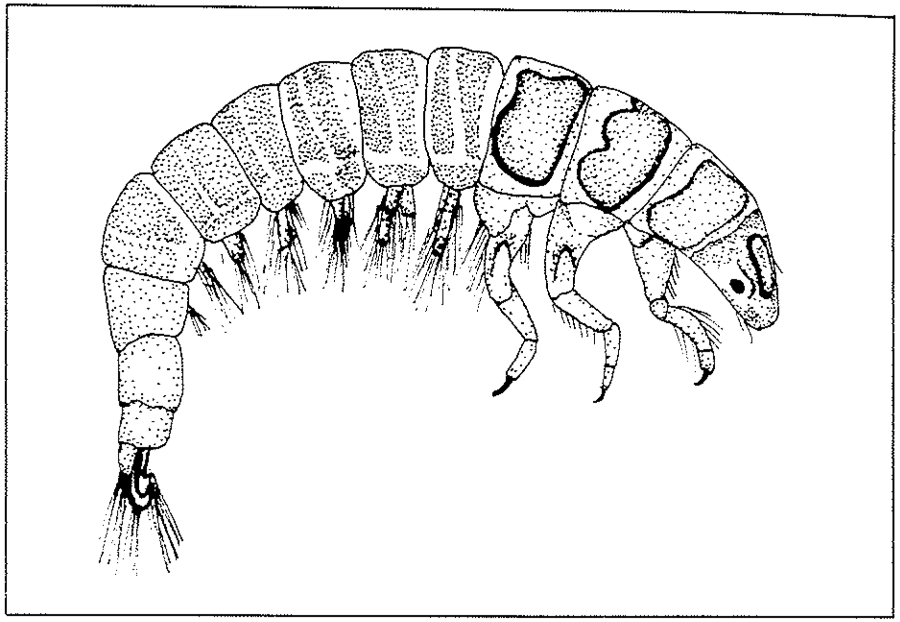


Figure 12: Caddis-fly nymph (Trichoptera) of approx. 20 mm length.

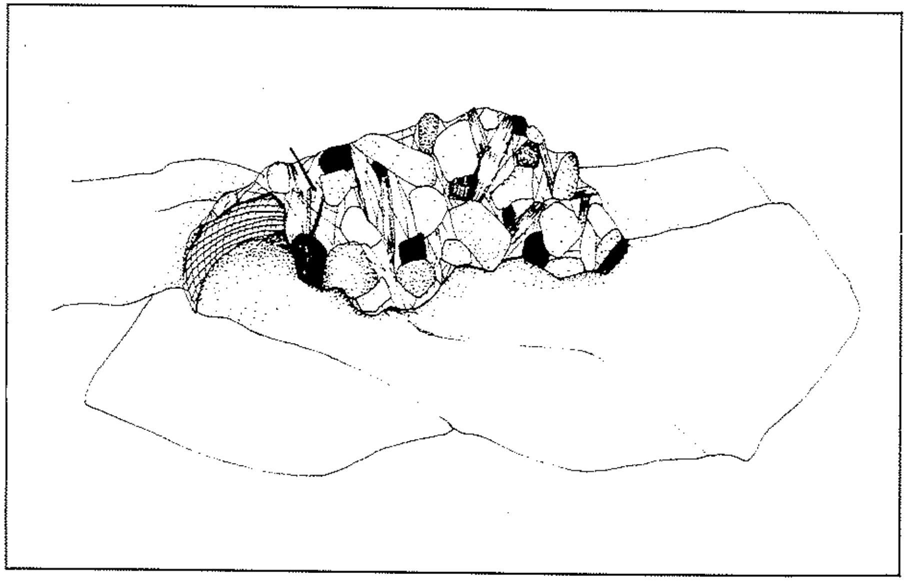


Figure 13: Case of a caddis-fly nymph of approx. 20 mm length.

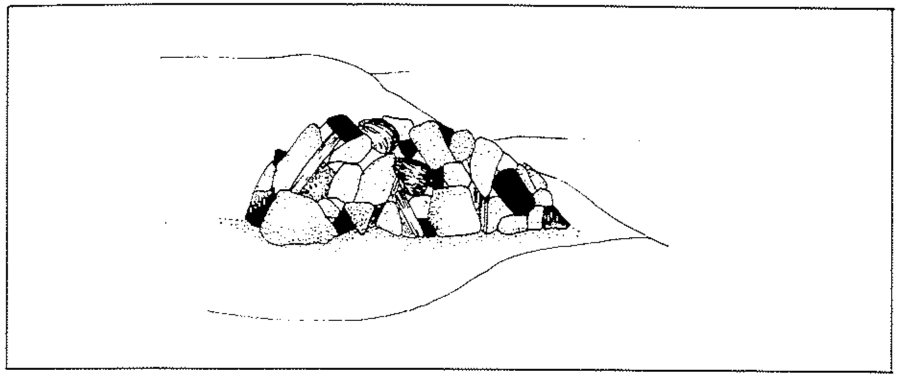


Figure 14: Cocoon of a caddis-fly nymph of approx. 11 mm length.

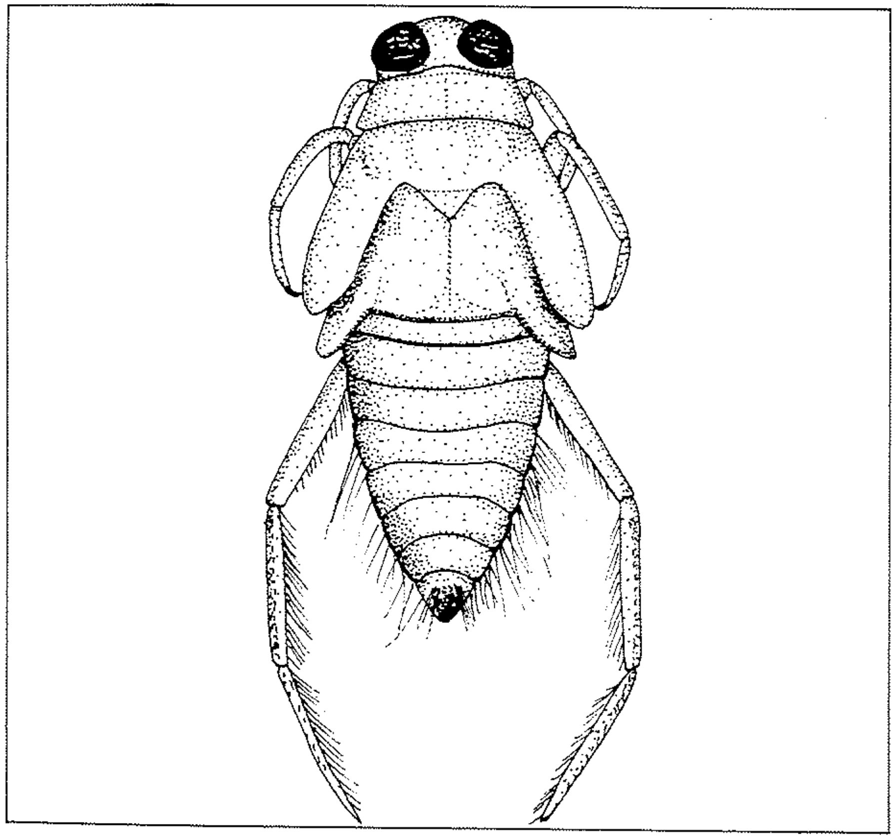


Figure 15: Aquatic bug (Hemiptera) of approx. 16 mm length.

prefer sluggish streams with a great deal of vegetation, irrigation canals and pools and can be found in clean to polluted water.

The Coleoptera (beetles, fig. 16) are represented here by a member of the Hydrophilidae. The aquatic beetles, like the aquatic bugs, lack gills and carry their air from the surface of the water down into their aquatic habitat. A number of species can usually be encountered in sections of the stream where vegetation is dense. Beetles can tolerate quite some pollution. All aquatic beetles are predators that feed on all kinds of smaller prey, catch them with their fron feet and chew them with the appendages of their mouth. Beetle larvae are also present, especially within pools and ponds.

Dipteran Larvae, that is larvae of flies, midges and mosquitoes, are found in a very wide variety of aquatic environments. Of the mosquito-like dipterans (Nematocera), a number of species of the midge larvae (Chironomidae) are present. However only two types are mentioned here. They can be differentiated clearly on sight in the streams

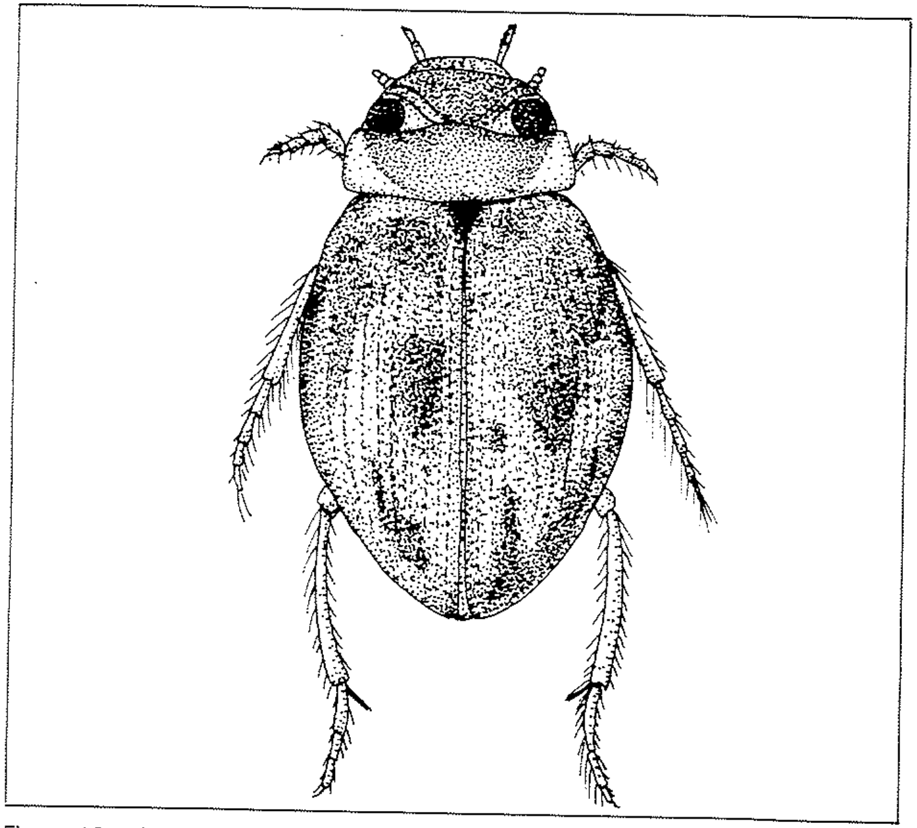


Figure 16: Water beetle of the Hydrophilidae (Coleoptera), approx. 11.5 mm length.

mentioned. Muddy sediments in pools of polluted streams and in the almost stagnant water of irrigation canals are often completely transferred into the U-shaped burrow systems constructed by a red-coloured midge larva, the so-called bloodworms, larvae of Chironomus. The occurrance of this larva in a stream is a good indication of organic pollution or eutrophication of the water. The long, worm-like body has 12 segments with a distinct head. On the first and the last 2 segments a pair of appendages with claws are seen. The larva swims by curling up and then expanding the ends of its body. A greenish larva of the Chironomidae (fig. 17) lives among rocks and aquatic plants in a sinuating tube composed of fine agglutinated particles of sediment. These larvae are smaller than the bloodworms and occur in clear, fast running streams which are not, or only slightly, polluted. The midge larvae take the oxygen they require for breathing from the water.

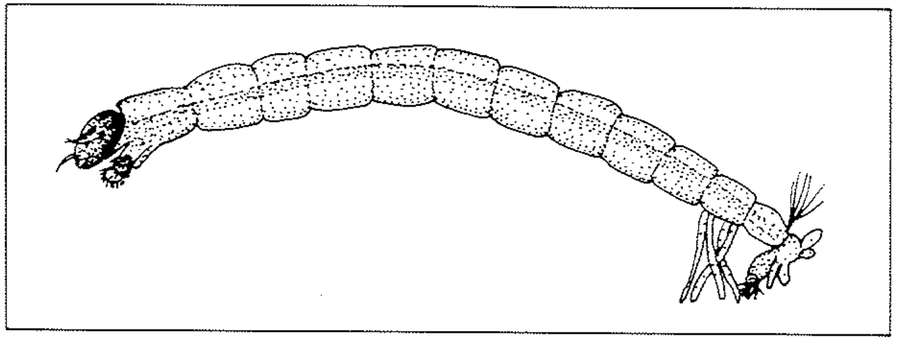


Figure 17: Larva of Chironomidae of approx. 10 mm length.

Mosquito larvae (Culicidae) are mainly found in standing water. They breathe air at the surface of the water through a special tube at the end of the abdomen. They can live in strongly polluted water and in water without dissolved oxygen. They feed on animal and plant remains and dissolved organic components of the water.

Larvae of the Simuliidae (black flies) with a greenish body of maggot-like appearance attach themselves in larger groups by an abdominal sucker to the upper surface of a rock in fast running streams. The body is held erect in the swiftly running water, little waterfalls, and areas of turbulence which are the preferred situations of these larvae. Two small fans of comb-shaped bristles form a grid in front of the mouth through which the larva sieves its food from the water. This food consists of small algae and other floating organic matter. The larvae can move about like leeches. They pupate in a cone-shaped, flat, bluish gray cocoon which is fastened to the sides or the undersides of a stone with its opening away from the direction from which the water flows. Two bunches of filaments protrude from the opening of the pupa on both sides. Pupae and larvae are found in abundance in swiftly running, clean streams fairly close to their springs. The pupae are quite characteristic and may still be present on the rocks when conditions have deteriorated as evidence of the recent change in environment.

Larvae of Tipulidae (crane flies, fig. 18) live in and on soft sediment on muddy ground in pools of shallow water. They feed on the organic components of the mud. The abdominal part of the body ends with 6 pointed appendages which surround the bristle-covered end of the breathing system. The larvae can take in air from the surface of the water with this abdominal end and with the aid of the 6 extentions can, in addition, carry a bubble of air down to the bottom. In favourable environments the larvae are also able to exchange gases with their entire skin.

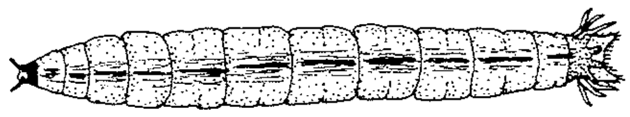


Figure 18: Larva of Tipula sp., a crane fly (Tipulidae), approx. 25 mm length.

Larvae of the Psychodidae (mothflies, fig. 19) feed on everything organic which they find in their living environment of heavily polluted water. They are "snorklers" and renew their air supply by rising to the surface and sticking a tube which is located on the abdominal end of the body out of the water. The dirty grey, hairy larvae have a sclerotized black head and black breathing tube. They were noted in particular abundance in the hospital waste water of the uppermost Wadi Sir together with the rat-tailed maggot.

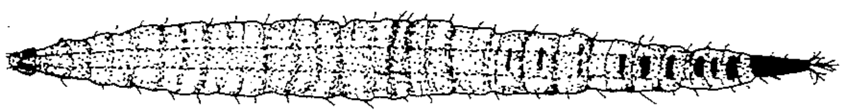


Figure 19: Larva of a moth fly (Psychodidae), 8 mm length.

There are two typical examples of dipteran larvae of flies (Brachycera) here. The first is the so-called rat-tailed maggot of the Syrphidae (syrphid flies, fig. 20) encountered in the most polluted environments inhabited by any member of the macrofauna in the area studied. The larvae of Eristalis have a very long breathing tube which somewhat resembles the tail of a rat. The dirty grey larvae up to 2 cm long, have 8 pairs of short appendages. Air is taken in with the tail-like appendage which can be pushed in and drawn out like a telescope. Rat-tailed maggots are sometimes responsible for intestinal myiasis in man (Borror & De Long, 1970).

Figure 20: Rat-tailed maggot (Syrphidae), 30 mm length.

Larvae of the Ephydridae (fig. 21) are maggot-like with 8 pairs of short appendage that have bristles at their ends. With these feet the larvae sluggishly crawl across the muddy bottom substrate mainly collecting unicellular algae. They sieve these from the bottom substrate with a special device located in their mouth. The larvae of Ephydridae breathe air through the branched abdominal tubes which are covered with bristles. In the shallow water of their living environment they can swim slowly by bending their body back and forth. To pupate the larvae crawl onto land. The cylindrical pupae are found in great numbers around pools and on the sides of sluggish streams such as the River Zerka at the point where it disappears in its gravel bed downstream from Zerka. Larvae of Ephydridae are very resistant to unfavourable living conditions.

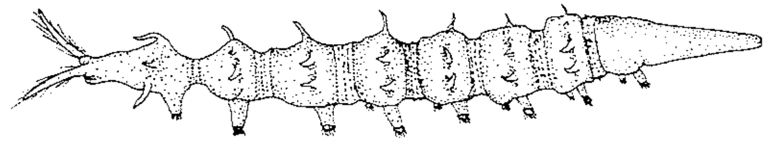


Figure 21: Larva of the Ephydridae, 18 mm length.

The molluscs are represented by a number of gastropods and one species of pelecypods. Wherever molluscs are absent from streams, springs and ponds in the studied area, this can be attributed to man-made pollution. The Prosobranchiata are represented by the species Theodoxus jordani (fig. 22), Valvata saulcyi, Hydrobia contempta, Hydrobia musaensis, Melanopsis praemorsa (fig. 23), and Melanoides tuberculata. Members of these species breathe by means of their gills. Theodoxus is found only in very clean water rich in oxygen where it crawls among rocks and scrapes off algal growths from their surfaces. In the area studied Theodoxus is restricted to the clean springs but this is due only to the effects of pollution. In the Wadi Hidan for example members of this species are also found in river and creek environments. Valvata is found only in pools, living among algae. It feeds on diatoms and other small algae and may also be able to filter food particles from the water. Hydrobia is found in

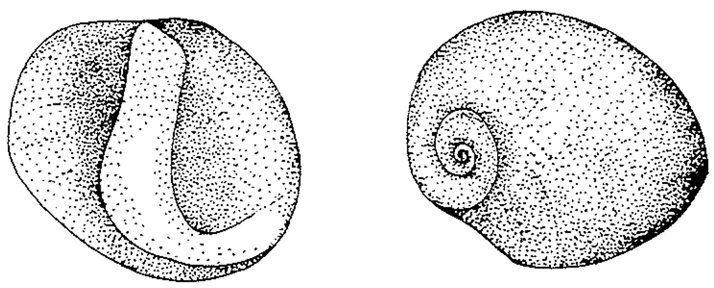


Figure 22: Theodoxus jordani (Gastropoda) of approx. 5 mm length.

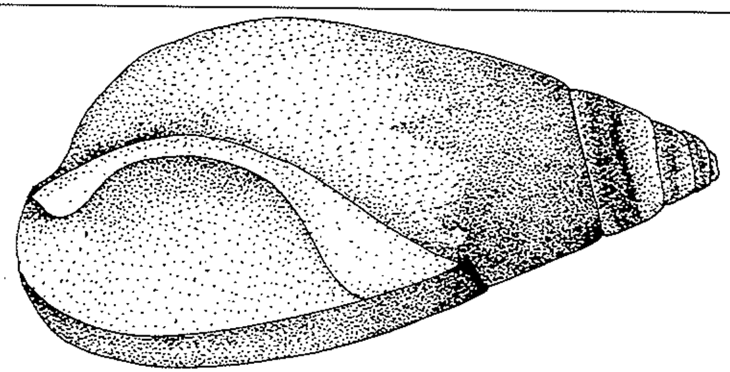


Figure 23: Melanopsis praemorsa (Gastropoda) of approx. 19 mm length.

creeks as well as in ponds but also only if they are not polluted. This small gastropod is a particle collector mainly feeding on algae. Melanopsis is not quite as sensitive to pollution as the other prosobranchiata. During the wet season it returns to the Zerka river above the King Talal Dam Reservoir and during the dry season it is present in the water of the river below the reservoir. Melanopsis feeds on decaying and fresh plant matter, algae, as well as leaves that have fallen into the water. Animal carrion is also eaten. Melanoides prefers creeks with soft bottom substrate in which it is usually hidden. It collects organic material from the bottom substrate as a source of food and in the area examined it has become almost extinct owing to pollution.

Only two species of pulmonate gastropods were discovered. Galba truncatula lives in pooled up creeks where it feeds on algae. Bulinus truncatus was found in the ancient Roman pool upstream of Jerash. This small pulmonate gastropod presents a danger to man since it is the intermediate host to the parasite causing bilharziosis. Pulmonate gastropods can breathe air with their lungs and can therefore penetrate water even when very little oxygen is dissolved in it. However in the area under discussion this is not of importance since both species encountered live in water rich in oxygen.

The only pelecypod found was the small Pisidium casertanum (fig. 24) with a round egg-shaped translucent shell and a long, lancet-shaped foot with which it can crawl and climb quite actively. It lives in clean streams and pools and can tolerate quite some current within the algal growth.

The larvae of amphibians (tadpole larvae), mainly of frogs and toads (Anura) are commonly found in the water of springs, pools and streams. These larvae can tolerate very strong pollution, but the eggs are even more resistant. Therefore in strongly polluted water, as in the hospital waste water of Wadi Sir, the eggs will hatch, while the larvae can not survive. Tadpole larvae feed on algae and other organic growths in the

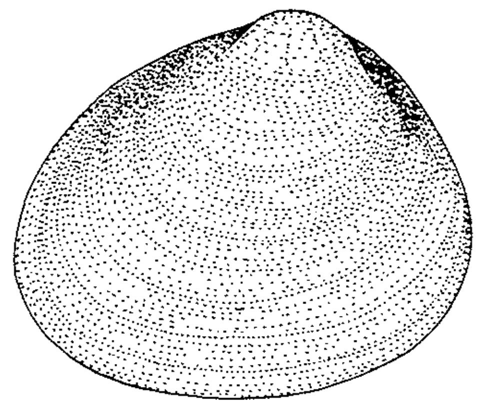


Figure 24: Pisidium casertanum (Pelecypoda) of approx. 4 mm width.

water as well as on decaying plant material and breathe with the help of gills taking oxygen from the water.

The fish found in spring water and the polluted water of streams and pools breathe in the same way. No attempt was made to differentiate species within the scope of this study. Fish mainly feed on small aquatic animals, namely crustaceans and insect larvae.

Results

1a. Wadi Shita (fig. 25, tab. II)

The creek has its origin in the sediments of the valley just above the bridge leading to the village of Wadi Esh Shita (loc. 1). Some 15 m downstream a new spring, used as the source of drinking water by the people of the village, joins the small creek. This water

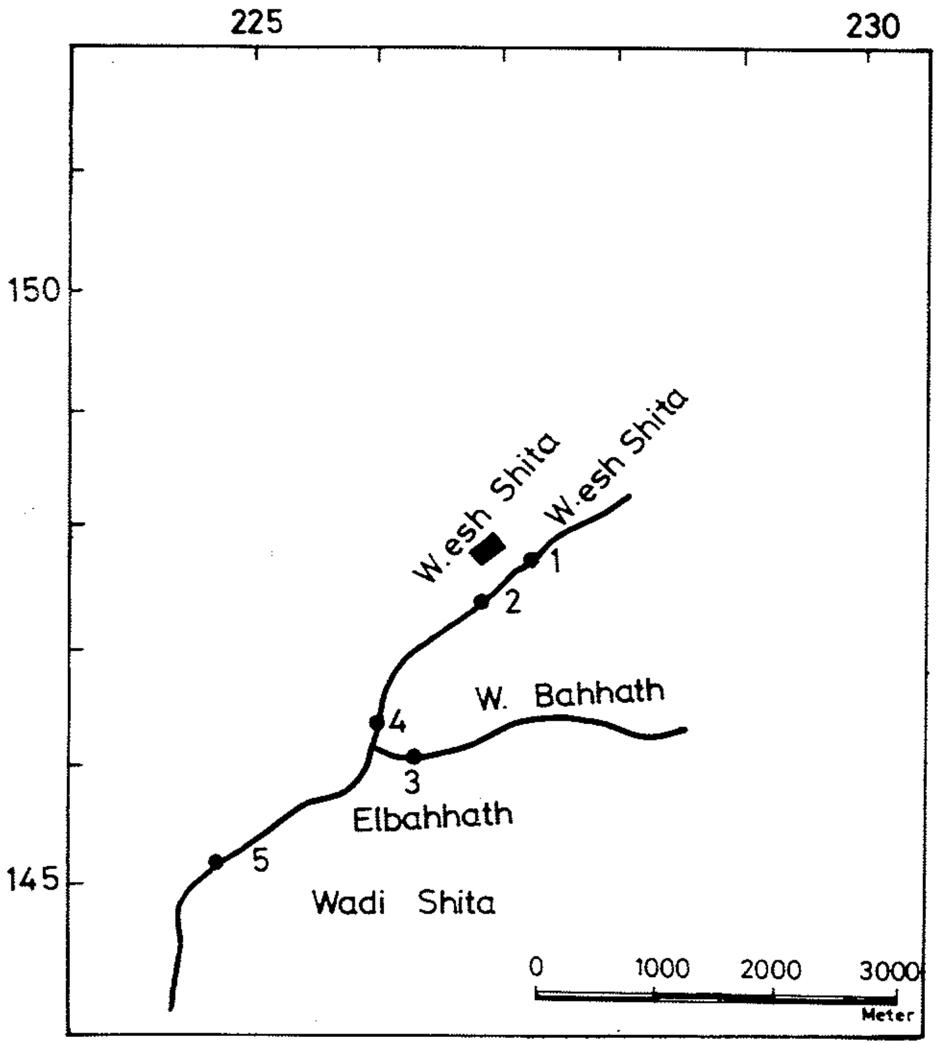


Figure 25: Sketch showing the course of the Wadi Shita with locations 1 to 5.

contains a fairly high amount of nitrate and iron. Here a fair amount of natural pollution, for example the faeces of donkeys and other animal wastes, is added to the water. Therefore, just below the village (loc. 2) the water is enriched with organic matter which provides nourishment for a rich ostracod and isopod population. Owing to the very precipitous course of the creek a good deal of oxygen is recharged into the water and caddisfly larvae are able to dwell on the rocks in little waterfalls.

To the west a strong spring issues from the limestone in a side valley (loc. 3), Wadi Bahhath. This water also has a high nitrate content. In the area of the spring itself the gravel is covered only by algal crusts while a little further downstream thicker algal crusts and filamentous algae are attached to the hard substrates. The creek coming from the village of Wadi Esh Shita joins the spring water (loc. 4) and continues in a rapid decline over a waterfall. Below it, location 5 is situated in a very strong and rapidly flowing creek. The water of the creek in the Wadi Shita in its whole course is barely affected by human pollution and still has almost normal conditions for fauna.

Table II

Loc.	Type	pH	Temp.	Turbidity	Water bed	Velocity	Quantity l/s	Quality	Flora and Fauna
1	Spring, gravel	6.5	20°	clear	gravel	slow	5	2–3	Filamentous and crust forming algae Turbellaria, Oligochaeta, Hirudinea Amphipoda, Isopoda, Ostracoda Hydracarina Ephemeroptera, Simuliidae, Chironomidae
2	Creek	6.5	18°	weakly turbid	gravel, boulders, mud, sinter	slow to fast	–	2	Filamentous and few crust forming algae Turbellaria, Oligochaeta Isopoda, Ostracoda, few Amphipoda, Brachyura Hydracarina Ephemeroptera, Chironomidae Pisidium
3	Spring, rock, creek	6.5	19°	clear	gravel	fast	250	1	Crust forming algae, later also filamentous algae Turbellaria, Oligochaeta, Hirudinea Amphipoda, Brachyura Ephemeroptera, Trichoptera, Chironomidae, Simuliidae Theodoxus, Melanopsis Frog Larvae, fish
4	Creek	6.3	19°	weakly turbid	gravel	fast	70	2	Crust forming algae Turbellaria, Oligochaeta Amphipoda, Brachyura Ephemeroptera, Trichoptera, Chironomidae, Odonata Melanopsis
5	Creek			weakly turbid	gravel, boulders, sand	very fast		2	Crust forming algae Turbellaria, Oligochaeta Brachyura Ephemeroptera Melanopsis
6	Spring, rock, creek	6.3	18°	clear	rock, gravel	slow	250	1	Crust forming algae, later also filamentous algae Turbellaria, Oligochaeta, Hirudinea Amphipoda, Ostracoda, Brachyura Hydracarina Ephemeroptera, Simuliidae, Chironomidae Theodoxus, Melanopsis, Hydrobia, Pisidium
7	Creek	6.3	19°	clear	gravel, sand	fast	290	2	Dense filamentous algae Hirudinea, Oligochaeta Isopoda, Brachyura Ephemeroptera, Chironomidae Melanopsis Frog Larvae, fish

1b. Seel Hisban (fig. 26, tab. II)

A small, somewhat polluted stream of about 40 liters per second is joined by water from the strong spring of Seel Hisban that is collected in a rock pool (loc. 6). The water of the spring is utilized by the neighbouring population, the army and drinking water tankers. As a result of washing activities aided by detergents right in the rock pool and animal wastes the emerging creek shows some pollution. This results in a dense growth of filamentous algae and of Characea. Here numerous frog larvae, fish and brachyuran crabs are present. Where the stream crosses the road below the old mill cars are washed and periodically oil wastes are discharged into the creek causing pollution of the water further downstream.

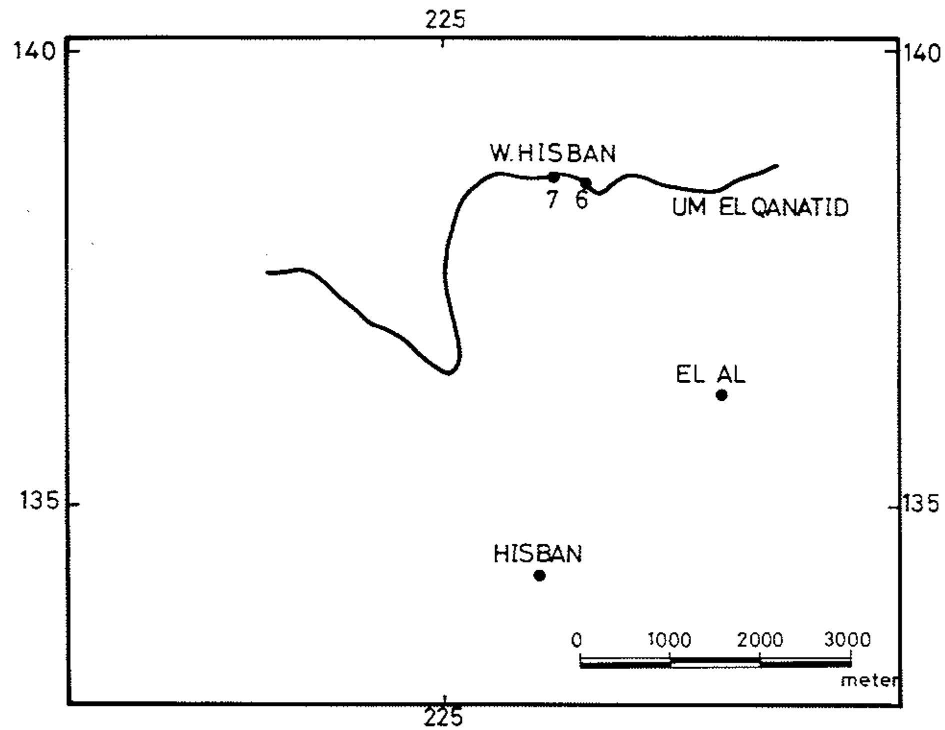


Figure 26: Sketch showing the Seel Hisban with locations 6 and 7.

2. Wadi Sir (fig. 27, tab. III)

The stream of the valley of Wadi Sir emerges from the Hussein Medical Centre and runs down the steep slope into the valley (loc. 8). This water is warm, produces an unpleasant smell and forms extensive foam mounts. The water is utilized in part by farmers for irrigation. Upon reaching the valley bottom it pools up and an organic sediment is deposited which produces gas bubbles. In these pools frog eggs develop until hatching of the larvae, which subsequently die. The fauna living in this waste water consists of dipteran larvae of which only the large rat-tailed maggot is especially conspicuous. Depending on the quite variable discharge the creek is continuous in its downward course or disappears in its gravel bed. In the latter case it reappears at a place downstream where the bed rock builds steps in the valley (loc. 9). The emerging water is a mixture of hospital water from the Miedical Centre and ground water and still foams. In little rock pools present here the muddy sediment is completely transformed into the tubes of bloodworms. Not all hospital water emerges at this location.

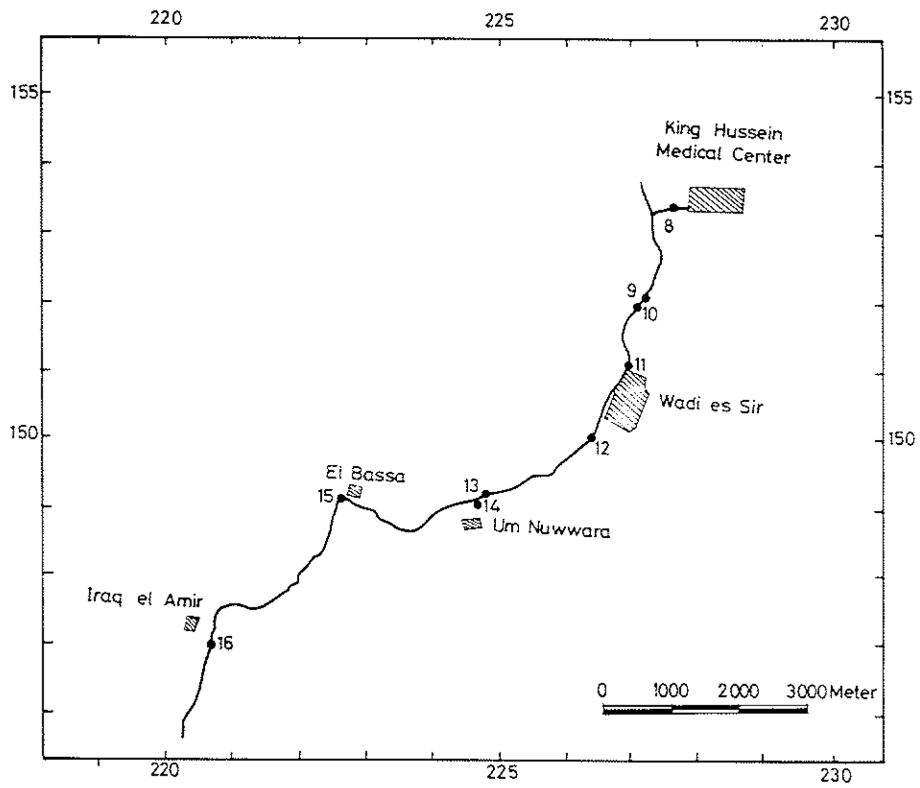


Figure 27: Sketch showing Wadi Sir with locations 8 to 16.

Loc.	Type	pH	Temp.	Turbidity	Water bed	Velocity	Quantity l/s	Quality	Flora and Fauna
33	reappearing river	–	–	clear	gravel	medium	100	4	Filamentous algae Hirudinea, Oligochaeta Bloodworms, Chironomidae, Culicidae
34	creek	–	–	turbid	gravel, oil	medium	5	5	Filamentous and crust forming algae Bloodworms, Tipulidae, Ephydridae, Culicidae
35	River	–	–	turbid	gravel	medium	300	4	Filamentous algae Eggs of Hirudinea Ephemeroptera, Bloodworms, Chironomidae Frog larvae, fish
36	River	–	–	clear	gravel	medium	60	4	Filamentous algae, Characea Oligochaeta, Hirudinea, Turbellaria Hydracarina Ephemeroptera, Bloodworms, Chironomidae, Simuliidae Frog larvae, fish
37	Spring, gravel	6.3	19°	clear	gravel	fast	5	1	Crust forming algae Turbellaria, Oligochaeta, Hirudinea Amphipoda, Brachyura Ephemeroptera Theodoxus, Melanopsis, Hydrobia Fish
38	Spring	6.3	17°	clear	rock	–	100	1	Filamentous and crust forming algae, Characea Turbellaria, Oligochaeta, Hirudinea Amphipoda, Ostracoda Ephemeroptera, Trichoptera, Hemiptera, Chironomidae, Simuliidae Theodoxus, Hydrobia, Melanopsis, Melanoides Pisidium Frog larvae, fish
39	Creek	6.3	18°	turbid	gravel, sand	medium	20	2	Filamentous algae Hirudinea Isopoda, Ostracoda Hydracarina Theodoxus, Hydrobia, Melanopsis, Pisidium
40	Mineral spring	–	–	clear	rock	–	15	–	Iron – bacteria Oligochaeta Hemiptera, Coleoptera
41	River	6.5	23°	weakly turbid	gravel	medium	900	4	Filamentous and crust forming algae Turbellaria, Oligochaeta Brachyura Hydracarina Ephemeroptera, Chironomidae Frog larvae, fish
42	Spring, pool	6.3	24°	weakly turbid	sand, silt, mud, rock	standing	39	2	Filamentous algae, Characea Oligochaeta, Hirudinea Isopoda, Ostracoda, Brachyura Hydracarina Ephemeroptera, Chironomidae, Hemiptera, Coleoptera Valvata, Hydrobia, Melanopsis, Bulinus Pisidium Frog larvae, fish
43	Creek	6.3	22°	weakly turbid	gravel	fast	9 30–40	2–3	Filamentous and crust forming algae Oligochaeta, Hirudinea Isopoda, Brachyura, Ostracoda Ephemeroptera, Melanopsis Frog larvae, fish
44	River	6.6	25°	clear	gravel	medium	1000	4	Filamentous and crust forming algae Oligochaeta, eggs of Hirudinea, Turbellaria Copepoda, Brachyura Hydracarina Ephemeroptera, Chironomidae Frog larvae, fish

Loc.	Type	pH	Temp.	Turbidity	Water bed	Velocity	Quantity l/s	Quality	Flora and Fauna
45	Creek	6.5	19°	weakly turbid	gravel, sinter	fast	40	1	Algal crusts Oligochaeta Amphipoda, Ostracoda Hydracarina Ephemeroptera, Chironomidae, Trichoptera, Odonata, Tipulidae Theodoxus, Hydrobia, Melanopsis, Pisidium
46	Creek	6.3	17.5°	weakly turbid	gravel, silt	fast	10	2–3	Filamentous algae Isopoda, Brachyura Hydracarina Ephemeroptera, Chironomidae, Coleoptera, Hemiptera, Tipulidae Melanopsis
47	Spring, gravel	–	–	clear	rock	fast	20	1–2	Algae crusts Hirudinea Ephemeroptera Theodoxus, Melanopsis
48	Spring	–	–	clear	gravel	–	5	4	Filamentous algae Oligochaeta Ostracoda, Cladocera Ephemeroptera, Chironomidae, Bloodworms
49	Creek	–	–	clear	gravel	fast	15	4	Filamentous and crust forming algae Brachyura Ephemeroptera, Bloodworms, Chironomidae, Tipulidae Frog larvae
50	Spring, gravel	–	19°	clear	gravel	fast	60	1	Algal crusts Turbellaria, Oligochaeta, Hirudinea Amphipoda Hydracarina Ephemeroptera, Simuliidae Theodoxus, Melanopsis
51	Lake	6.5	22°	turbid	mud, CH_4 producing	standing	–	5	Filamentous algae Oligochaeta Cladowa, Birawiyvra Ephemeroptera, Bloodworms, Ephydridae Fish, Frog larvae

The tabulated data (tab. III) is only true for the time of little discharge from the hospital; when the discharge is greater the water of locality 9 is quite similar to that of locality 8. Then bloodworms can not survive here but only further downstream where more fresh water is mixed by extensive populations of this midge larva form. Somewhat downstream some rock springs appear (loc. 10) from which the local population takes drinking water. But the water from these springs is mixed with water coming from locality 8. This is indicated by the high values of nitrate, sulfate and iron present and the absence of the typical spring gastropods.

Table III

Loc.	Type	pH	Temp.	Turbidity	Water bed	Velocity	Quantity l/s	Quality	Flora and Fauna
8	Hospital waste water	variable	warm, variable	turbid, foam	soil, gravel	fast	3	7	Some filamentous algae, algal covers and mats Psychodidae, Syrphidae Frog eggs
9	Gravel discharge	6.5	–	clear, foam	rock, gravel	slow	1	6	Crust forming algae Bloodworms, Psychodidae, Ephydridae Frog larvae
10	Rock spring, creek	6.8	18°	clear	rock	fast	main spring 5 creek 12	variable	Filamentous and crust forming algae Oligochaeta Isopoda, Amphipoda Ephemeroptera, Coleoptera, Bloodworms, Chironomidae Frog larvae
11	Spring, gravel	6.2	18.5°	clear	gravel	fast	after pumpage 70	2–3	Crust forming algae, later also filamentous algae Oligochaeta Ostracoda, Brachyura Hydracarina Ephemeroptera, Simuliidae, Chironomidae, Tipulidae Pisidium Frog larvae, fish
12	Creek	6.8	19°	clear	gravel, sludge	fast	150	8	Bacterial mucus layers, algal slimes Brachyura Frog larvae
13	Creek	6.5	18°	clear	gravel	fast	200	4	Filamentous and crust forming algae Turbellaria, Oligochaeta Brachyura Hydracarina Ephemeroptera, Bloodworms, Chironomidae, Tipulidae, Ephydridae Frog larvae, fish
14	Spring	6.5	18°	clear	rocks, ponds	–	12	1–2	Crust forming algae, filamentous algae, Characea Turbellaria, Oligochaeta, Hirudinea Amphipoda, Ostracoda, Brachyura Hydracarina Ephemeroptera, Hemiptera, Coleoptera, Chironomidae, Simuliidae Theodoxus, Valvata, Hydrobia, Melanopsis Pisidium Frog larvae, fish
15	Creek	6.5	18°	clear	rock, gravel	fast	250	3	Filamentous and crust forming algae Turbellaria, Oligochaeta Isopoda, Brachyura Hydracarina Ephemeroptera, Chironomidae Melanopsis Fish
16	Creek	6.5	18°	turbid	rock, gravel	very fast	250	3	Crust forming algae Turbellaria, Oligochaeta Isopoda Ephemeroptera, Trichoptera, Chironomidae Melanopsis Fish

These rock springs enrich the creek with water much of which is used for irrigation. The remainder disappears during the dry season a few hundred metres above the Wadi Sir main water supply pumping station (loc. 11). Here the water reappears where the ground water table intersects the morphology of the river bed. About 1.5 MCM are pumped from here to the city of Amman to be used as drinking water. The content of nitrate is fairly high in this well. The water pumping station itself is a major pollutant of the stream below it. Oil contaminated water from the station is added to the Wadi Sir creek. Further downstream at the confluence of the outlet and the creek the rich fauna of the creek very suddenly disappears. Instead we note for a long distance downstream (loc. 12), far below the village of Wadi Sir, that the creek fauna is destroyed and that gelatinous mucus material covers all hard surfaces in the creek bed. Soft substrates have a vesicular appearance and are formed by dark, organic sludges containing a large amount of oil. The water acquires a waste water odour.

By Um Nuwwara (loc. 13) the water of the creek has cleaned itself to some extent. Much of the water is taken for irrigation. In Um Nuwwara a spring emerges from the bedrock (loc. 14). This water is very clean and is characterised by rich fauna, but sometimes one of the irrigation canals carrying water from the creek upstream joins the spring water and is mixed with it in the concrete pools that have been constructed here. The spring water itself has quite a high nitrate and iron content. Where the spring water joins the creek a number of species disappear as a result of the mixing of the water.

The disappearance of the Hirudinea, the Amphipoda, Isopoda, Ostracoda and all gastropods is particularly conspicuous. About 1 km downstream a small spring below the village of El Bassa holds leeches, Amphipoda, Theodoxus and Melanopsis, all of which do not enter the creek. Further downstream about 2 km above Iraq El Amir the water was checked again (loc. 15) and the final examination was made below the ancient temple of Iraq al Amir (loc. 16). In both localities populations of Melanopsis and Isopoda could again establish themselves after continued self-cleaning.

3. Zerka river and tributaries (Tab. IV, fig. 28)

The first and most upstream locality (17) taken into account is situated in the Zerka river bed at Ain Ghazal just above the Amman sewage treatment plant. The water arriving at this point is derived from several sources of waste water of the city of Amman during the dry season. The water has a thick cover of mineral oil and runs sluggishly on gravel covered with oil and algal slime. The river bed is strewn with decaying organic material (carrion) rusting metal wastes and other refuse. The water has a very strong, bad smell. Because of obvious pollution no water sample was taken but fauna, consisting of rat-tailed maggots, was collected.

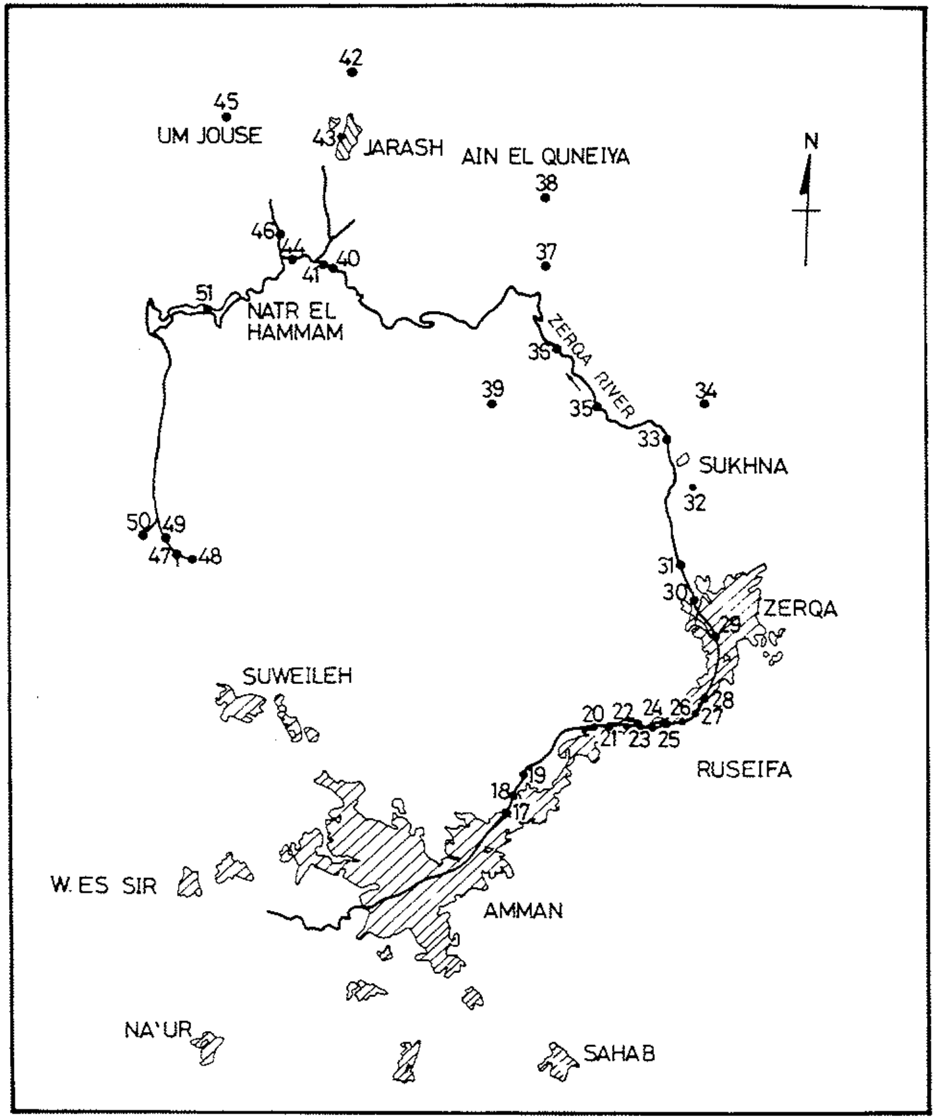


Figure 28: Sketch showing the Zerka River and tributaries with locations 17 to 51.

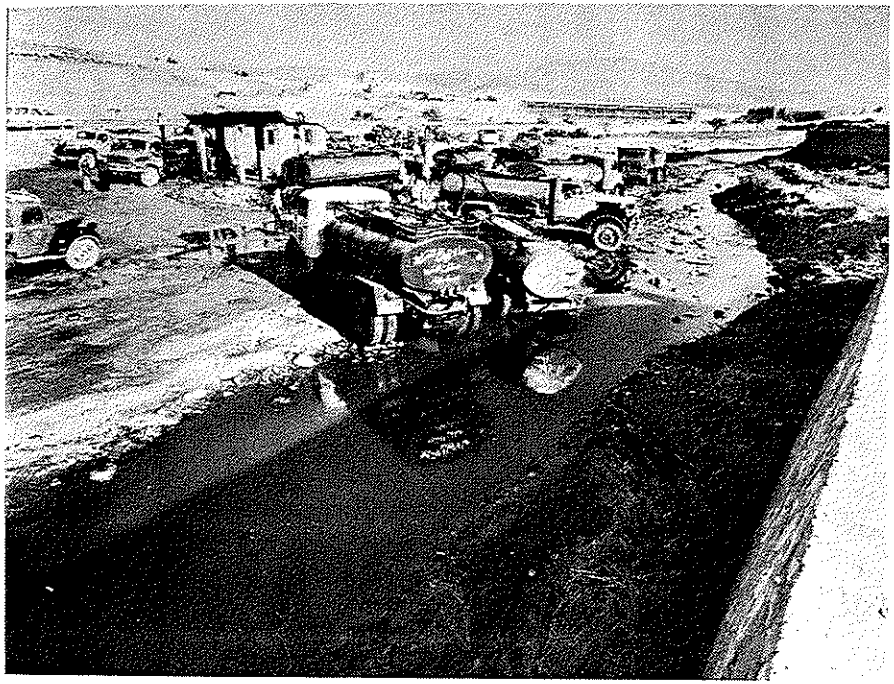
Table IV

Loc.	Type	pH	Temp.	Turbidity	Water bed	Velocity	Quantity l/s	Quality	Flora and Fauna
17	Creek	variable	variable	very turbid, oil	gravel, rubbish	slow	30	9	Algal slimes and crusts Syrphidae
18	Sewage outlet	variable	variable	very turbid, foam, oil	concrete, mud	medium	200	–	Algal and fungal slimes and crusts
19	River	variable	variable	very turbid, foam, oil	gravel, mud	medium	400	9	Algal slimes and crusts Syrphidae
20	Spring gravel	–	18°	clear	gravel	fast	5 100	8	Filamentous and crustal algae Frog larvae
21	Yeast factory outlet	–	warm	very turbid	rubbish	–	40	10	No flora and fauna
22	Phos-phate Co. outlet	–	hot	very turbid	mud	variable	variable	10	No flora and fauna
23	River	variable	variable	turbid	gravel, mud	medium	250	10	Filamentous and crust forming algae
24	Washing powder fact. outlet, river	variable	variable	very turbid	gravel, mud	medium	10 outlet 350 river	10	Algal mats and slimes
25	Dairy fact. outlet, river	variable	variable	very turbid	gravel, mud	slow	3 outlet	9	Algal mats and slimes algal bloom Syrphidae
26	River	variable	variable	turbid, foam	gravel, mud	medium	250	10	Dense growth of algae, mass population of planktonic algae
27	Alcohol fact. outlet, tanning fact. outlet, river	variable	variable	turbid, foam	gravel, mud	medium	3 3 200	10	Algae mats, slimes and suspensions
28	Beer fact. outlet	variable	variable	very turbid	gravel, mud	medium	10 200	10	Algal mats, slimes and suspensions
29	river	variable	variable	very turbid	gravel	medium	100	10	Filamentous algae and algae slimes and crust
30	river, pools	–	–	turbid	gravel	slow	30	7	Algal mats and covers, filamentous algae Bloodworms, Culicidae, Syrphidae, Ephydridae
31	pools	–	–	clear	gravel	standing	–	6	Algal mats, filamentous algae Bloodworms, Hemiptera, Ephydridae Frog larvae
32	spring, pool	6.4	22°	clear	silt, sand	standing	well 15	3–4	Filamentous algae, other water plants Ostracoda, Brachyura Hydracarina Ephemeroptera, Hemiptera, Coleoptera, Chironomidae, Culicidae Rarely Melanoides Frog larvae, fish

The outflow of the Amman sewage treatment plant (loc. 18) joins this waste water some hundred meters downstream. The discharged water has a strong sewage odour and forms extensive foam mounts. The surface of the water is covered with a thin layer of oil, and the water itself is a suspension of flocculated organic material and showed no evidence of megafauna. In more quiet water abundant gas bubbles arising from the deposited sludge break the surface. Below the confluence of these two highly polluted sources of the river Zerka, just below the railway bridge (loc. 19) the water is extremely turbid with flocky organic materials deposited in pools and near the banks, forming thick black mud deposits from which gases ascend to the surface. The only fauna here consists of rat-tailed maggots leaving their tracks on the muddy surface. Foam forms where the water runs more swiftly among the stones.

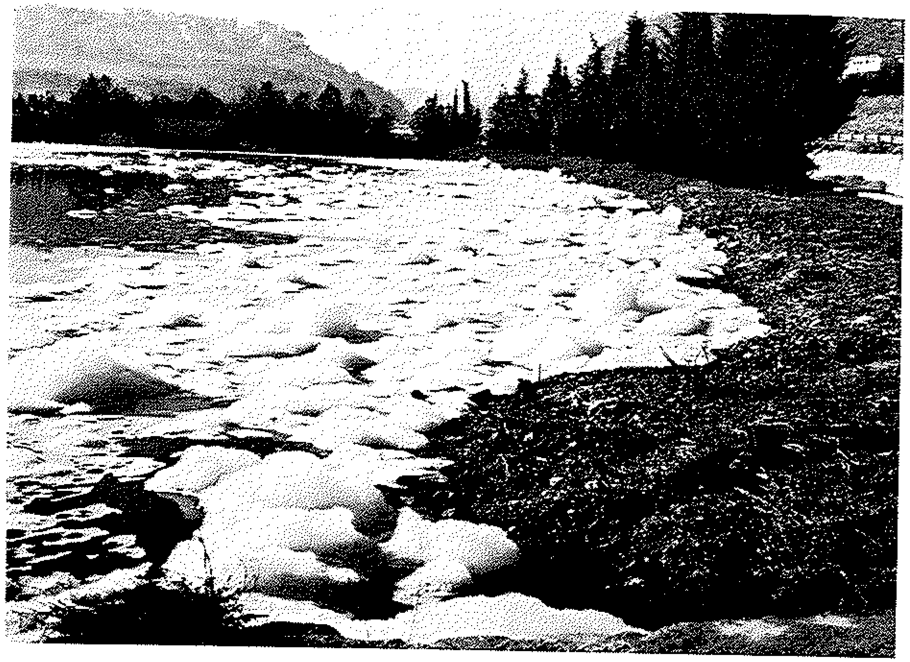
Just below the Schneller Camp of Ruseifa the water of the river becomes somewhat less turbid. However, there is still foam and waste water odour and no evidence of macrofauna. Here, springs emerge from the gravel bed (loc. 20) with clear water. But apart from algae and frog larvae this clear spring water is devoid of higher life. Danger is also indicated by the very high nitrate and chlorine values of this spring water.

Further downstream waste water of the yeast factory is discharged into the Zerka river (loc. 21). This rusty brown, turbid water has a very strong yeast odour and mixes with



the greyish water of the river in which, just upstream, there were the first signs of algal growths. Upon mixing, the water of the river becomes brown and a strong sedimentation of digested sludge takes place. Upstream of the discharge of the waste water of the phosphate washing plant, the river water has cleared itself to some extent. The phosphate waste water is discharged into the river periodically (loc. 22) and consists of a whitish-grey, thick suspension of warm to hot water. In the river bed, downstream, phosphate muds together with organic suspension form a putrid mud deposit. In the center of Ruseifa near the mosque, extensive putrid mud deposition occurs (loc. 23). Here the river bed is covered with rubbish.

The washing powder factory of Ruseifa discharges its untreated water directly into the river (loc. 24). This water forms a high foam mount at the outlet and consists of a whitish-grey suspension. Upon mixing with the water of the river, about 100 m downstream, a flocculation of grey-brown material occurs. The water is covered with a thick surface layer of opaque silky consistency with an oily luster. It emits a strong odour of dirty washings. In addition oil films are present and the river bed is littered. Further downstream the waste water of a factory for dairy products is discharged into the river (loc. 25). This water has a yogurtlike consistency. Not only has the dairy waste water discharged here a strong odour of sewage, but also the whole river. Extensive surface films cover the water, macrofauna is present in the discharged water only in the form of



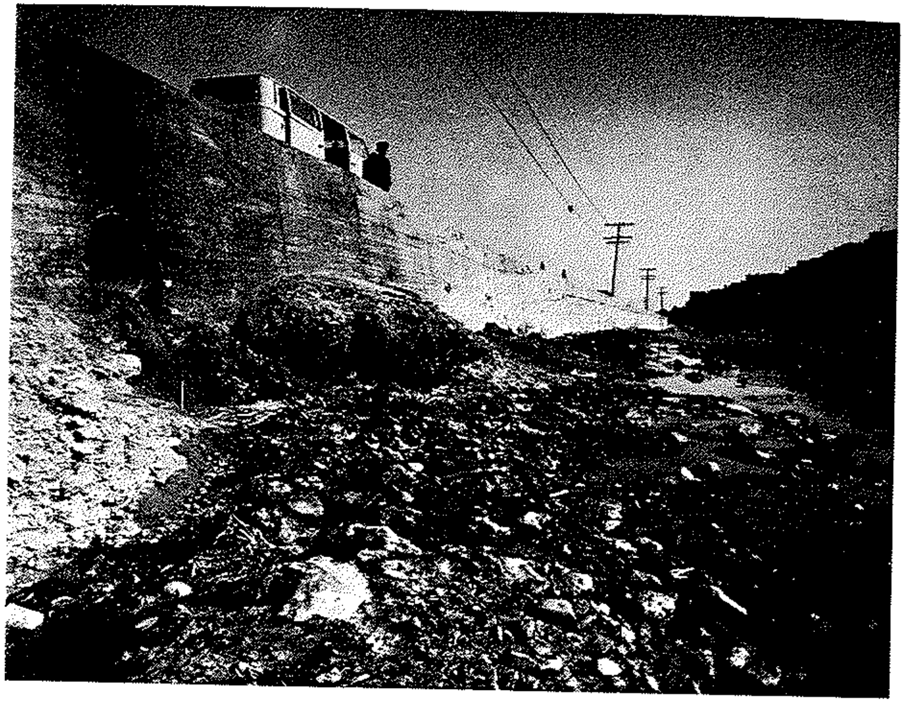
the rat-tailed maggot. The very strong eutrophication of the water results in a mass development of benthonic and planktonic algae during summer months which can be seen very clearly below the old bridge of Ruseifa (loc. 26).

Further downstream the waste waters of the alcohol factory and of the tanning factory are discharged into the river (loc. 27). The former consist of a dark brown, warm outflow with a foul malt smell mixing with the dark green river water. The latter, consisting of dyes, is discharged periodically and may add all possible colours to the river water which is already colourful. The deposition of digested sludge is intensified by the discharge of the beer factory (loc. 28) and the water remains unsuitable for the life of macrofauna. This same water is used extensively to irrigate vegetable fields between Ruseifa and Zerka.

Downstream of the Zerka bridge during the dry season, the water of the river gradually disappears into its gravel bed. The water quality here remains the same (loc. 29) as in the locations upstream. In addition large quantities of rubbish and oil pollute the river bed. These conditions do not change below Zerka where the water totally disappears or is used for irrigation. The re-emerging water now contains some macrofauna. Between Zerka and Sukhna the river mainly flows underground. Here and there some of the water reappears on the surface depending on the season and the water intake for

irrigation pumped from wells situated in the river bed, which consists of gravel. Some pools with slowly flowing water are present at places (loc. 30, 31). At both localities, which are about 2.5 km apart from each other, the water is foaming and has a bad smell. The differences in the fauna indicate a decrease of organic matter dissolved in the water. In Sukhna water emerges in a river bed spring and is collected in a pond (loc. 32). A well in the gravel bed of the Zerka river (Sukhna Spring) produces the water for Sukhna. Even though quite a number of aquatic animals live in the pool connected to this well, the almost complete absence of worms, lower crustaceans and molluscs indicates that the water is not, by any standards, pure. Just below Sukhna (loc. 33) the river reappears from its gravel bed. Flocculation takes place forming organic muds that cover the gravel. The water foams and has a faint sewage smell.

Near Sukhna the Wadi Duleil joins the Zerka river. Just below the oil-refinery (loc. 34) the running creek of this wadi has a waste water odour and shows development of foam and rudimentary fauna. The gravel bed is littered with refuse and the rocks are covered with oil. Where the Duleil creek joins the Zerka river the water is foaming and is not clear (loc. 35). Here the iron and the sulphate content of the water are rather high. Ephemeroptera larvae are only present in those parts of the river where the water is turbulent. Only 3 km downstream the quality of the water improves quite a bit (loc. 36). On the right side a creek enters the Zerka valley near El Quneiya. A gravel spring is



found on the road to this village (loc. 37) and just above El Quneiya a strong spring emerges from limestone bedrock (loc. 38). From the pool of this spring onward through the valley the creek has rich and varied fauna until it joins the Zerka river.

Another creek between El Quneiya and El Masarra joins the Zerka river on the left side (loc. 39). About 1 km upstream from the highway bridge (Amman-Jarash road) across the Zerka, a mineral spring (Natrel Hammam) issues from the gravel (loc. 40). The water is warm and contains CO_2 in abundance. Before joining the river iron oxides flocculate from this water.

The water of the Zerka river was checked some 500 m upstream of the bridge (loc. 41) before its confluence with the Jarash creek. The latter has its origin in an ancient Roman pool above Jarash (loc. 42). This pool is on average about 40 cm deep, covers a surface of about 30 x 50 m, and teems with life. The water is derived from a valley base spring. Some pollution is expected to occur because of the presence of a refugee camp further upstream in the valley and because of the strongly polluted creek coming from the Suf village. The dense growth of algae among other gastropods gives shelter also to Bulinus trunctus. This pulmonate gastropod acts as a host to the parasite causing Schistosomatosis in humans as soon as a person suffering from that disease infects the water of the pool. The water of this pool flows into irrigation canals and the creek that

passes through Jarash (loc. 43) where it has a light waste water odour. Before its confluence with the Zerka river the amount of water in the creek increases slightly while the fauna remains similar throughout its course.

About 1 km downstream of the Jarash bridge the water of the Zerka river increases to one cubic meter per second (loc. 44). The river bed in general is composed of gravel but finer sediments caught by algal growths and deposited in quiet portions of the river consist of putrid muds. The content of potassium, sodium, chlorine and sulphate in the water here is quite high. Just downstream a creek joins the Zerka river on the right side. This creek has its origin in a number of small rock springs above the village El Kitta (loc. 45). Here calc-sinter forms in the bed of the creek and fauna of many species are abundant. Further downstream polluted water from the Jarash refugee camp, if not completely used for irrigation of vegetables, may enter the creek. The faunal life in the lower portion of the creek (loc. 46) is therefore less abundant than upstream, but more species are encountered here than in the Zerka river, just downstream. The water of the Zerka river, basically unchanged from here onward, reaches the King Talal Dam Reservoir into which a creek coming from the Baqaa area discharges its water. This creek has two sources. One is a rock spring with clear, clean water (loc. 47) and the other comes from the gravel bed. This water constitutes the reappearance of waste water from the large refugee camp of Baqaa (loc. 48). After the water is mixed the creek continues downstream (loc. 49) with a spring near the village of Rumeimin (loc. 50) adding its water as well. In May 1978 the King Talal Dam Reservoir (loc. 51) contained a certain amount of marcro-organisms such as cladocerans, may-fly, midge, and fly larvae, oligochaete worms, and quite a number of fishes, frogs and crabs. The presence of digested sludge as sediment was indicated by a continuous production of CH_4 bubbling throughout to the lake surface from the shore. A survey in October 1978 showed the exposed putrid muds because the level of the lake had been lowered considerably during summer. The Zerka river taking its course through these mud deposits was found to be devoided of higher life.

Hashawa & Salameh (1978) presented a report on the water quality of the King Talal Dam Reservoir and stated that their latest results show that the lake is highly eutrophied. The water body is stratified as far as temperature and oxygen content are concerned. The water is turbid and hydrogen sulphide increases in concentration from a depth of 10 m downwards to the bottom. The total dissolved solids of the lake water amount to more than 1000 ppm per litre. The water is also rich in ions of heavy metals that have been dissolved from the bottom sediments owing to the anaerobic conditions and the high hydrogen sulphide content. The upper layers of the lake are rich in planktonic organisms such as bacteria and algae. Seasonal algal blooms are apparent. Hashawa & Salameh concluded that the water of the lake is quite unsuitable for human and animal consumption.

Water quality (fig. 29, 30)

10 grades of water quality can be distinguished in the Amman Zerka area, mainly by the composition of the macrofauna present in the streams or pools. The first grade of water is the least polluted and only encountered in the surroundings of a few springs e.g. Wadi Shita (loc. 3), Sir Hisban (loc. 6), at El Quneiya (loc. 38) and near Rumeimin (loc. 45). The characteristic animals here are Amphipoda and Theodoxus. The fauna is abundant but becomes even more so at a short distance away from the actual spring. The sediment of grade 1 springs or creeks is aerobic and numerous animals live in it.

The sediment of grade 2 water is also usually aerobic and full of life. This degree of water purity is usually found directly below the springs. The pollutants consist of animal wastes and come from washing activities carried out by the inhabitants in the area of the springs. There is a larger pool filled with grade 2 water at the Roman pool (loc. 42) upstream of Jarash. In grade 2 water both Theodoxus and fresh water shrimps (amphipods), usually become rare. Typical of these waters are isopods and large populations of ostracods. As a whole the animal life in grade 2 water is more varied and numerous than in grade 1.

The water of grade 3 is inhabited only by the prosobranch Melanopsis, while Theodoxus, Valvata and Hydrobia can not survive in such a degree of pollution, which is now clearly caused by the industrial products of man (oil, washing powder, fertilizers, insecticides etc.). Water of this quality was noted in the Wadi Sir creek near Iraq El Amir (loc. 15, 16). Here the sediment is nevertheless aerobic and rich in animal life.

The dividing line between the 3rd and 4th grade water is clearly defined here by the disappearance of the last prosobranch gastropod Melanopsis, the lamellibranch Pisidium, the isopod crustaceans and the leeches (hirudineans). A transitional grade can be established in the Sukhna well-pool (loc. 32), where these faunal indices are present and the sediment is still aerobic. In true grade 4 water the sediment is usually black and anaerobic and animal life may be found only on its uppermost surface. The chironomid bloodworms now represent a new faunal element usually present in large populations. There may also be maggots of Ephydridae. Most of the water of the Zerka river below the point at which it reappears downstream of Sukhna and until its discharge into the King Talal Dam Reservoir can be classified as grade 4. When the pumping activity upstream of Sukhna is intensive during the late summer months, only little water can reappear below Sukhna; the water of the lower course of the Zerka river improves somewhat in quality owing to the decrease in volume of the polluted creeks discharging into it. Therefore in the later part of the dry period the quality of the river water may improve to grade 3 and Melanopsis may reappear until the first flash flood of the winter season poisons all life. The King Talal Dam Reservoir is filled with grade 5 water. This stage of pollution is tolerated only by oligochaete types of worms. Ostracoda, the insect larvae of the Simuliidae and most of the Chironomidae apart from the specialized bloodworms all disappear. The bottom substrate is now inhabited only when the water is very shallow; in deeper water the anaerobic conditions in the putrid muds make the

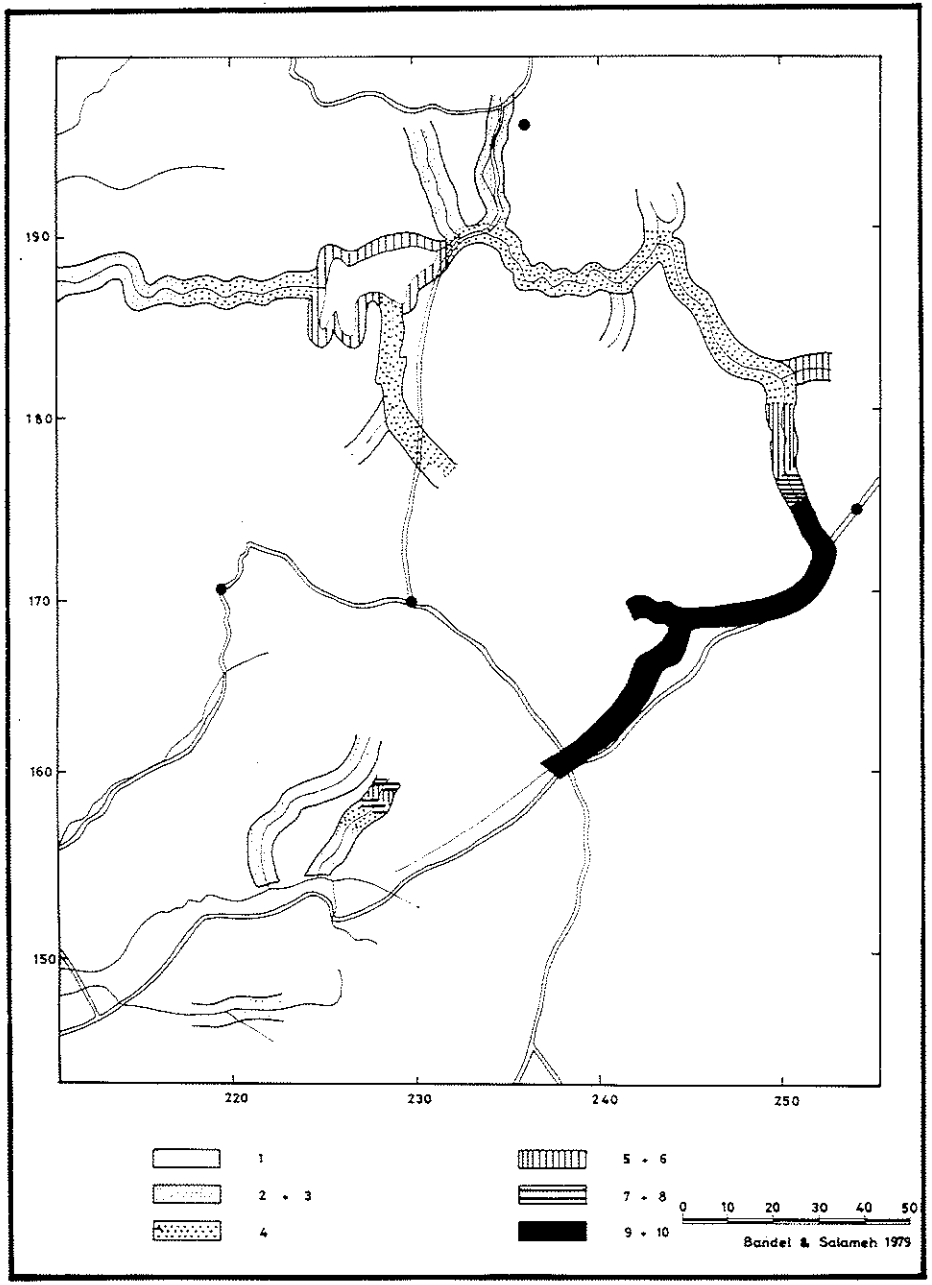


Figure 29: Sketch enlarged from fig. 1 showing the different grades of water quality present during spring and summer 1978.

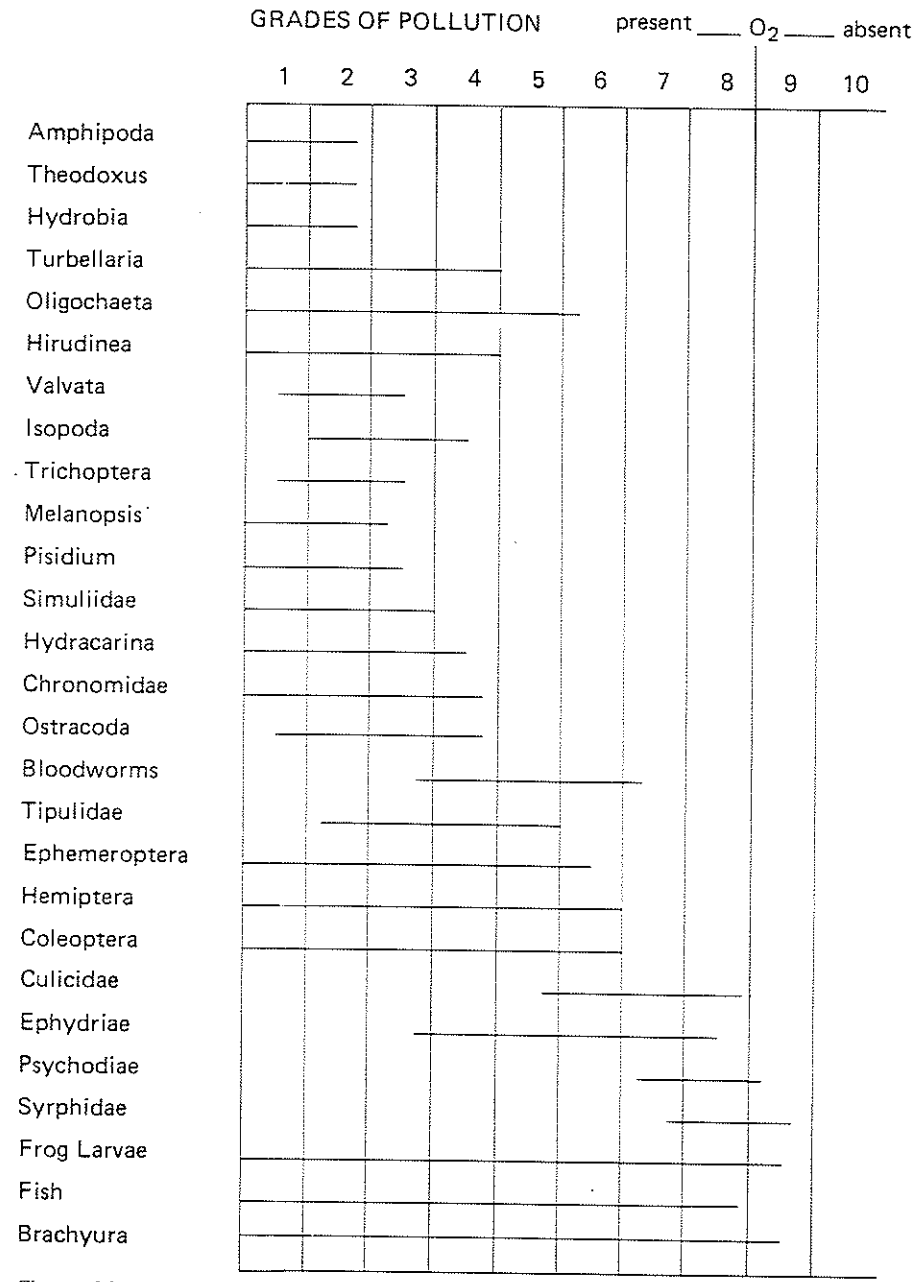


Figure 30: Diagram relating fauna to grades of pollution.

surface of the sediment an unfavourable environment for higher life. Grade 5 water is present in sections of streams where a large amount of organic matter is dissolved in the water and consumes most of the oxygen present. Therefore Ephemeroptera are found only in the rapids of the streams, while more slowly flowing sections no longer provide enough oxygen for these gill-breathing insects which have to extract oxygen from the water.

The deviding line between grades 5 and 6 is marked by the disappearance of the Ephemeroptera. Of the gill breathing insects only the bloodworms survive in large colonies in extremely shallow water and bring oxygen from the surface down to their burrows by continuous movements of their bodies. More characteristic for grade 6 water are now air breathing insect larvae. This water quality can be encountered at the place where the waste water of the King Hussein Medical Center reappears from its gravel bed (loc. 9) and where the Zerka river appears in pools and small streams between Zerka and Sukhna (loc. 31).

In polluted grade 7 waters the bloodworms disappear while air breathing mosquito larvae and maggots of Ephydridae, Psychodidae and Syrphidae are characteristic. Such water is seen in the gravel bed of the Zerka river close to Zerka (loc. 30). The hospital waste water of location 8 can also be classified as grade 7. The sediment now consists of putrid sludge and no higher life exists in or on it.

The only insect larva surviving in water of further grades of pollution i.e. grades 8 and 9 is the rat-tailed maggot (Syrphidae). But this creature only lives in sewage very rich in organic material. In grade 8 water fish are no longer found, but frog larvae still survive and brachyuran crabs may be present. Clear water of this quality issues from the gravel bed of the Zerka river below the Schneller Camp (loc. 20). It is also found (loc. 12), in the creek below the water pumping station at Wadi Sir, due to oil pollution. In the latter case the sediment is a digested sludge rich in oil and rocks are covered with an oily bacterial slime.

Grades 9 and 10 denote waters which are extremely polluted, as found in the Zerka river between Amman and Zerka. Here higher life is usually absent and the sediment consists of digested sludge or putrid muds. The water is extremely turbid and issues a strong to very strong, foul odour. The surface of the water is covered with slime and oil-films. Grade 9 in comparison to grade 10 only indicates a certain self-cleaning of the river with regard to floating and suspended matter between the different industrial discharges which again and again reverse this cleaning process.

Comparison of Chemical and Biological Grades of Pollution

In location 3, the rock spring of Wadi Shita, the biological and chemical analyses of the water reveal pure spring water of grade 1. Here no pollution is present and the water can be regarded as a potential source of good drinking water. By contrast, location 1 has water that has been polluted owing to agricultural activities and the effects of population. Once again, both values of chemical and biological analyses concur. This is true as well of location 4, also situated in the valley of Wadi Shita. The high values with regard to the iron are due to the iron rich aquifer from which the water is discharged, consisting of Lower Cretaceous sandstone. However, it is only in this valley, where agriculture is the only pollutant, that the chemical and biological gradations of water pollution or purity correlate. They diverge in all other areas studied, where other pollutants play a role owing to urbanisation and industrialisation.

A difference between the chemical and biological grades can be established in the neighbouring valley of Wadi Sir. Here the main pollutants are present in the waste waters of the hospital which have a high chemical content, in oil pollution and in the seepage from cesspools of the town and the villages. Therefore, locality 10 has a mixed animal community which cannot be classified easily, while the chemical analysis reveals quite heavy pollution (grade 5). The water well of Wadi Sir supplies fairly unpolluted water from the point of view of the biological gradation. The chemical pollution correlates with the biological pollution only at periods of the year when the ground water discharge is high, while at times of less ground water discharge (during summer) the chemical pollution increases. This is especially evident in the rise of the nitrate and chloride ion concentration, indicating that the hospital water has a strong influence on this drinking water source.

Just below the pumping station (loc. 12) the opposite effect is observed. While the chemically traceable pollution does not rise above the spring values, the oil pollution produces a very strong reaction by the fauna. The spring of Um Nuwwara (loc. 14) presents almost unpolluted water (grade 2) from a biological view, while the chemical analysis shows a high concentration of nitrate, sulphate and iron ions. This is clearly pollution which is probably derived from the cesspools of the villages near the spring. This type of pollution shows extremely few effects on the fauna present. The discrepancy between biological and chemical degrees of pollution occurs continuously in the creek of the Wadi Sir (loc. 15).

In the area of the Zerka river, the clear spring of Ruseifa (loc. 20), below the Schneller Camp demonstrates heavy pollution chemically even more clearly than biologically, especially if the nitrate, chloride, and sodium ions are considered. The pollution of the Zerka river downstream until the Zerka bridge shows degrees of biological and chemical pollution which cannot be exceeded (10). Downstream from Zerka City onwards, the fauna reacts favourably to the cleaning effect of the underground flow through the gravel bed. Thus the water quality of the Sukhna water supply well only indicates some pollution in so far as the fauna is concerned, while the chemistry illustrates just as high cation and anion contents as are present upstream. This can be also observed further downstream in the river (loc. 35, 44).

The chemical pollution does not improve at all, even with the additional creeks and springs of better water quality discharged into it along its course until collected in the King Talal Dam Reservoir. Here the quality of the water from a biological point of view varies considerably in different seasons from strongly to very strongly polluted, whereas chemically speaking it is heavily polluted throughout.

During floods all deposited wastes and finer sediments are washed from the heavily polluted stream bed between Amman and Sukhna into the King Talal Dam Reservoir. During this heavy rain cesspools all over the area are also flushed clean and oil dumps find their way into the river.

Differences in the chemical and biological aspects of the pollution grading are due to the incomplete chemical information. Very important pollutants such as most metals and all organic substances (herbicides, insecticides, oil-derivates etc.) were not analysed in this study.

Recommendations

This study shows that most of the water of the area around Amman-Zerka is strongly polluted. This pollution is increasing with continuous urbanisation and industrialisation. Thus in some sections of the Zerka river the present pollution can hardly become worse in the future. Since very much of this water is used as a source of drinking water and for the irrigation of vegetables we recommend the following:

1) The use and protection of the springs of Wadi Shita (loc. 3), Wadi Hisban (loc. 67), Quweiyna (loc. 38), and Rumeimin (loc. 50). This is a good quality drinking water and it should be kept clean. Waste waters of villages within the catchment areas of these springs should be disposed of in a way such that ground water is not polluted.
2) The waste water of the King Hussein Medical Centre must immedeately be treated properly and not be discharged into the catchment of the Wadi Sir spring. Strict control should be applied to guarantee the elimination of this serious danger to health.
3) The Wadi Šir water supply pumping station should be repaired, that is, the leakage of oil should be stopped.
4) The spring of Um Nuwwara used as drinking water must be controlled and the sources of pollution must be eliminated.
5) The water of the Zerka river is for the time being non-potable. Springs that produce water that, in total or in part, comes directly or indirectly from the Zerka river should not be used as drinking water at present. We recommend the construction of effluent treatment systems for the cities and towns in the catchment area studied. No more cesspools should be constructed. The industry should treat its effluent before discharging it.
6) Since the Zerka water is collected in the King Talal Dam Reservoir this water is also not fit for drinking purposes.
7) Dumps and industrial wastes should not be spread or kept in the catchment area where they can be leached to the ground water or can be washed off into the streams and then into the King Talal Dam Reservoir during floods.
8) Waste water of Suf and the refugee camp further up the valley the pool starts to spoil the water of the Roman pool north of Jarash. Since the pool water is used for drinking purposes, this leakage should be controlled. These pools also hold a population of the disease carrying gastropod Bulinus which should be exterminated.

References

Borror, D.J. and D.M. De Long, 1970
An Introduction to the study of Insects. – Holt, Rinehart and Winston, New York, 812 pp.

FAO, 1970
Investigation of the sandstone aquifer in East Jordan; unpubl. Report, Rome

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and Agrar- und Hydrotechnik, 1978
National Water Master plan of Jordan; Report

Masri, M.R., 1963
The Geology of the Amman-Zerka area; CWA, Amman, unpubl. Report

Mudallal, U.H., 1973
Hydrogeologie de la Région d'Amman Zerka; Université Louis Pasteur de Strasbourg, unpubl. Report

VBB and Fawzi and Associates, 1977
Water Resources study for Amman Water Supply; Stockholm-Amman, unpubl. Report

Welch, P.S., 1952
Limnology; McGraw-Hill Book Comp., New York, 538 pp.

Schriftenreihe der GTZ

Schriftenreihe Nr. 1
Gachet, Paul und Jaritz, Günther: „Situation und Perspektiven der Futterproduktion im Trockenanbau in Nordtunesien". 1972. 30 Seiten. DM 5,–.

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Wienberg, Dieter; Weiler, Norbert und Seidel, Helmut: „Der Erdbeeranbau in Südspanien". 1972. 92 Seiten. DM 5,–.

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Neumaier, Thomas (Redaktion): „Beiträge deutscher Forschungsstätten zur Agrarentwicklung in der Dritten Welt". 1973. 568 Seiten. DM 5,–.

Schriftenreihe Nr. 6
Neumaier, Thomas (Redaktion): „Deutsche Agrarhilfe – Was, wo, wie 1973?" 1973. 600 Seiten. DM 5,–.

Schriftenreihe Nr. 7
Seidel, Helmut und Wienberg, Dieter: „Gemüsesortenversuche in Südspanien". 1973. 102 Seiten. DM 5,–.

Schriftenreihe Nr. 8
„Tsetse- und Trypanosomiasisbekämpfung". 1973. 102 Seiten. DM 5,–.

Schriftenreihe Nr. 9
Schieber, Eugenio: „Informe Sobre Algunos Estudios Fitopatologicos Efectuados en la República Dominicana" (Bericht über einige phytopathologische Studien in der Dominikanischen Republik). 1973. 66 Seiten, 35 Abbildungen. Spanisch. DM 5,–.

Schriftenreihe Nr. 10
Bautista, Juan Elias; Hansen del Orbe, Raymundo und Jürgens, Gerhard: „Control de Malezas en la República Dominicana" (Unkrautbekämpfung in der Dominikanischen Republik). 1973. 40 Seiten. Spanisch. DM 5,–.

Schriftenreihe Nr. 11
Neumaier, Thomas (Redaktion): „Internationale Agrarentwicklung zwischen Theorie und Praxis" (Bericht über die vierte landwirtschaftliche Projektleitertagung Bonn 1973). 1974. 390 Seiten. ISBN 3-980030-1-9. DM 5,–.

Schriftenreihe Nr. 12
Adelhelm, Rainer und Steck, Karl: „Agricultural Mechanisation – Costs and Profitability" (Mechanisierung der Landwirtschaft – Kosten und Rentabilität). 1974. 70 Seiten. Englisch. ISBN 3-9800030-2-7. DM 5,–.

Schriftenreihe Nr. 13
„Mokwa Cattle Ranch" (Modell eines Rindermastbetriebes für Westafrika). 1974. 44 Seiten. Englisch, Französisch und Deutsch. 35 Abbildungen. ISBN 3-980030-3-5. DM 5,–.

Schriftenreihe Nr. 14
„La Lutte contre la Mouche Tse-Tse et la Trypanosomiase" (Tse-tse- und Trypanosomiasisbekämpfung). 1973. 106 Seiten. Französisch. DM 5,–.

Schriftenreihe Nr. 15
Zeuner, Tim: „Mandi – Projekt in einer indischen Bergregion" 1974. 76 Seiten. 1 Karte. 41 Abbildungen. Englisch und Deutsch. ISBN 3-9800030-5-1. DM 5,–.

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