WATER IS THE BASIS OF LIFE AND THE BLUE ARTERIES OF THE EARTH…EVERYTHING IN THE NON-MARINE ENVIRONMENT DEPENDS ON FRESHWATER TO SURVIVE….

Sandra Postel
Global Water Policy Project, Grist Magazine
Water Wisdom Book, 2006
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Our Mission

Education, training, research and consultancy for the planning, provision and management of water and environmental aspects.
Water Studies Institute (WSI) at Birzeit University is always concerned with the management and development of water and environmental related projects as well as the education and training of professionals, students and employees working in these areas.

The WSI’s role could be regarded as an effective intermediate between various societal bodies including ministries, municipalities, educational institutions, governmental/non governmental organizations, public and private institutions locally and internationally - through the increasing number of projects that it was able to conduct; therefore the WSI’s outreach is being increased in both quantity and quality in the last two years.

Due to recent political changes in Palestine this year, the WSI is facing new challenges that form obstacles in its way towards attaining its mission. Despite these challenges, the WSI is still going on with its mission and trying to increase its outreach by the variety of training programs that it organizes especially in the year 2006. The first training program in this year was held in February 2006 on water net design through e-learning. Then, in May 2006; the WSI started a series of six training blocks for Palestinian professionals through the EMWater project. In addition, another training program on vocational trainings on water management in water and sanitation sectors was organized in July – August, 2006.

This issue of the BWD includes five new articles that were published in refereed journals in the areas of integrated water resources management (IWRM), sanitation, chemistry and metal pollution. In addition, updates on the WSI’s activities and staff news are also included.

Ziad Mimi
Director, Water Studies Institute
Water Conservation and Its Perceptions in Palestine, a Case Study

Ziad Mimi, Mohammad Ziara and Hani Nigim

The article can be quoted as:

Water Conservation and Its Perceptions in Palestine, a Case Study

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ABSTRACT

This paper describes a pilot project, based upon a specific approach for encouraging effective water use in schools. The project included (a) constructing two low-cost sewage-treatment plants for irrigation water re-use in two schools, and (b) conducting an awareness campaign for effective water use in fifteen schools in the Jenin rural area. Data show that the campaign increased the pupils’ knowledge of water and positively impacted on attitudes and practices.

Statistical analysis demonstrates that good knowledge and positive attitudes in students will result in improved effective water use. The schools with pilot sewage-treatment plants for irrigation water re-use benefited the most and encouraged students to modify their water-use practices.

Key words: Awareness campaign; Palestine; re-use; schools; water conservation.

INTRODUCTION

Palestine is located on the eastern shore of the Mediterranean and comprises two separate areas: Gaza Strip and the West Bank (Fig. 1). In this part of the world there are two distinctive climatic seasons, i.e. a wet winter and a dry summer – the rainy season extending from mid-November to the end of April. Annual average rainfall in the West Bank and Gaza is 450 and 400 mm, respectively. January is the coldest month with average temperatures in the range 8-12°C, while August is the warmest month with temperatures ranging 22-34°C. The Jordan river system is the only surface-water resource in the West Bank. There are two aquifers shared by Palestine and Israel: the mountain aquifer underlying the West Bank and the coastal aquifer underlying Gaza.

Palestine, Israel, Jordan and most other mid-eastern countries have limited water resources, and future population projections in these countries place severe demands on already fragile reserves. Palestine will experience a serious deficit (271 million m³) by the year 2020. There are numerous studies and plans for expanding water resources through various schemes, including water transfers from other basins and desalination; these schemes are expensive and face daunting logistical and political barriers. In recognition of the water scarcity and inevitable population growth in the region, the conservation of existing water sources is becoming imperative. Saving water, rather than the development of new water-resources and supply projects, might prove to be the optimal policy. Also, it is advisable (for environmental reasons) to minimise leakage, prevent pollution, and reduce sensitivity to emergencies, e.g. drought.

The supply and management of water resources and wastewater remain a key priority for Palestine; 26% of households are mainly located in rural areas which are not connected to a piped water supply. Only 29% of the population in the West Bank and Gaza Strip are connected to a sewerage system. Crude sewage continues to be diverted into cesspits or percolating pits. The cesspits are emptied by vacuum trucks, and (in most cases) their contents are disposed of in nearby valleys – posing an environmental hazard to the underground aquifers (the main water resource). Only a few small sewage-treatment plants have been constructed in Palestine for the protection of the aquatic environment. The wastewater-related problems are continuously increasing, resulting in the gradual increase of nitrates in groundwater wells and freshwater springs.

Major water and wastewater development projects and strategies for Palestine are urgently needed. As emergency measures, international aid donor agencies and non-governmental organisations (NGOs) have funded several small water and wastewater projects; studies of long-term projects are also being undertaken. However, strategic planning for water and wastewater management for rural communities is still lacking. Major international funding agencies such as the United States Agency for International Development (USAID) and the Department for International Development (DFID), financed by the UK, have recognised the importance of supporting small community-based water and sanitation projects to enhance rural planning and sustainable development; thus they have funded several water-supply and wastewater projects. Through this study, Birzeit University has demonstrated an effective and innovative approach for encouraging effective water use in schools. It has been

Key words:

Fig. 1. Location map of study area
Based on the principal of wastewater re-use and an awareness campaign for effective water use. The effectiveness of the approach has been demonstrated by measuring knowledge, attitudes, and practices of students related to water topics. A pilot project has been implemented in many schools in the District of Jenin (Fig.1) by the University, with close collaboration and financial support of an Italian NGO, the Civil Volunteer Group (GVC).

STUDY APPROACH

The approach was to construct a low-cost sewage-treatment plant adjacent to the main school of each of the rural villages to enable wastewater re-use. The aim was to determine the effectiveness of the awareness campaign, using and not using pilot sewage-treatment plants in schools in the West Bank. The objectives were to:

(i) Convey the significance of the best use of available water resources through the construction of low-cost treatment plants and the re-use of wastewater;
(ii) Minimise the risk of environmental hazards associated with existing unhealthy sanitation practices;
(iii) Use awareness campaigns which are designed to create interest, and promote information on the need to use water more efficiently;
(iv) Encourage student participation in the solution of water problems; and
(v) Determine the degree of improvement of the students’ knowledge, attitudes and practices related to water issues, after implementing the two components of the approach.

TREATMENT PLANTS

The low-cost treatment plants were designed to be simple, efficient and flexible. Operational requirements mainly related to electro-mechanical tasks, and maintenance was minimal. The plant comprised a septic tank, two biological filters, a sand filter and a storage tank. Fig. 2 shows the pilot sewage-treatment plant which was constructed at Jaba school. Sewage flows into the two-compartment septic tank by gravity. Organic material, which is retained at the base of the septic tank, undergoes facultative and anaerobic decomposition and is converted into more stable compounds and gases. Septic-tank effluent is distributed evenly to the bottom of the up-flow anaerobic gravel filter. Filter effluent is collected at its surface and applied to the surface of the down-flow aerobic gravel filter — the resulting effluent being applied to the sand-bed filter to remove bacteria and viruses. Filter effluent is discharged to a collection tank, then pumped to a storage tank on the roof of the school for ultimate use in irrigation of the school gardens and nearby fields.

AWARENESS CAMPAIGN

The aim of most water-education programmes is to (a) inspire young people to take an interest in water resources and (b) become active environmental stewards. The water-education programme should consider many principles to inform and motivate young people to take action. These principles include clear educational goals, a link to community water issues, matching youth education needs with desires, and an appropriate message which should not be too specialised, narrow in relevance, or too technical. Using these principles, relevant educational material was prepared and taught to the trainers. The trainers were carefully selected students from Birzeit university, who were either studying for an MSc in Water Engineering or were final-year engineering students.

The prepared educational material comprised three main parts: (i) a theoretical background on water education and water-promotion approaches and theories used in schools; (ii) water topics, including lectures on the elements of a local watershed, water resources, water demands and possible water-conservation measures, and (iii) the necessary tools for project implementation and the use of an active learning methodology. The theme of the educational modules was the same for all grades, although the means for conveying the message was varied to match each age group. Modules were interdisciplinary, with prepared lesson plans in various subjects including science, art, religion and social science (Table 1). Leaflets, photographs and posters were prepared and given to the students. A pre- and post-study questionnaire was used to assess the cognitive effectiveness of the water-awareness campaign activities. Each questionnaire contained three sets of questions aimed at assessing (a) the general background of the student and his/her knowledge with respect to water issues, (b) the student’s attitudes towards putting this knowledge into practice, and (c) a self-report about adopting effective water use.

Table 1. Sample lessons of education modules

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Sample lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science/ ecology</td>
<td>Water resources, water demand and impacts of humans on water, and conservation problems with small populations.</td>
</tr>
<tr>
<td>Art/photograph</td>
<td>Water in art, painting, and nature photography.</td>
</tr>
<tr>
<td>Religion</td>
<td>Water in the Holy Koran, the role of water in ancient cultures, and religious laws pertaining to the protection of nature.</td>
</tr>
<tr>
<td>Social and political sciences</td>
<td>How different groups view water and nature (national, economic, religious, demographic), trans-border water and environmental problems.</td>
</tr>
</tbody>
</table>

PILOT PROJECT

The pilot project with its two components (i.e. the treatment plant and the awareness campaign) commenced in late 1999 in fifteen villages in Jenin District, which depends upon groundwater as the main sources for domestic and agricultural water supply and where 61% of the population have access to piped water and 52% have their own wells. The project was implemented in close collaboration with a committee from the Palestinian Ministry of Education, Birzeit University and the GVC Group. The selected villages lacked sewerage systems and depended mainly on cesspits as a primary method of sewage disposal.

In the first phase of the pilot project, only two sewage-treatment plants were commissioned at two schools, but the awareness campaign was held in the fifteen schools. Eighty-eight classes from grades 7-12
were included (approximately 2500 students) from male, female and co-education schools. Each student was exposed to two 1-h lectures, and data collection regarding the impact of the awareness campaign was carried out in two stages. The first-stage survey (pre-test) was carried out before implementation of the awareness campaign and included a random sample of 462 students from the fifteen schools. The second-stage post-test survey was conducted at the end of the awareness campaign and included a random sample of 450 students.

**EVALUATION OF APPROACH**

**Efficiency and Standards for Sewage-Treatment Plants**

The sewage-treatment plant at Jaba School (Fig. 2) was used to describe the relevant standards and efficiencies which were achieved in the pilot study. The average flow was 15 m$^3$/d, and the organic loading for the septic tank, anaerobic upflow gravel filter and aerobic downflow gravel filter, was 8, 6, and 1.8 kg BOD/d respectively. Composite samples of influent and effluent were analysed for total suspended solids (TSS), biochemical oxygen demand (BOD), ammoniacal nitrogen (amm. N), nitrate nitrogen (NO$_3$-N), total nitrogen (tot. N) and faecal coliforms (FC)\(^{10}\). The treatment plant was designed to meet Palestinian standards (1998) for landscape irrigation areas where there is public access, i.e. the BOD and TSS of the effluent should be less than 45 mg/l. Table 2 demonstrates that the effluent quality met the targets for landscape irrigation; faecal coliforms were within WHO acceptable limits (<1000/100 ml)\(^{10}\).

The schools planned and implemented special agricultural programmes to utilise the treated wastewater. The treatment plants also reduced existing environmental hazards in the school areas caused by previous wastewater disposal practices. Further significant environmental improvements could still be achieved if such plants were used for treating the sewage from all the villages.

**Effectiveness of Campaign**

Descriptive statistics were used to analyse the data which were obtained in the two surveys. The frequency distribution of correct answers was broken down by the three components under study, i.e. knowledge, attitudes and practices. Data and results of the awareness campaign are presented separately for the two types of schools, i.e. Group A - schools with no pilot sewage-treatment plant, and Group B - schools with a pilot sewage-treatment plant.

**Knowledge**

In the pre-test, the proportion of students who answered knowledge questions correctly ranged from 30.3% to 70.5% for Group A, and 35.1–72.0% for Group B. In the post-test, students demonstrated their improved knowledge by scoring 87.6–92.1% for Group A and 85.3–96.2% for Group B (Table 3).

<table>
<thead>
<tr>
<th>Theme</th>
<th>Correct knowledge answers</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>Post-test</td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Water pollution</td>
<td>Septic tanks can pollute groundwater</td>
<td>65.3</td>
<td>87.9</td>
</tr>
<tr>
<td>Treated wastewater</td>
<td>Treated wastewater can be used for restricted irrigation</td>
<td>40.3</td>
<td>90.1</td>
</tr>
<tr>
<td>Water resources</td>
<td>Water can be imported in tankers from other countries</td>
<td>30.3</td>
<td>92.1</td>
</tr>
<tr>
<td>Sustainability of water resources</td>
<td>Water is a finite and vulnerable resource</td>
<td>45.4</td>
<td>88.5</td>
</tr>
<tr>
<td>Water-saving devices</td>
<td>Water-saving devices are applicable in Palestine</td>
<td>66.3</td>
<td>87.6</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>53.0</td>
<td>89.1</td>
</tr>
</tbody>
</table>

**Attitudes**

Changing attitudes through an intervention awareness campaign is important: positive attitudes towards effective use of water might indicate good intentions of the target students to modify practices. Attitudes in the pre-test ranged from 65.3% to 77.1% for Group A and 66.1–75.3% for Group B. These improved attitudes ranged from 75.1% to 84.1% for Group A and 85.8–94.5% for Group B in the post-test. Table 4 shows the proportions of the students who had positive attitudes in all themes, before and after the intervention.

**Practices**

Effective water-use practices constituted the key variable among the three components of knowledge, attitudes and practices. Abu-Taleb and Murad\(^{16}\) considered practices as the hardest characteristic that can be influenced by any awareness campaign; therefore, significant outcomes are difficult to achieve in a short period of time. Practices in the pre-test were low and ranged from 15.1% to 45.0% for Group A and 20.1–49.3% for Group B. Significant improvements in effective water-use practices resulted following the completion of the awareness campaign – as demonstrated by the improved scores ranging from 50.5% to 78.7% for Group A and 80.1–93.3% for Group B. After the campaign, students started to talk about the water crises in their villages, practising water-conservation measures, trying not to pollute water and commencing to install water-saving devices at their homes. Table 5 shows the frequency distribution of improvement in all grades before and after the intervention. The results of pre-test analysis for both groups indicate that students seem to have good basic knowledge and positive attitudes towards effective water use. The post-test analysis showed that the awareness campaign succeeded in influencing student knowledge, attitudes and practices to a satisfactory extent in both Groups (Table 6). When comparing the results of the two groups, it can be seen that the proportion of students in the post-test stage who correctly answered the knowledge, attitudes and practices questions for Group B, was higher than Group A.

**Table 2. Jaba School sewage-treatment plant analysis and efficiency**

<table>
<thead>
<tr>
<th>Component</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BOD (mg/l)</td>
</tr>
<tr>
<td>Influent</td>
<td>530</td>
</tr>
<tr>
<td>Effluent</td>
<td>31</td>
</tr>
<tr>
<td>Removal (%)</td>
<td>94</td>
</tr>
</tbody>
</table>
Multiple regression analysis

Multiple-regression analysis techniques, using SPSS-X computer software, were used to analyse the data. Effective water-use practices were taken as the main dependent variable in this research, while knowledge, attitudes, age and gender were taken as independent variables. Tables 7 and 8 show the relationship between the effective water-use practices and the explanatory variables for Groups A and B, respectively. Table 7 (Group A) shows that only the female gender was strongly correlated to effective water-use practices in the post-test stage (Sig. T value is less than 0.05); therefore, it is the only variable that appears to be of significance in predicting effective water-use practices. Table 8 (Group B) shows that good knowledge, positive attitudes and female gender could significantly predict practising effective water use in the post stage of the survey.

Multiple R values in Tables 7 and 8 (0.62-0.79) are close to 1, therefore the regression groups fit the data well. The mean squares are the sums of squares divided by their respective degrees of freedom. Large F values suggest that there is a linear relationship between the two variables. The F value in Tables 7 and 8 are from 70.43 to 82.65, and the large F values suggest that there is a linear relationship between the two variables. The F value is from 70.43 to 82.65, and the large F values suggest that there is a linear relationship between the two variables.
observed significance levels (Sig. F) associated with them are less than 0.00005; therefore the regression for both groups fits the data well. The R square values are from 0.52 to 0.62 (Tables 7 and 8), therefore 52-62% of the dependent variable (effective water use) can be explained by the independent variables (knowledge, attitudes, age and gender). The results of the multiple-regression analysis of the two groups indicate that good knowledge and positive attitudes in the post-test stage might not predict changes that are conducive to an effective water use (Group A), and that good knowledge and positive attitudes could significantly predict the practising of effective water use (Group B). The existence of the treatment plants within the school yard (Group B) support and help the students in adopting effective water-use practices Therefore, a special effort should be made with regard to the school environments in any future awareness campaigns.

One of the basic assumptions of the implemented awareness campaign (and campaigns in general) is that implementation will help to create interest in and inform people about using water efficiently. As people gain new and more knowledge, they will develop more positive attitudes towards water conservation and, finally, will adopt new practices which make sense to them. Basically, it is easy to promote ideas and knowledge, but it is difficult and time-consuming to change attitudes and habits that people have acquired over their life-time.

CONCLUSIONS

1. The treatment plants and re-use of water in irrigation acted as reinforcing factors in supporting the water-awareness campaign and helped to achieve optimal water conservation.
2. Water education should be recognised as a pertinent and integral part of the daily life of Palestinian schools.
3. Improving attitudes and practices of effective water use can be achieved through action-oriented methods in water education and out-of-classroom oriented approaches and activities.
4. On-site anaerobic-aerobic treatment technologies have proved to be feasible, with high organics removal efficiency; they are simple, with low building costs and have minimum land, operational and maintenance requirements.

REFERENCES

Sustainability Assessment of Onsite Sanitation Facilities in Ramallah – Albireh District with Emphasis on Technical, Socio – Cultural and Financial Aspects

Rashed Al -Sa’ed and Sana Mubarak

The article can be quoted as:

Sustainability Assessment of Onsite Sanitation Facilities in Ramallah – Albireh District with Emphasis on Technical, Socio – Cultural and Financial Aspects

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Abstract
Purpose – This paper seeks to evaluate the present onsite sanitation systems in Palestinian rural areas in Ramallah-Albireh district with special emphasis on technical, socio-cultural and financial aspects.

Design/methodology/approach – A specialized questionnaire was developed and distributed to 200 households in four randomly selected villages with less than 5,000 persons and having onsite sanitation facilities. WAWTTAR software package was used to evaluate 16 different treatment systems and to select a sustainable onsite treatment system for these rural areas based on technical, environmental, financial and socio-cultural considerations.

Findings – Major findings indicated that most of the respondents were in favor of using treated grey wastewater and equally rejected the use of mixed treated effluent for agricultural irrigation. More than 50 percent of the respondents were against having new onsite treatment systems and favored centralized wastewater treatment options, as only 18 percent showed willingness to participate partially in construction costs. The WAWTTAR data analysis on feasible onsite treatment alternatives revealed that the septic tank-subsurface wetland system offers a higher level of sustainability to rural communities in Ramallah-Albireh district. Finally, the social and economical aspects have an equal status in technical and financial issues.

Practical implications – The results obtained can be utilized by local and international experts seeking a carrier in the planning and design of sustainable sanitation facilities in developing countries or for those who have newly filled a post in governmental, non-governmental or academic institutions.

Originality/value – This paper highlights adequate tools for the selection of sustainable onsite sanitation systems in Palestinian rural communities. Methodology and dissemination of the obtained results can be applied to other rural communities in developing countries.

Keywords Palestine, Sewerage, Economic sustainability, Sanitary appliances

Paper type Research paper

Introduction
Wastewater management in Palestine has been a neglected issue over the past years. Due to financial constraints, inadequately equipped lab facilities and un-trained lab personnel no comprehensive data on wastewater characteristics and amounts discharged are yet available. Similarly, the effectiveness of the current urban treatment facilities is usually constrained by limited capacity, poor maintenance, process
malfunction, poor maintenance practices, and lack of experienced or properly trained staff. In some districts of the West Bank (Nablus, Jenin and Hebron), where farmers have limited access to available water resources, raw or partially treated wastewater discharged into the wades (seasonal small streams) is used for irrigation purposes. The situation of the sewerage system is extremely critical. About 73 percent of the households in the West Bank have cesspit sanitation and almost 3 percent lack any sanitation facilities, where less than 2 percent of the households in small communities are connected to sewerage networks (Abu-Madi et al., 2000). The 2000 Census indicated that 192,000 households used onsite systems or cesspools. Data on systems failure rate is lacking and no national estimate is available (PCBS, 2000).

Lack of financial national funds and inequitable political power placed domestic wastewater management in Palestinian rural communities at a second priority within the Palestinian water strategy. With donor financial aids, some local non-governmental organizations as the Palestinian Hydrology Group (PHG) and Palestinian Agricultural Relief Committees (PARC) have provided onsite sanitation facilities in some Palestinian small communities. Despite the huge efforts made by some local non-governmental organizations (NGOs), the initial decision to install a particular onsite treatment system was primarily made within the NGOs by non-experienced developers based on principles of low-cost treatment systems and NGOs profitability. In small communities, developers often chose onsite systems which could be easily installed for each dwelling. Once the onsite systems were installed, they were usually rarely examined again or maintained unless an emergency situation evoked. In some cases wastewater was either leaking or backing up into land; hence they were contributing to pollution of ground water and nearby surface waters bodies. In all Palestinian small communities, existing onsite sanitation facilities are inadequately designed, poorly sited, and rarely maintained over their service life cycle. Furthermore, the lack of experienced technical staff by the water related Palestinian institutions responsible for technical review and licensing as well as the outdated local municipal regulatory codes still facilitate and promote the continued use of such onsite systems (Al-Sa’ed, 2004).

The water quality of groundwater wells and some freshwater springs is experiencing signs of gradual nitrate pollution (Mukhallalati and Safi, 1995; Alawneh and Al-Sa’ed, 1997). Among the nitrogen pollution sources is untreated municipal sewage from urban areas, domestic discharges and septic tanks from Palestinian rural communities and Israeli colonies, excessive fertilizer usage, leachate from solid waste dumpsites (UNEP, 2004). The newly issued Palestinian Environmental Law aiming at the environment improvement imposes stringent penalties for polluters. However, regulations for effluent quality standards for sewage works, industrial discharges, and wastewater and biosolids reuses are still undefined (PNA, 1999).

Most of the rural sanitation facilities installed recently entail trickling filters, anaerobic and rapid filters as well as natural treatment systems (algal and duckweed pond systems) preceded by septic tanks (Theodory and Al-Sa’ed, 2002). Until now, all implemented small rural sewage treatment plants showed positive removal rates of organic matter and suspended solids but were poor in nitrogen removal (Al-Sa’ed and Zimmo, 2000). While selecting the treatment technology no attempts were made to assess the socio-economic aspects of the suggested treatment technology. The result is
often system failure and an unsustainable solution in achieving safe and affordable wastewater treatment facilities. A recent study (Al-Sa‘ed, 2005) conducted on the socio-economical aspects of decentralized sanitation in small Palestinian communities revealed that about 85 percent of the people accepted the idea while about 60 percent of them refused small onsite sanitation systems. The major reason behind these findings is that most (80 percent) of the respondents did not show willingness to pay or participate in construction costs.

According to Al-Sa‘ed (2004), both PHG and PARC implemented onsite wastewater treatment systems of different types and sizes in the range between 5 and 1,000 inhabitants over the last five years. The established onsite sanitation systems are illustrated in Figure 1.

Sustainable development definitions vary according to which it is applied. Even in the evaluation of onsite wastewater treatment systems presented in this research, the relative weights for the sustainability criteria are affected by the values of the specific communities using the system. For example, environmental and climatic features, the neighborhood and other social factors, and the ability of the users to pay for the system and other economic factors affect the relative importance of each criterion. Key factors to success in formulating rural community wastewater management programs should include public acceptance and local political support, funding availability and reasonable costs, visibility and accountability of local leaders (USEPA, 1994).

Unfortunately, there are many examples of wastewater systems that do not relate to the local conditions; some of them are working despite their lack of suitability to the local environment, while other such systems fail altogether. Examples of the latter are some of the so-called ecological plants that work well in warmer climate, but without sufficient heat and sunlight they have no or very little effect or demand a lot of energy to work. Other examples are the projects where the users are not properly informed about the vulnerability of a plant to the contents of the wastewater. Van der Graaf et al. (1990) has conducted a study on small community wastewater treatment systems but did not investigate the socio-economical impact on the technology selection and comparison. Therefore, sustainability must be assessed in a local context. The main goal of this study was to evaluate rural onsite sanitation systems from the perspective of the community with special emphasis on technical, socio-cultural, environmental, and financial aspects.

**Methodology**

*Social-cultural impacts on sustainability of rural sanitation facilities*

Sustainable development must be environmentally friendly, socially acceptable and financially viable. It is widely agreed that progress towards sustainable services requires the integration of these three elements into the decision making process. For this purpose, a work plan has been prepared to identify the impact of socio-cultural issues on the existing rural onsite sanitation facilities of randomly selected four Palestinian rural communities in Ramallah-Albireh district (Figure 2). The selection of these rural communities was based on the population number (less than 5,000 persons); the existence of onsite treatment systems and incremental nitrate pollution signs in groundwater and surface water bodies (PWA, 2004).

A unified questionnaire format was developed and distributed during field technical site visits to the rural communities under study. Site visits were conducted in
Figure 1. Schematic diagram of onsite wastewater treatment systems in rural Palestine

**ANAEROBIC POND – FACULTATIVE POND – POLISHING POND**
PALITA COMI

**UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR**
ARTAS VILLAGE

**SEQUENCING BATCH REACTORS**
JERICHO CASINO

**SEPTIC TANK – ANAEROBIC FILTER**
ABA SCHOOL

**LOW RATE TRICKLING FILTER**
AL-SAMU’ SCHOOL

**OVER LAND FLOW**
ISRAELI COLONIES
Figure 2.
West Bank districts-Ramallah-Albireh study area with nitrate pollution signs
November 2003 to the rural communities in Ramallah-Albireh district. Facilities were chosen in four villages: Billein, Rammun, Kober and Ni’llin, where only Billein village has an onsite treatment system, the rest have septic tanks. The questionnaire was distributed to rural areas inhabitants of all ages. The selection of a random sample (50 households for each village) was made; then, a one person from each household was chosen and interviewed.

The questionnaire focused on the following main issues:

- Is the sanitation system socially and culturally acceptable to the community?
- Is the system affordable with respect to capital and annual running costs?
- Which type of waste management is it preferable: centralized or decentralized?
- Do you have benefits of wastewater separation; grey and black wastewaters?
- Would you be willing to buy vegetables irrigated with treated effluent?
- Is it safe for you to have an onsite treatment system?

Selection of financially sustainable onsite treatment systems

The choice of an adequate solution should be based on an integrated assessment of the local technical, environmental and social aspects. The selection of existing onsite sanitation facilities in the study area was based solely on a financial basis. In this study, technology and environmental impacts and appropriateness, in the context of the availability of skilled personnel to operate and maintain it, as well as socio-cultural factors were taken into account (Figure 3).

Capital costs are an important item in the selection of an appropriate treatment technology. Decision makers need to be aware of the relative costs of technologies, so that a decision to select a particular technology can be based on sound financial and economic considerations. For this purpose, WAWTTAR software package was used to assist in technology selection and comparison based on environmental, social and economical aspects (Finney and Gearheart, 1998). The main use of WAWTTAR, as a tool for individuals with a technical background, is not to design but to screen and investigate possible wastewater treatment options. The user accomplishes this by examining the public health status, water resource requirements, material availability, cost structures and ecological conditions of a particular community. The program assesses these combined factors to generate a set of comparable and feasible technical sanitation solutions.

Results and discussions

Socio-cultural aspects and public participation

Figure 4 illustrates the distribution of rural population and households in all districts of the West Bank (PCBS, 2000). About 38.1 percent (609,203 capita) of the total population in the West Bank is concentrated in small rural communities, where the Ramallah-Albireh district has the most rural areas among the West Bank districts. Ramallah/Al Bireh rural areas occupy about 21.8 percent (133,084 capita) of small communities with around 8.3 percent of the total rural population in the whole West Bank.

In the study area, the average population for each village is shown in Table I, where the families have around 10 persons per household. Large family size may be related to
general trends in poverty levels and fertility, and to proximity of the villages to one another.

The data gathered were analyzed qualitatively and quantitatively (Table II). Data analysis shows that the level of knowledge regarding hygiene is high in all the communities covered during the research. However, this knowledge is not practiced for a number of reasons:
• Lack of financial means to ensure a more hygienic life style.
• Most of the people in rural communities do not have enough water to bath daily or provide hand-washing facilities at the existing toilets available.
• Lack of knowledge on cause, transmission and prevention of waterborne diseases. The level of knowledge regarding the treatment of these diseases is high because the incidences of these diseases are high. The knowledge regarding the treatment of these diseases was obtained mostly from clinic and hospital personnel.

<table>
<thead>
<tr>
<th>Name of village</th>
<th>Average population (capita)</th>
<th>Average family size (capita/household)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Billein</td>
<td>1,631</td>
<td>14.8</td>
</tr>
<tr>
<td>Rammun</td>
<td>2,983</td>
<td>9.2</td>
</tr>
<tr>
<td>Kober</td>
<td>3,411</td>
<td>10.1</td>
</tr>
<tr>
<td>Ni'lin</td>
<td>4,414</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Table I. Population and family size distribution in the villages under study

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Mean</th>
<th>Std Dev.</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Open-ended questions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Age (year)</td>
<td>37.6</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Gender a (%)</td>
<td>73.0</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Education b (%)</td>
<td>62.5</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Children (under 18 years age) (capita)</td>
<td>4.3</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Rooms number per household (rooms)</td>
<td>3.9</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Average income (US$/month)</td>
<td>400.0</td>
<td>75.0</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Empty cost rate c (US$/each pumpage)</td>
<td>10.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>II.</td>
<td>Awareness (people concerned about the project)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>People agreed completely to use treated wastewater</td>
<td></td>
<td></td>
<td>25%</td>
</tr>
<tr>
<td>2.</td>
<td>People refused completely to use treated wastewater</td>
<td></td>
<td></td>
<td>75%</td>
</tr>
<tr>
<td>3.</td>
<td>Accepting decentralized system</td>
<td></td>
<td></td>
<td>75% accepted</td>
</tr>
<tr>
<td>4.</td>
<td>Accepted onsite sanitation with reservations</td>
<td></td>
<td></td>
<td>40% accepted</td>
</tr>
<tr>
<td>III.</td>
<td>Social criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Interference with customs</td>
<td></td>
<td></td>
<td>75% interfered</td>
</tr>
<tr>
<td>2.</td>
<td>Contradiction with cultural tradition</td>
<td></td>
<td></td>
<td>65% contradicted</td>
</tr>
<tr>
<td>3.</td>
<td>Participation in new onsite sanitation</td>
<td></td>
<td></td>
<td>55% refused</td>
</tr>
<tr>
<td>4.</td>
<td>Separation black and domestic</td>
<td></td>
<td></td>
<td>63% agreed</td>
</tr>
<tr>
<td>5.</td>
<td>Wastewater irrigation</td>
<td></td>
<td></td>
<td>75% with wastewater irrigation</td>
</tr>
<tr>
<td>IV.</td>
<td>Economic criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Readiness to pay the full construction costs</td>
<td></td>
<td></td>
<td>82% not ready</td>
</tr>
<tr>
<td>2.</td>
<td>Pay only the construction costs</td>
<td></td>
<td></td>
<td>75% refused</td>
</tr>
<tr>
<td>3.</td>
<td>Centralized sewerage network construction</td>
<td></td>
<td></td>
<td>85% agreed</td>
</tr>
<tr>
<td>4.</td>
<td>Safe disposal to valleys</td>
<td></td>
<td></td>
<td>65% agreed</td>
</tr>
</tbody>
</table>

Notes: a Gender: Male I, female O; b Education: consists of five classes, from illiterate to university graduate; c Cost of emptying the cesspool

Table II. Questionnaire data and results on socio-cultural and economical issues
Table II illustrates the results of the site visits and data analyzed from the questionnaire distributed in the study area. Initial results showed that household status (income, education and occupation) has an impact on water consumption rates. Households of higher status tended to use more water than those households of lower status. It was also clear that most (75 percent) of the respondents have rejected wastewater reuse for agricultural applications. This rejection stems from socio-cultural considerations, where 55 percent of the interviewed people were even against the establishment of new onsite facilities. Against our technical advice, 85 percent of the respondents agreed on having a centralized wastewater management facility, as their financial share will be minimal due to donor countries financial and technical support.

**Financial and economic issues**

The basic information obtained from the questionnaire (Figure 5) with regard to willingness to pay, revealed that the willingness to pay only extended to what users saw as a benefit or priority and were not willing to pay neither full investment costs (82 percent) nor partial construction cost (75 percent). Hence, supplementary financing will always be necessary to ensure the sustainability of the services. This may be done through a variety of taxes. However, tax collection in many developing countries is not efficient or effective and, moreover, a large part of the population do not pay taxes that can be used for sewage management (Nisipeanu, 1998).

The costs of managing onsite wastewater treatment systems are mostly determined by the local conditions and the corresponding types of wastewater treatment technologies used. In areas with deep, permeable soils, septic tank-soil absorption systems can be used. In areas with shallow soils to a limiting condition, very slowly permeable soils, or very highly permeable soils, more complicated onsite systems will
be required. Most of the costs come from the salary and benefits needed for the services of the operator. All systems will require periodic septic tank pumping and for some systems, worn out pumps and other parts will have to be repaired or replaced.

**Evaluation and selection of a cost-effective wastewater treatment technology**

Decision makers in developing countries are challenged with the fact that poor urban residents cannot afford and reject costly conventional sewage treatment systems. Fortunately, a broad range of cost-effective technological options are available to respond to the demands of urban consumers beyond the urban centre, with the potential to reduce costs to the order of US$ 100 per household. The UNDP/World Bank Water and Sanitation Program has worked with many countries over the past decade to develop, demonstrate, document and replicate many of these low-cost sanitation options. In Palestine, there is a need for such programs in the smaller communities, where recently a study funded by the World Bank revealed that subsurface wetland system was identified as a low-cost treatment option for small communities (PWA, 2004).

In this study, a septic tank system serving as a pre-treatment stage followed by various post-treatment alternatives were investigated based on the relative cost values and analyzed to choose the best alternative. Table III shows the different types of wastewater treatment systems that can be used in small communities. Capital investment costs for each option were estimated and the preferable treatment option was identified using the WAWTTAR software package.

Information on capital cost and the cost for operation and maintenance for a wide range of technologies that are not available in Palestine can be derived from experience in a limited number of countries. Extrapolation of the data to other locations is fraught with difficulty. Relative costs may be sufficient to narrow the choice of technology, although it should be borne in mind that the relative values may change from location to location, dependent of specific local conditions. Cost of land and labor in particular

<table>
<thead>
<tr>
<th>Number</th>
<th>Code</th>
<th>Treatment system option</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>Septic tank</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>Blackwater-holding tank and greywater-septic tank</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>Blackwater-composting toilet and greywater-septic tank</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>Blackwater-incinerating toilet and greywater-septic tank</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>Aerated tanks (aerobic units)</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>Septic tank-intermittent sand filter</td>
</tr>
<tr>
<td>7</td>
<td>G</td>
<td>Septic tank-recirculating intermittent sand filter</td>
</tr>
<tr>
<td>8</td>
<td>H</td>
<td>Septic tank-subsurface wetland system</td>
</tr>
<tr>
<td>9</td>
<td>I</td>
<td>Septic tank-anerobic filter-intermittent sand filter with recirculation</td>
</tr>
<tr>
<td>10</td>
<td>J</td>
<td>Septic tank-trickling filter with recirculation</td>
</tr>
<tr>
<td>11</td>
<td>K</td>
<td>Septic tank-rotating biological contactor with recirculation</td>
</tr>
<tr>
<td>12</td>
<td>L</td>
<td>Septic tank-anerobic filter to trickling filter with recirculation</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>Separated gray and blackwater denitrification systems</td>
</tr>
<tr>
<td>14</td>
<td>N</td>
<td>Textile filter pressure closed dispersal system</td>
</tr>
<tr>
<td>15</td>
<td>O</td>
<td>Septic tank-sequencing batch reactor (SBR)</td>
</tr>
<tr>
<td>16</td>
<td>P</td>
<td>Septic tank-wetland/trickling filter</td>
</tr>
<tr>
<td>17</td>
<td>Q</td>
<td>Septic tank-wetland/mound system</td>
</tr>
</tbody>
</table>

*Table III. Onsite systems evaluated using WAWTTAR software package.*
can vary considerably. The information provided here should therefore be used only as a guide of the relative costs needed. Actual costs for a particular location and community should be ascertained from suppliers of equipment, materials and labor. Detailed calculations and assumptions made on capital costs of onsite wastewater treatment systems can be found elsewhere (Mubarak, 2004).

Figure 6 shows clearly that the preferable option is the Septic tank–subsurface wetland (Number 8, code H; Table III) compared with all other 16 researched alternatives. Using the WAWTTAR software package revealed that this option was financially feasible (US$ 4000) and had the most economical benefits (US$ 6000) determined as the net present value (NPV) over a 20 years life cycle period.

The performance of the least expensive systems was compared for every criterion. Each system was assigned a score, with five being the most desirable and one the least desirable. For this analysis, experience and judgment were used to establish the performance score. The final score per asset was normalized by dividing the score per asset by the number of assets. The individual performance and related scores are provided in Table IV. The sum of the overall sustainability scores for the conventional septic systems was 11.42 and 13.55 for the septic tank-subsurface wetland system (most feasible option). These scores are relative to each other and are not meant to suggest an overall sustainability score for either of these systems as compared to some absolute score for sustainability (which does not exist), or as compared to other onsite systems or centralized collection and treatment systems.

A detailed comparison of the two options suggests that a principal trade-off between the two systems is that the wetland filter system increases initial installation as well as operations and maintenance costs, while producing a higher quality effluent that can be reused for landscape irrigation. Effluent reuse has environmental benefits of reducing the discharge of pollutants to surface water and using the nutrients for the growth of landscape plants.

For this particular example, the highest weighted social criteria are for protection of human health (weighted score of 10) and preservation of cultural traditions, ways of

![Figure 6. Estimated capital cost of onsite wastewater treatment systems analysed](image-url)
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Criteria weight</th>
<th>Value</th>
<th>Norm</th>
<th>Septic system</th>
<th>Performance</th>
<th>Septic–subsurface wetland</th>
<th>Score</th>
<th>Overall weighted score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>The treatment system protects public health</td>
<td>10</td>
<td>0.21</td>
<td></td>
<td>No pathogens enter groundwater and septic tank is operating well</td>
<td>3.5  Much higher effluent quality is achieved</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promotes societal virtues such as the public trust</td>
<td>6</td>
<td>0.13</td>
<td></td>
<td>Consumers little understand how system works and are not supported by health agencies</td>
<td>3    Consumers understand how but are not supported by health agencies</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preserves cultural traditions, ways of life, and physical heritage</td>
<td>9</td>
<td>0.19</td>
<td></td>
<td>Allows for dispersed human settlement and opportunities for rural lifestyles and livelihoods</td>
<td>5    Allows dispersed human settlement and smaller lot sizes may erode way of life</td>
<td></td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community makes informed decisions and actions reflect local values</td>
<td>7</td>
<td>0.15</td>
<td></td>
<td>Costumer is the manager and has ownership sense; treatment capacity limits and reuse create limits to the sense of ownership</td>
<td>4    Costumer is the manager of the system and has ownership sense. Reuse potential promote ownership sense</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preserves aesthetically-valued environments (beauty, open space). No odors or audible impacts</td>
<td>8</td>
<td>0.17</td>
<td></td>
<td>Promotes large lots and open space. Unsuitable soils with high rainfall will produce odors. Environmental impacts may reduce aesthetic quality</td>
<td>4 Less area demand. Unsuitable soil with high rainfall to produce odors is unlikely. High housing density may reduce visual aesthetics</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community ability to attain highest potential as appropriate natural resource-based development</td>
<td>8</td>
<td>0.17</td>
<td></td>
<td>Septic system promotes low density and rural lifestyles and cannot support high density development</td>
<td>3    Wetland systems promote low rural lifestyles, but can support higher density development. Effluent reuse is possible</td>
<td></td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social criteria</td>
<td>8</td>
<td>0.19</td>
<td></td>
<td>Septic systems are widely used, widely available, and of modest cost. Most cost goes to trenching and equipment installation</td>
<td>5    Modest cost and the higher costs for design &amp; equipment are balanced by lower trenching costs</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability of most community members to fund system implementation costs</td>
<td>10</td>
<td>0.24</td>
<td></td>
<td>Septic systems are widely used at modest cost. As individual systems, no capital investment in advance is required</td>
<td>5    Wetland systems are not used widely and newly promoted at low cost. No capital investment in advance is required Periodical filter rinsing and septage pumpage. Pump failure must be maintained. A challenge is septage disposal</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community financial capacity and necessary capital improvement, considering initial and final population</td>
<td>9</td>
<td>0.21</td>
<td></td>
<td>No resident’s involvement. Maintenance septic tank, septage disposal is a challenge</td>
<td>4    Home owner is responsible for long-term repair/replacement; home owner often has the financial resources. Disposal field lining is less likely</td>
<td></td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community capacity to finance the necessary system operation and maintenance</td>
<td>7</td>
<td>0.17</td>
<td></td>
<td>Home owner is responsible for long-term repair/replacement, and often has financial resources. The cost is usually associated with lining or leaking tank</td>
<td>3</td>
<td></td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(continued)
### Table IV.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Criteria weight</th>
<th>Septic system</th>
<th>Performance</th>
<th>Score</th>
<th>Septic–subsurface wetland</th>
<th>Performance</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>The system supports the community economic development objectives</td>
<td>8 0.19</td>
<td>Septic systems are of modest cost, but produce no recreational or water resource benefits</td>
<td>25</td>
<td></td>
<td>Textile systems have many potential financial benefits if water reused; landscape improvements increased property value; economical gain from irrigated food crops</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Economic criteria</td>
<td>Overall weighted score</td>
<td>398</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water quality and quantity</td>
<td>9 0.16</td>
<td>Assumed adequate distance from surface water to attenuate water quality impacts, and the septic system works well. The septic system does not promote conservation and the permit conditions eliminate reuse</td>
<td>3</td>
<td></td>
<td>When limited distance to attenuate water quality impacts, wetland works well as of added treatment provided by the soil filter. System promotes conservation through root-zone reuse in the shallow trenches</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Groundwater quality and quantity</td>
<td>8 0.14</td>
<td>With adequate distance to groundwater to attenuate water quality impacts, the septic system works well. Septic systems promote groundwater recharge</td>
<td>4.5</td>
<td></td>
<td>Works well to attenuate water quality impacts. Promotes groundwater recharge, and water resource conservation through root-zone reuse</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Aquatic ecosystems</td>
<td>10 0.18</td>
<td>With adequate distance from surface water, septic systems protect aquatic ecosystems. Septic systems do not promote conservation and permits do not allow reuse</td>
<td>3.5</td>
<td></td>
<td>With adequate distance from surface water, system provides significant protection of aquatic ecosystems. Wetland systems promote conservation and reuse. Subsurface reuse is feasible within most permits</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Land-based ecosystems</td>
<td>10 0.18</td>
<td>Septic systems do not promote conservation; permits do not allow reuse, both of which would reduce impacts by water withdrawals. Systems may promote urban sprawl</td>
<td>1.5</td>
<td></td>
<td>Wetland systems promote conservation through reuse which will reduce impacts by water withdrawals. This system may promote urban sprawl</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Soil quality</td>
<td>7 0.13</td>
<td>Septic systems may promote soil salt accumulation. Lining may clog with bioslimes over time but the problem is localized. The pH is normally not altered unless greywater only is dispersed in the leach lines</td>
<td>3.5</td>
<td></td>
<td>May promote accumulation of salts in soil, however minimized by drip lines usage; treated effluent is dispersed over larger area. Drip lines may clog with bioslimes but can be designed to have self-cleaning devices</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Air quality</td>
<td>6 0.11</td>
<td>Under normal operating conditions, no odors are produced, but lack of ventilation might cause toxic air emissions</td>
<td>5</td>
<td></td>
<td>Usually wetlands systems do not cause odors. Some emissions of household toxics may be emitted intermittently but at low-risk levels</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Energy use</td>
<td>6 0.11</td>
<td>Normally no energy use except gravity and septage pumpage</td>
<td>5</td>
<td></td>
<td>Recirculation of treated effluent might consume energy</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Environmental criteria</td>
<td>Overall weighted score</td>
<td>3.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The table includes criteria and their associated scores for evaluating the performance of septic systems and subsurface wetlands. The criteria are categorized into economic, environmental, and performance aspects.
life, and physical heritage (weighted score of 9). Based on the analysis summarized in Table IV, it is obvious that the application of the various criteria could result in tradeoffs when selecting a real system. However, that is a typical dilemma for treatment technologies and environmental infrastructure. The value of this type of decision making is that it is based on a balanced approach, providing equal importance to the three types of community capital. Given the long-lasting effects of environmental infrastructure, the sustainability analysis provides a basis for making credible tradeoffs. Overall, advanced onsite wastewater systems, such as the septic tank-subsurface wetland filter system, offer a higher level of sustainability to users, the community, and the environment. At the same time, reductions in sustainability may occur because such systems will allow for higher housing densities in rural communities.

Given the prevailing political and economic conditions in Palestine, a pragmatic and step by step approach is recommended to improve wastewater management and water reuse agenda in rural areas. Sustainable solutions for wastewater management building upon pollution prevention at the source, low cost alternatives as subsurface wetlands are essential. In addition, public-private partnerships should be investigated as an important management potential if the Palestinian governing regulatory system is strong enough (PWA, 2004).

Management options for onsite sanitation facilities

In the rural areas, village councils provide water and sanitation services. These institutions are weak for many reasons, but particularly due to their lack of autonomy, inadequate performance incentives, no access to capital, and human resource constraints. Several non-governmental organizations (NGOs) executed several water and sanitation projects and engaged in research and development. However, most the rural water and sanitation projects are on a small scale, where the main NGOs include the Palestinian Hydrology Group (PHG), Palestinian Agricultural Relief Committees (PARC), Birzeit and Alquds universities.

Some municipal water departments and utilities prepared master plans several years ago. However, these plans have rarely been implemented. The staff involved with municipal services lack motivation and have little to no opportunity to improve their skills. The co-ordination among the municipal departments, and between the water utilities themselves, is poor. A possible unified administrative structure is suggested and illustrated in Figure 7. Policies of the wastewater authority will be determined by a board, composed of representatives from the Palestinian National Authority. Representatives of the municipalities and/or users will also be included in this board and, the authority will include planning, financial and technical units.

Although wastewater treatment regulations have been imposed by the different agencies and NGOs in the West Bank, it appears that in rural areas there has been little concern within the institutional and administrative structures to support the necessary changes. The traditional bureaucratic services have proven inadequate, both in terms of supervision effectiveness and the lack of experience of the existing personnel. The technical shortfalls are only one side of the problem. The willingness of the institutional structure to implement new nationwide policies is perhaps the major concern. Thus, for such policies to be effective and viable there must be concomitant changes at the institutional level. These changes should be continuously monitored
and evaluated. It is proposed that a single national authority should be in charge of the water sector to provide more effective control, to promote wastewater treatment and to avoid a conflict of roles and overlapping responsibilities (Figure 7). In addition, inter-municipal enterprises for sanitation should be established between municipalities within the watershed area.

Finally, certification of on-site system service providers should be considered. Site evaluations by geotechnical scientists are the foundation of subsequent on-site system design and installation. An inaccurate soil evaluation can negate all other attempts to construct and maintain an effective treatment system. Certification should also be considered for individuals who provide for the operation and maintenance of the on-site systems. Certification will not overcome all of Palestinian’s problems, but it will provide evidence that on-site professionals meet a minimum level of expertise. It also serves as an avenue to inform and train personnel. Many donor countries have already recognized this need and suggested certification of onsite system contractors and operators. This may be done more effectively on a statewide basis.
Conclusions
Existing onsite wastewater systems in small Palestinian communities are unsustainable as they were mainly constructed based on the low-cost alternative, which was not necessarily the most appropriate solution. Respondents were aware of the impacts of poor sanitation services and had major fears as to pollution problems adversely affecting their health. In addition, they had doubts about projects liability and were not ready to pay for on-site sanitation facilities. Sustainable development incorporates social, economical and environmental factors into the evaluation and selection of wastewater management options. An assessment approach was developed and applied to evaluate in detail two systems using these factors. By considering various sanitation alternatives and their combinations, the WAWTTAR software package was an adequate tool to identify the most feasible and cost-effective sanitation system for a variety of site conditions and community goals. The septic tank-subsurface wetland system offers a higher level of sustainability to users in Ramallah-Albireh rural areas. As new and improved onsite wastewater treatment technologies are developed, decentralized management of domestic wastewater in rural communities offers greater sustainability, reliability and flexibility.

References


**Further reading**

Removal of Cadmium from Polluted Water Using Decaying Leaves – Effect of Acidity

Oraib Sayrafi, Sami Sayrafi and Salim Radi

The article can be quoted as:

Removal of Cadmium from Polluted Water Using Decaying Leaves – Effect of Acidity

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ABSTRACT
The effect of pH on the removal of cadmium from aqueous solutions by dry leaves has been studied. Reed leaves showed a high capability of cadmium adsorption at almost any pH. The adsorption was particularly high at pH = 1. Cypress, oak and pine leaves showed lower adsorption of cadmium ions at low pH values and this adsorption increased steadily at higher pH values. Reed and oak leaves have been found more efficient for removing cadmium from aqueous solutions than cypress and pine leaves in acidic, neutral or basic media. Reed was particularly efficient at very low pH which makes it suitable for removing cadmium from polluted water affected by acid rain. Almost all of the cadmium present in solutions having concentrations 10mg/L was removed by reed leaves within 24 hours.

INTRODUCTION
Pollution of water with toxic metals has been a matter of great concern for the past several years. The need for controlling this pollution and finding ways for removing it from polluted water has been recently a subject of great interest to environmental scientists.

Cadmium is one of the most toxic metals affecting the environment. It is, thus, considered among the group of pollutants designated by the European Economic Community as “priority pollutants” (Barbur, 1983). Cadmium has a high and cumulative toxicity, its excretion from the body is very slow with a $t_{1/2}$ of about 20 to 40 years (Friberg et al., 1974), therefore, even low levels of contamination with cadmium presumably contributes to its accumulation in the body. The total cadmium body burden at birth is less than 1 $\mu$g and it gradually increases with age to about 30 mg as indicated by U.S. Department of Health and Human Services (1990). Cadmium is especially dangerous because it combines synergistically with other toxic substances (e.g. Zn) (Cherimisinoff and Habib, 1972). Toxicity of cadmium may result in serious cardiovascular diseases (Cherimisinoff and Habib, 1972; Fassett, 1975), bone diseases (The U.S. Department of Health, 1990; Waldbott, 1973), anemia (The U.S. Department of Health, 1990; Fassett, 1975), liver damage (The U.S. Department of Health,
27, 1990), carcinogenic effects (Lemen et al., 1976), hypertension (Shroeder, 1965; Nagawa and Kido, 1990), formation of kidney stones (Kazantzis et al., 1963) and reproductive disorders (Ragan and Mast, 1990).

Several methods have been suggested for the removal of cadmium and several other toxic heavy metals from polluted water. These include precipitation (Scott, 1977), ion exchange (Fane et al., 1992), complexation (Wing and Rayford, 1978), ozonation (Shambaugh and Melnyk, 1978), electroplating (Fane et al., 1992), cementation (Gould et al., 1987) and foam fractionation (Huang and Talbot, 1973). However, most of these methods require the use of chemicals which make them costly and hardly accepted by the public. A large number of publications have recently suggested methods using living and nonliving algae (Volesky and Prasetyo, 1994; Volesky and Holan, 1995), bacteria (Grapelli et al., 1992; Hao et al., 1994), lichens (Nieboer et al., 1978; Ramelow et al., 1991) and yeast (Volesky and May-Phillips, 1995) for accumulation and removing heavy metals from polluted water. However, application of this research has the disadvantage of the high cost required for growing the necessary cultures of cells and microorganisms and for separating these microorganisms from water.

Common and low-cost adsorbents such as activated carbon (Huang and Bowers, 1978), pulverized coal (Bhattacharya and Vencobachar, 1984), fly ash (Yadava et al., 1987), zeolite (Kesraouiouki et al., 1994), geothite (Balistrieri and Murray, 1982), pumice (Hara et al., 1979), clay (Jonse and William, 1981) and coconut shell carbons (Bhattacharya and Vencobachar, 1984), and other biological-originated adsorbents such as peat (Gosset et al., 1986), hair (Tan et al., 1985; Wilhelm et al., 1989), silk and wool (Kobayashi and Nishi, 1974) have been examined for their adsorption capabilities for removing toxic heavy metals from polluted water.

Aquatic plants have been also used to remove heavy metals. These included duckweed (Ornes, 1994; Kwan and Smith, 1990), water hyacinth (Hardy and O’Keeffe, 1985; Chigbo et al., 1982), seaweed (Ramelow et al., 1992), water velvet (Jain et al., 1990) and aquatic microphytes (Rai et al., 1995). The efficiency of metal removal by these aquatic plants is low because of their small size and slow-growing roots, also their high water content complicates their drying process.

The potential use of agricultural based products and modified products as simple, cheap and acceptable methods which can be applied to remove many problem metals has been proposed by several authors. Doshenkov et al., (1995) made use of indian mustard, roots of sunflower and grass roots to remove heavy metals. Other products used for that purpose included maize (Okieimen et al., 1986), shea butter seed husks (Eromosale and Otitolaye, 1994), apple wastes (Maranon and Sastre, 1991), modified cellulose (Okieimen et al., 1985; Okieimen and Orhorhoro, 1986), thiolated maize (Okieimen and Okundaye, 1989), treated rice hulls (Suemitsu et al., 1986), treated oil palm pressed
fibers (Low et al., 1993; Low et al., 1996) and starch xanthate (Chaudhari and Tare, 1996). Dry roots were found less effective in removing metals from solution than live roots (Doshenkov et al., 1995). EDTA modified cellulosic materials showed greater sorption of cadmium, copper and lead than untreated materials (Okieimen et al., 1985; Okieimen and Orhorhoro, 1986). Rice hulls coated with dyes led to more efficient removal of heavy metals from aqueous solutions (Okieimen and Okundaye, 1989). Treating oil palm fibers also greatly enhanced their capabilities for adsorption (Low et al., 1993; Low et al., 1996). Using starch xanthate gave the ability for the selective adsorption and recovery of mercury, copper, cadmium and nickel (Chaudhari and Tare, 1996).

Decaying leaves have been proposed as a simple, cheap, available and very acceptable method for removal of toxic metals such as aluminum (Salim and Robinson, 1985a; 1985b), nickel (Salim, 1988a; 1988b), lead (Salim et al., 1994), and cadmium (Salim et al., 1992; Sayrafi et al., 1996). Finding a suitable type of leaves efficient for removing toxic metals can give the option of planting the required trees around a water source allowing the falling leaves to alleviate possible contamination by toxic heavy metals. The removal process using leaves, has been found to be dependent on several factors such as pH, type of leaves, concentration of metal ions, concentration of leaves, way of drying and crushing leaves, and the presence of foreign ions. The amounts of aluminum removed from solution by leaves were very dependent on pH (Salim and Robinson, 1985a). Maximum removal of nickel was reported using pine leaves at pH~6.7 (Salim, 1988a) while maximum adsorption on cypress leaves was at pH~8.5 for nickel and pH~6.7 for lead (Salim, 1988b; Salim et al., 1994). Maximum removal of cadmium using beach leaves was at pH~5.0 (Salim et al., 1992).

In a previous paper (Sayrafi et al., 1996), the effects of the type of leaves and of the concentration of cadmium in solution were studied for the removal of cadmium by the leaves of cypress, oak, pine and reed. The results of the paper showed an exceptionally high capacity of reed leaves in removing cadmium from unacidified polluted water. The aim of the present paper is to study the effect of the acidity on the capacity of the above four types of leaves for removing cadmium from polluted water.

**EXPERIMENTAL**

**Treatment of Leaves:**
Samples of dry cypress, pine and oak leaves were collected from the neighborhood of the campus of Birzeit University. Reed samples were collected from the Dead Sea coast (El-Fashkha). To assess the cadmium content of the various leaves, each type was soaked in 1 M HNO₃ for two days and the solution was analyzed for cadmium. The cadmium
content was found to be negligible.
Leaves used in the removal experiments were washed well with distilled water and left to air dry at room temperature. Dry leaves were crushed roughly and used as such.

**Treatment of containers**
Polyethylene bottles (500 mL) were used. These were decontaminated by soaking in 0.1M HNO₃ for two days and then washed thoroughly with distilled water before being used. Adsorption of cadmium on these bottles was determined experimentally from solutions similar in concentration to those used in this work and was found to be negligible.

**Measurements of Removal of Cadmium**
Removal of cadmium from solution was measured by following the loss of concentration of cadmium from solution in presence of 20 g/L dry leaves. The pH of the leaf suspensions was adjusted to the desired value by careful addition of a very small amount of concentrated NaOH or HClO₄ (as may be needed) and the pH was monitored by a pH-meter. It was necessary to adjust the pH several times through any particular run to bring it back to its initial value. Two milliliter aliquots of solution were taken periodically. The aliquots were taken more frequently during the early stages of any run, but at later stage one could afford longer periods between one aliquot and another. To each aliquot, 8 mL of 0.01M HClO₄ were added [this medium was found previously to be suitable for analysis of cadmium by anodizing stripping voltammetry] (Salim, and Cooksey,1979) and then analyzed by the method of differential pulse anodic stripping voltammetry.

To attain deaeration, nitrogen was bubbled through each solution for 4 minutes. This was followed by the usual preconcentration step in which the cadmium ion from the stirred solution was deposited into the mercury drop. After the deposition, the stirring was stopped for a rest period and the potential was scanned positively and Cd was stripped back into solution. Quantitative analysis was achieved from the magnitude of the peak currents. The evaluation method used was a pre-established calibration graph. This was checked several times during each experiment. Each reading was repeated three times and the average of these readings was recorded. The maximum allowed relative standard deviation of the readings was 10%.

**Apparatus**
The instrument used was a Polarographic Analyzer Model 174 A supplied by Princeton Applied Research Corporation, New Jersey. The electrodes used were: hanging mercury drop electrode with a drop weight of 7 mg as a working electrode, a platinum wire as the counter electrode and an Ag/AgCl electrode as the reference electrode.

The Electrodeposition potential used was -0.85 V, the scan rate was 5 mV/sec and the deposition
time was 2 minutes. The stirring rate was 300 rpm and the rest period was 30 seconds. The pH measurements were recorded using a Corning pH meter 140.

RESULTS AND DISCUSSION
During the first part of our study, we examined the effect of pH on loss of cadmium from 1 ppm solutions in the presence of oak and reed leaves as indicated by Figures 1-2. The results indicated that reed leaves were capable of efficient removal of cadmium from solutions with very little dependence on pH values. Under similar conditions, oak leaves showed efficient removal of cadmium ions in neutral or basic solutions. However, loss of cadmium was suppressed at low pH values. It was thought prudent to increase the concentration of cadmium (to 10 ppm) in the hope of magnifying the effect of pH.

![Figure 1](image1.png)

**Effect of pH on the removal of cadmium from 1 ppm aqueous solutions using 20 g/L dry oak leaves.**

Figures 3-6 show the loss of cadmium from 10 ppm solutions at various pH values in the presence of cypress, oak, pine and reed leaves. It is worth noting that experiments carried out at pH higher than 8.5 were complicated by the precipitation of cadmium hydroxide. Attempts to study the effect of pH at values higher than 8.5 were aborted. The general trend emerging from this study indicated that the rate loss of cadmium started high but slowed down after a period of contact with the leaves. The length of this period varied from one plant to another. Reed leaves showed the same trend that was observed in dilute (1ppm) solutions. The percentage of cadmium adsorbed was high at almost any pH. The adsorption was particularly high (96%) after 120 hours at pH = 1 and its minimum value (73%) after 120 hours was observed at pH = 3.4. The other three plants showed lower adsorption of cadmium ions at low pH values and this adsorption increased steadily at higher pH values.
The amount of cadmium removed by a constant weight of leaves was plotted against pH (Figure 7) for cypress, oak, pine and reed leaves. The amount of cadmium was chosen for each type after 120 hours. This time represented the region of slow change in cadmium concentration and would avoid magnified experimental errors.

In very acidic solutions (pH < 2), the amount of cadmium removed by the leaves followed the order: Reed >> Oak > Pine > Cypress.
Effect of pH on the removal of cadmium from 10 ppm aqueous solutions using 20 g/L dry oak leaves.

Effect of pH on the removal of cadmium from 10 ppm aqueous solutions using 20 g/L dry pine leaves.
Effect of pH on the removal of cadmium from 10 ppm aqueous solutions using 20 g/L dry reed leaves.

Relation between pH and amounts of cadmium eliminated from 10 ppm solutions after 120 hours of contact with leaves.
In acidic solutions of the pH range of 2-6, the general trend was: Reed, Oak > Cypress > Pine.

In neutral solutions, the amount of cadmium removed by the leaves followed the order: Reed > Oak > Pine > Cypress.

In weakly basic solutions, the general trend was: Reed > Oak, Cypress > Pine.

**CONCLUSION**

Cadmium ions can be removed from polluted water using decaying plant leaves. About 96% of the cadmium present in aqueous solutions containing 10 mg Cd\(^{2+}\) were removed within 24 hours using 20 g/L suspensions of dry reed leaves in very acidic solutions. This might be suitable for removing cadmium from polluted natural waters exposed to acid rain. The removal of Cd ions by reed leaves was affected by pH changes to a small degree. Cypress, oak and pine leaves removed Cd ions but showed a distinct pH dependence. The removal was small at very low pH but showed steady increase at higher pH values.

**REFERENCES**


Monitoring Urban Heavy Metal Pollution Using the House Sparrow (*Passer domesticus*)

Khalid Swaileh and Ramzi Sansur

The article can be quoted as:

Monitoring Urban Heavy Metal Pollution Using the House Sparrow (Passer domesticus)

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The House Sparrow (Passer domesticus) is one of the most successful birds in the urban environment, and has a global distribution. The present study aims to provide baseline data about metals in sparrows from urban environments in the West Bank and to investigate the possibility of using the House Sparrow to monitor metal pollution in urban environments. Concentrations of Cu, Cd, Pb and Zn were measured in different tissues and organs of male and female juvenile (1–4 weeks old) and adult House Sparrows from the West Bank. Tissues and organs had the following order of metal richness: liver > stomach > bone > lung, feathers > muscles > egg contents, brain > heart > egg shell. Significant correlation coefficients were observed for the concentrations of Cu, Pb, and Zn in the egg shell and for the egg contents. Male and female Sparrows showed no significant differences in their metal concentrations. Adult Sparrows collected from rural areas were found to have significantly less Cu, Pb, and Zn (but not Cd) concentrations than those from urban environments. In order to investigate metal accumulation with age, metal concentrations were plotted against age stage (egg. 1-, 2-, 3-, and 4-week-old juveniles and adults). Significant relationships were observed between age stage and Cu, Pb, and Zn concentrations. The results provide some evidence for the potential of the House Sparrow as a biomonitor for urban heavy metal pollution. However, further issues regarding metal physiological regulation and the correlations between metals in the environment and those in tissues of the House Sparrows have to be addressed before recommending this bird as a biomonitor for urban metal pollution.

1. Introduction

Large quantities of pollutants have continuously been introduced into ecosystems as a consequence of urbanization and industrial processes. Metals are persistent pollutants that can be biomagnified in the food chains, becoming increasingly dangerous to human and wildlife.¹ This has led to the development of monitoring schemes aimed at directly measuring levels of contaminants in various organisms, and biomonitoring schemes that use indicator species to estimate the levels in other parts of the ecosystem.²

Therefore, assessing pollutants in different components of the ecosystem has become an important task in preventing risk to natural life and public health.³ Analyzing pollutants in living organisms is more attractive and promising than analyzing pollutants of the abiotic environment, as living organisms provide precise information about the bioavailability of pollutants and the magnification and bio-transference of pollutants.⁴

Earlier studies have led to an increased interest in the use of birds as monitors of geographical, historical and global patterns of heavy metal pollution in the environment, as they occupy a wide range of trophic levels in different food chains.⁵–⁹

Birds are easier to study and monitor than other bioindicators, making them ideal for monitoring purposes.¹⁰–¹² In addition, metals in bird nestlings, like Sparrows, reflect local pollution levels, as nestlings are fed entirely on food collected by parents near their breeding colony.³

Birds, like other organisms, are harmed by heavy metals. For example, metals were found to suppress the immune system of birds,¹³ increase aggressive behavior in territorial song birds,¹⁴ cause reproductive dysfunction, increased susceptibility to diseases and stress and changes in behavioral patterns.¹⁵,¹⁶ High lead levels in the urban-dwelling Pigeon (Columba livia) were observed in specimens from London.¹⁷ Several symptoms of lead intoxication were detected, mainly in specimens with the largest lead burden. Symptoms included increased kidney weight, altered mitochondrial structure and function, and the presence of renal intranuclear inclusion bodies.

In urban environments, feral Pigeons (Columba livia) were suggested as a biomonitor for urban Pb contamination and as a model for chronic lead toxicity.¹⁸–²¹ Another common urban-dwelling bird, which has not received as much attention as the feral Pigeon, is the House Sparrow. This is reflected by the limited number of studies investigating this bird.³,²²,²³

The House Sparrow is a non-migratory sedentary bird that is primarily associated with urban environments. It inhabits
houses, farms, villages, industrial facilities, etc. Its ecological niche is characterized by the interaction with anthropogenic structures and the incorporation of different rubbish substances. Moreover, the bird has a global distribution, is not endangered, seems to be tolerant of urban environmental stress, and has a high reproductive rate. These characteristics make the House Sparrow one of the most suitable candidates for urban biomonitoring of heavy metals.

In the West Bank, studies investigating heavy metals in urban birds are completely lacking. Consequently, the present study aims at establishing baseline data about levels of metals in an urban-dwelling bird (the House Sparrow) from the West Bank, and to draw attention to the possibility of using it as a possible biomonitor for urban heavy metal pollution.

2. Materials and methods

2.1. Sample collection and preparation

In 2002–2003, a total collection of 40 House Sparrows of different ages were collected (under license from Palestinian Ministry for Environmental Affairs, MEnA) from urban (two cities: Qalqila and Ramallah) and rural (two villages: Birzeit and Immatin) regions in the West Bank. Specimens had the following distribution: 20 adults (10 urban and 10 rural, each consisting of 5 males and 5 females), and 20 juveniles (5 specimens from each of the four juvenile age stages). Adult birds were caught by cage traps. Nests with eggs were visited regularly to determine the hatching date. Juveniles from each desired age group were then collected by hand from these nests. In addition, 10 fresh-laid eggs were collected from nests in the same regions. Birds were sacrificed, put in plastic bags, and deep-frozen for later analysis. Eggs were kept in the refrigerator (4 °C) until analysis. Thereafter, birds were dissected and specimens of following tissues were obtained: breast feathers and muscles, liver, lungs, heart, brain, stomach (with contents) and bones (femur and tibia fibula).

To remove loosely adhering external contaminants, feathers were washed thoroughly with acetone and then with doubly distilled water. All specimens were transferred into clean, acid-washed glass vials, and oven-dried at 60 °C until constant weights were obtained.

2.2. Analytical procedure

Specimens were digested in a mixture of super-pure nitric and perchloric acids (Merck) (2:1, v/v). The volume of the digestion mixture was 10 times the sample’s mass in g. After soaking the specimens in the acid mixture overnight at room temperature, the mixture was gradually heated to 200 °C in a sand bath over a period of 3 h. Digestion was then continued until no fumes were observed and the mixture became pale yellow. Mixtures were then diluted to 25 mL with doubly distilled water. Blanks and reference material (Copepod homogenate, MA-A-1 TM, IAEA) were run with the samples. Finally, concentrations of Cu, Cd, Pb, and Zn were measured by inductively coupled plasma – atomic emission spectrophotometry (ICP Optima 3000, Perkin–Elmer, USA). Certified values of the reference material and the percent recoveries obtained are shown in Table 1.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Mean certified value/μg g⁻¹</th>
<th>Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>7.6 ± 0.2</td>
<td>95–103</td>
</tr>
<tr>
<td>Cd</td>
<td>0.75 ± 0.03</td>
<td>91–98</td>
</tr>
<tr>
<td>Pb</td>
<td>2.1 ± 0.3</td>
<td>94–101</td>
</tr>
<tr>
<td>Zn</td>
<td>158 ± 2</td>
<td>93–105</td>
</tr>
</tbody>
</table>

Table 1. Mean certified values (± standard error), and the range of percent recoveries obtained for metals in the reference material copepod homogenate, MA-A-1 TM, IAEA.

<table>
<thead>
<tr>
<th>Organ</th>
<th>Metal concentration/μg g⁻¹ dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu</td>
</tr>
<tr>
<td>Bone</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>Brain</td>
<td>9.8 ± 1.0</td>
</tr>
<tr>
<td>Egg contents</td>
<td>4.3 ± 0.5</td>
</tr>
<tr>
<td>Egg shell</td>
<td>1.0 ± 0.1</td>
</tr>
<tr>
<td>Feathers</td>
<td>19.5 ± 1.6</td>
</tr>
<tr>
<td>Heart</td>
<td>3.1 ± 0.6</td>
</tr>
<tr>
<td>Liver</td>
<td>39.2 ± 6.9</td>
</tr>
<tr>
<td>Lung</td>
<td>1.9 ± 0.3</td>
</tr>
<tr>
<td>Muscle</td>
<td>15.8 ± 1.1</td>
</tr>
<tr>
<td>Stomach</td>
<td>22.8 ± 3.8</td>
</tr>
</tbody>
</table>

Table 2. Descriptive statistics of trace metal concentrations in tissues and eggs of adult House Sparrows (Passer domesticus) from urban regions in the West Bank. Values represent means of 10 samples ± standard error. Minimum and maximum values are shown in parentheses.

2.2. Statistical analysis

Statistical analysis of the data was carried out using SYSTAT for Windows software (SYSTAT for Windows Inc.26). Differences were considered significant where P was ≤0.05. Data were tested for normality using the Shapiro–Wilk Normality Test before ANOVA was applied. The Tukey Test was used to determine which pairs of means differed significantly. The T-test was applied to check for differences between specimens from rural and urban environments and between males and females. Pearson’s correlation was applied to inspect correlations between metals in egg shell and egg contents.

3. Results and discussion

3.1. Metals in tissues and eggs

Some descriptive statistics of the concentrations of metals in tissues and eggs of the House Sparrows collected from an urban environment in the West Bank are shown in Table 2. Different tissues and eggs showed a great variation in mean metal concentration. Concentrations of Zn were the highest in all tissues analyzed, and those of Cd were clearly the lowest. Mean Cu concentration in tissues ranged between 0.81 μg g⁻¹ (bones) to 39.2 μg g⁻¹ (liver). Mean Cd concentrations ranged
between 0.01 µg g⁻¹ (egg shell) and 0.07 µg g⁻¹ (liver). Concentrations of Pb were between 1.41 µg g⁻¹ (muscles) to 34.2 µg g⁻¹ (liver) while concentrations of Zn ranged between 19.6 µg g⁻¹ (heart) to 150 µg g⁻¹ (bones). In general, the concentrations of Zn and Cu were always higher than those of Cd and Pb. This might be because the former two metals are essential, having a biological role, while the latter are non-essential metals that have no biological function.³ The levels of Pb were much higher than Cd in all organs, reflecting its abundance as an urban pollutant (lead fuel was still used in the Palestinian Territories at the time of the study). The low concentrations of Cd in different tissues could be due to the lack of heavy industry in the Palestinian regions. Similarly low concentrations of Cd in roadside plants (0.050–0.017 µg g⁻¹) and soil (0.09–0.59 µg g⁻¹) were observed in previous studies from the same region.²⁵ In addition, Jaradat and Momani²⁷ found that levels of Cd in roadside plants and dust from neighboring Jordan were below detection limits of the flame atomic absorption spectrophotometer.

Results of the present study were compared to other studies found in the literature for sparrows (Table 3). Cd concentrations in the present study were lower than those reported for Sparrows from other regions. On the other hand, concentrations of Pb were clearly higher than those reported in the literature, possibly due to the banning of leaded fuel in industrialized countries some time ago (up to the end of the study, leaded fuel was still used in the Palestinian Territories). The concentrations of the essential metals, Cu and Zn, were comparable to those found in the literature.

When ranked according to metal richness (Table 4), tissues and eggs showed a variable capacity for metal accumulation. This is clearly expressed by the high total rank score (TRS) of the liver (39) and the low one of the egg shell (10). Tissues and organs had the following order of metal richness: liver > stomach > bone > lung, feathers > muscles > egg contents, brain > heart > egg shell. The liver is the site of detoxification in the body; this explains its high metal content.

Gragnaniello et al.³ observed high concentrations of metals in House Sparrows from urban environments. Chao et al.²³ found that concentrations of metals in Tree Sparrows (Passer montanus) were high in liver and bones, and low in muscles. These results are in agreement with this study. The high metal concentration in the stomach may be because it was analyzed with its contents. This indicates the importance of food as a source of metals. According to Burger and Gochfeld,²⁸ avian exposure occurs from three sources: feeding (the major source), inhalation, and maternal metals deposited in eggs. Egg contents did not exhibit abnormal metal levels, indicating that House Sparrows do not sequester significant amounts of heavy metals in their eggs. Egg shell, on the other hand, contained twice as much Pb as egg contents, but less Cd, Cu and Zn. Walsh²⁹ found that Pb transfer to eggs is low. Dauwe et al.³⁰ found that egg contents from a polluted site had higher concentrations of the essential metals, Cu and Zn, than egg shell, but lower concentrations of Pb and Cd. These findings are in agreement with the results of the present study. According to Morera et al.³¹ Cu and Zn are carried by vitellogenin from the liver to maturing oocytes during egg formation. In egg white, ovalbumin and conalbumin bind both Cu and Zn (Richards and Steel³²).

Lungs and feathers occupied the fourth and fifth ranks in metal richness, respectively. The high rank occupied by the lungs could reflect atmospheric pollution in the urban environment. Use of feathers as biomonitor of heavy metal contamination has been recommended by many researchers.³³–³⁶ Metals in feathers reflect environmental contamination during the short period of feather growth but not necessarily body burden.³⁷ However, feathers have been promoted extensively as a non-lethal and non-invasive indicator.³⁴ In the present study, feathers were found to occupy the fifth rank in metal richness, which makes them good indicators for metals.

### Table 3 Mean concentrations of metals in livers of sparrows according to different studies found in literature, compared to the present study

<table>
<thead>
<tr>
<th>Region</th>
<th>Cu (µg g⁻¹)</th>
<th>Cd (µg g⁻¹)</th>
<th>Pb (µg g⁻¹)</th>
<th>Zn (µg g⁻¹)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>61.8</td>
<td>0.48</td>
<td>2.7</td>
<td>154</td>
<td>3</td>
</tr>
<tr>
<td>Urban</td>
<td>42.0</td>
<td>1.31</td>
<td>3.7</td>
<td>205</td>
<td>3</td>
</tr>
<tr>
<td>Industrial</td>
<td>17.2</td>
<td>0.24</td>
<td>107</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>25.7</td>
<td>0.12</td>
<td>137</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Non-industrial</td>
<td>15.5</td>
<td>0.24</td>
<td>104</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>27.0</td>
<td>1.01</td>
<td>172</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>27.0</td>
<td>0.07</td>
<td>18.0</td>
<td>97</td>
<td>Present study</td>
</tr>
<tr>
<td>Urban</td>
<td>38.2</td>
<td>0.07</td>
<td>37.6</td>
<td>121</td>
<td>Present study</td>
</tr>
</tbody>
</table>

### Table 4 Tissues and eggs of adult House Sparrows (Passer domesticus) from urban regions in the West Bank ranked according to their richness in metals. TRS: total rank score

<table>
<thead>
<tr>
<th>Organ</th>
<th>Cu (µg g⁻¹)</th>
<th>Cd (µg g⁻¹)</th>
<th>Pb (µg g⁻¹)</th>
<th>Zn (µg g⁻¹)</th>
<th>TRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone</td>
<td>1</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>Brain</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Egg contents</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>Egg shell</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Feathers</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Heart</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Liver</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>39</td>
</tr>
<tr>
<td>Lung</td>
<td>3</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>Muscle</td>
<td>7</td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>Stomach</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>32</td>
</tr>
</tbody>
</table>

### Table 5 Concentrations of metals in the liver of adult House Sparrows (Passer domesticus) collected from two regions in the West Bank. Values represent means of 10 samples ± standard error

<table>
<thead>
<tr>
<th>Region</th>
<th>Cu (µg g⁻¹) ± SE</th>
<th>Cd (µg g⁻¹) ± SE</th>
<th>Pb (µg g⁻¹) ± SE</th>
<th>Zn (µg g⁻¹) ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>39.2 ± 6.9</td>
<td>0.07 ± 0.00</td>
<td>34.2 ± 6.2</td>
<td>131.4 ± 14.3</td>
</tr>
<tr>
<td>Rural</td>
<td>27.0 ± 2.7</td>
<td>0.07 ± 0.00</td>
<td>18.0 ± 1.6</td>
<td>97.0 ± 3.7</td>
</tr>
<tr>
<td><em>P</em> (t-test)</td>
<td>0.039</td>
<td>0.957</td>
<td>0.005</td>
<td>0.029</td>
</tr>
</tbody>
</table>
be used as an indicator for these metals in the egg content. From the correlation coefficients, it is clear that the shell reflects the concentration of the Cu and Zn better than Pb. According to Dauwe et al., egg shell can be used as an indicator for metal pollution, especially in contaminated sites.

3.3. Metals in sparrows from urban and rural regions

In order to check the ability of the House Sparrow to reflect environmental differences in metal contamination, adult sparrows were collected from rural areas in addition to those from urban areas. Livers of Sparrows from urban areas were found to have significantly higher Cu, Pb, and Zn concentrations than those from rural regions (Table 5), indicating bioaccumulation of these metals in Sparrows from urban environments. Cd concentrations in specimens from urban and rural habitats did not show any significant difference. In a previous study, Swaileh et al. did not observe any elevated levels of Cd in roadside soil and vegetation from the West Bank. This means that, so far, Cd might not be an important pollutant in the Palestinian Territories. In addition, Jaradat and Momani found that levels of Cd in roadside plants and dust from neighboring Jordan were below detection limits of the flame atomic absorption spectrophotometer, which indicates that Cd is not a significant pollutant in the region. This is due to a lack of significant heavy industry. Generally, these results provide some early indications about the possibility of using the House Sparrow as a bioindicator for urban metal pollution. However, the diverse feeding habit of this bird must be taken into consideration when drawing conclusions concerning metal pollution relevant to human health.

3.4. Metals in males and females

No statistical differences between metals in the livers of male and female specimens were observed (Table 6). According to Donaldson and Braune, the principal reason for differences in metals between male and female birds is the ability of the female to deposit metals into eggs and the physiological differences with regard to some metals between males and females. He concluded that Cd and Pb are not readily transferred to eggs; therefore, they are not expected to differ

<table>
<thead>
<tr>
<th>Sex</th>
<th>Metal concentration/µg g(^{-1}) dry weight</th>
<th>Cu</th>
<th>Cd</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td>39.2±6.8</td>
<td>0.07±0.00</td>
<td>36.1±4.7</td>
<td>122.4±11.5</td>
</tr>
<tr>
<td>(n = 5)</td>
<td></td>
<td>(22.0–55.0)</td>
<td>(0.06–0.08)</td>
<td>(21.0–46.0)</td>
<td>(93.0–152.0)</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td>33.7±3.9</td>
<td>0.07±0.00</td>
<td>29.0±3.1</td>
<td>124.4±18.9</td>
</tr>
<tr>
<td>(n = 5)</td>
<td></td>
<td>(24.5–48.0)</td>
<td>(0.06–0.08)</td>
<td>(23.1–40.0)</td>
<td>(77.6–180.0)</td>
</tr>
<tr>
<td>(P) (t-test)</td>
<td></td>
<td>0.51</td>
<td>0.42</td>
<td>0.24</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Fig. 1 Metal levels in the livers of different age stages of House Sparrows (\textit{Passer domesticus}) collected from urban environments in the West Bank. 5–10 samples were analysed for each age stage.
between males and females. Hutton and Goodman 20 found that female Pigeons (Columba livia) from London had higher bone lead levels than males. Similar results were observed by Janiga and Zemberyová. 19

3.5. Metal accumulation with age

To determine metal accumulation with age of House Sparrows, eggs and specimens of different ages were collected and analyzed for metal content. Levels of Cu, Pb, and Zn were found to accumulate significantly (ANOVA, P < 0.001) with increasing age stage (Fig. 1). Cd levels, on the other hand, did not exhibit a significant accumulation pattern. The Tukey test showed that adults contained significantly higher levels of Cu, Pb and Zn than all other age stages, whereas all other pairwise comparisons between age stages resulted in no significant difference. The strongest multiple correlation (R) values were obtained for Pb (0.92), followed by Cu (0.88), and Zn (0.77). Fig. 1 shows that accumulation of these three metals starts early after hatching, and reaches a maximum value in adults. Adults contained about 4 times Pb as much as one-month-old juveniles and about 25 times as much as the eggs. They contained twice as much Cu as much as one-month-old juveniles and 9 times as much as the eggs. However, Zn levels in adults were about 1.5 times as high as in one-month-old juveniles and 2 times as high as in eggs. The concentration of Pb in adults compared to one-month-old juveniles or eggs reflects urban Pb pollution, which originates mainly from leaded gasoline. In addition, Pb is a non-essential metal that can be bioaccumulated in living tissues, Zn and Cu, on the other hand, are essential metals which play a biological role in living organisms such as in egg development and feather formation. 9,31 Nam et al. 39 investigated the effect of age on the accumulation of Pb and Cd in feral Pigeons (Columba livia), and found that concentrations of both metals increased in the order: eggs < chicks < adults. Burger 40 reviewed literature data on age differences in metal levels in feathers and found that age differences occurred for metals in 17 species. Burger and Gochfeld 41 found that young Brown Noddies and Wood Storks had significantly lower levels of Cd and Pb than adults. Maedgen et al. 42 found that concentrations of metals in adult Royal Terns were markedly higher than those in pre fledging terns, suggesting that accumulation of metals continues as birds age.

Acknowledgements

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References

Identification of Nitrate Sources in Groundwater by \( d_{15}N_{\text{nitrate}} \) and \( d_{18}O_{\text{nitrate}} \) Isotopes: A Study of the Shallow Pleistocene Aquifer in the Jericho Area, Palestine

Saed Khayat, Stefan Geyer, Heinz Hötzl, Marwan Ghanem and Wasim Ali

The article can be quoted as:

Identification of Nitrate Sources in Groundwater by $d_{15}N_{\text{nitrate}}$ and $d_{18}O_{\text{nitrate}}$ isotopes: A Study of the Shallow Pleistocene Aquifer in the Jericho Area, Palestine

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This study describes the impact of septic tanks on the groundwater quality of the shallow Pleistocene aquifer in Jericho area, Westbank, Palestine. Septic tanks are widely used for storage and disposal of sewage in the populated and agricultural city of Jericho. Routine hydrochemical tests for groundwater quality performed for several years identified the problem of a gradual nitrate increase, without pinpointing its definite sources. The geological formations of the Jericho area and the shallow nature of the Pleistocene aquifer, together with the mechanism of recharge, make the groundwater in this aquifer highly susceptible to contamination, particularly along sewers. The lithology of the Samara (high hydraulic conductivity) and the Lisan formation (low conductivity but increased infiltration along fractures) promote easy seepage of agricultural and anthropogenic inputs into the groundwater. Nitrate concentrations are elevated near septic tanks and animal farms, with nitrate values exceeding 74 mg/L. $\delta^{15}N_{\text{nitrate}}$ and $\delta^{18}O_{\text{nitrate}}$ signatures suggest sewage and manure as the main sources of high nitrate concentration in the groundwater. Samples taken during the end of the dry season indicate that a slight denitrification in the aquifer.

Keywords: Water quality / nitrate / pollution / isotope / N-15 isotope / O-18 isotope / Westbank, Palestine

1 Introduction

The problem of high nitrate concentrations in drinking water constitutes a major health risk to both humans and stock life. Nitrite reacts directly with haemoglobin in human blood and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen. This condition is especially serious for babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1 mg/L should not be used for feeding babies. Also the WHO assigned the nitrate of 50 mg/L as a health significant value in drinking water [1].

For this matter of fact, the identification of the possible sources of nitrate in groundwater is very important as a first step to solve these problems. Many studies were performed using hydrochemical ratios, but they didn’t identify the various possible sources. Stable isotope techniques have successfully been used for more than three decades [2]. Nitrate in the environment may have various sources, including atmospheric deposition, soil organic nitrification, fertilizer, sewage and manure. Nitrate from each source is typically characterized by a distinct isotopic signature. Typical $\delta^{15}N_{\text{nitrate}}$ values for chemical fertilizers range from ~4 to +4 ‰, for human and animal waste from +7 to more than +30 ‰, and for soil nitrate from less than −10 to +4 ‰.
On nitrate values for atmospheric deposition exceeds +25 ‰. For chemical fertilizers they range from +18 to +22 ‰, and for human and animal waste and soil nitrate +10 to +15 ‰. Hence, the isotopic composition of nitrate constitutes a useful tracer for determining nitrate sources, provided that no alteration of isotopic ratios by biogeochemical reactions such as denitrification has occurred.

Nitrogen isotopes, mainly $^{15}N$, provide information about nitrogen sources and sink. Furthermore, the nitrate $^{18}O$ and $^{17}O$ are promising new tools in determining nitrate sources and reactions, and complement conventional uses of $^{15}N$ [4], since they provide a mean to distinguish between nitrate of atmospheric deposition from fertilizers, sewage [5], and from soil nitrification processes [6].

The objective of this study is to use the tracer isotopes $^{15}N$ and $^{18}O$ to identify the main sources of nitrate in the shallow Pleistocene wells and springs in Jericho area, Palestine.

### Study area

Jericho is located at the eastern boundary of the West Bank. It extends from 10 km to the north of the Dead Sea, and 7 km to the west of the Jordan River (Fig. 1). While it has a desert climate, it is well protected by the Jerusalem and Ramallah Mountains in the west which make it an area of high water resources. Jericho has an area of approximately 35,330 hectares. Of this, 5,917 hectares are occupied by Palestinian settlements and 5,174 hectares are occupied by Jewish settlements. The rate of annual precipitation varies between 120 mm and 250 mm, with an annual groundwater recharge rate of about 180 Mio m$^3$, while the annual consumption rate is about 140 Mio m$^3$ distributed between domestic and agricultural use, according to ARIJ [7].

In general, the per capita water consumption for domestic use in the West Bank is between 30 l/d and 50 l/d. The quantity of wastewater generated in Jericho for 1996 [8] was about 2 Mio m$^3$. Wastewater collection networks are totally lacking in Jericho. Septic tanks are in common use for wastewater disposal, serving normally one or a cluster of houses.

The soil in Jericho developed mainly on top of the Samara formation which has a thickness of 20 m, and is composed of silt, clay, gravels, and conglomerates. The Samara formation possesses a good hydraulic conductivity and serves as a good groundwater reservoir. In contrast, the overlying Lisan formation has a thinner thickness of 30 to several hundred meters and is composed of clay and silt, chalk, gypsum, and argonites. The permeability of the Lisan formation...
is very low and the formation is considered an aquiclude \( (K \approx 4.6 \cdot 10^{-9} \text{ m/s}) \). However, because the unit contains thin sand and silt beds of 20 to 30 cm thickness and because of its high salt content, the water has developed pathways, resulting in relatively more porosity and permeability [9]. The septic tanks built mainly in the top few meters within the Samara layer are usually lined by concrete walls, sealing the four sides of the tanks but not the bottom [7]. Besides the possibility of waste seepage through the bottom, the concrete walls, especially in old tanks, may be fractured with time and, thus, wastewater seeps through these fractures (Fig. 2).

Jericho is considered to be an important agricultural area; it is the food basket of Palestine. High amount of fertilizers, up to about 82.697 t/a are used [8]. This amount which is mainly distributed on a seasonal basis does not reflect the application of nitrogen fertilizers, which comprises only a small part of the total fertilizer load. This applications lead to a fertilizer accumulation in the soil, percolating with the irrigation flow to the groundwater in the transmissive Samara formation.

### 3 Methods

In November 2003, water samples were collected from 19 working wells and 2 springs in the Jericho area (Fig. 1). The sampling covered most of the area surrounding Jericho city. The samples for nitrate analyses were collected in 60-mL bottles, preserved by HgCl₂, and kept in refrigerator. Nitrate was extracted by ion exchange from 1.5 L of water and converted to AgNO₃, as described in Silva et al. [10]. Collection of nitrate on an anion-exchange resin eliminates the need for sending large quantities of chilled water back to the laboratory, eliminates the need for hazardous preservatives, makes it easier to archive samples, and enables analysis of water with extremely low nitrate. Nitrogen and oxygen isotope measurements were performed by continuous flow isotope ratio mass spectrometry (CF-IRMS) with an overall analytical precision of \( \pm 0.1 \) \%o for \( \delta^{15}N \) and \( \pm 0.3 \) \%o for \( \delta^{18}O \) values.

CF-IRMS separates the ions of the element \( (^{14}N/^{15}N) \) on the basis of their different mass/charge ratio. Sample preparation consists of converting solid or liquid material to nitrogen gas \( (N_2) \) and isolating the particular gas for analysis.

All analyses were carried out in the Environmental Isotope Laboratory of the UFZ-Environmental Research Centre in Leipzig-Halle, Germany.

### 4 Results

Nitrate concentrations, \( \delta^{15}N_{\text{nitrate}} \) and \( \delta^{18}O_{\text{nitrate}} \) for groundwater sampled taken from 21 wells and springs are shown in Table 1. All of the wells are of the Pleistocene...
aquifer, while the springs are mainly draining from the mountain’s cretaceous aquifer through the fault system to the west. The nitrate concentrations varied depending on the well location and surrounding activities, the values were between 5.2 mg/L in the well (19-14/062) to the north-west of Jericho city and 72.7 mg/L in (19-13/006) which located within an area with extensive agriculture and green houses.

Table 1. Nitrate concentrations, $\delta^{15}N_{\text{nitrate}}$ and $\delta^{18}O_{\text{nitrate}}$, for groundwater samples of the Jericho area.

<table>
<thead>
<tr>
<th>Location</th>
<th>Well Name</th>
<th>Well Code</th>
<th>Nitrate mg/L</th>
<th>$\delta^{15}N_{\text{nitrate}}$</th>
<th>$\delta^{18}O_{\text{nitrate}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Springs Area</td>
<td>Ein Dyouk (Spring)</td>
<td>AC060</td>
<td>29.07</td>
<td>10.48 ‰</td>
<td>3.9 ‰</td>
</tr>
<tr>
<td>West spring Area</td>
<td>Ein Sultan (Spring)</td>
<td>AC061</td>
<td>42.46</td>
<td>10.08 ‰</td>
<td>3.3 ‰</td>
</tr>
<tr>
<td>Jericho North</td>
<td>Saeed Aladeen</td>
<td>19-14/062</td>
<td>5.18</td>
<td>10.12 ‰</td>
<td>13.9 ‰</td>
</tr>
<tr>
<td>Jericho North</td>
<td>Mohammed Masri</td>
<td>19-14/038</td>
<td>7.5</td>
<td>2.99 ‰</td>
<td>14.7 ‰</td>
</tr>
<tr>
<td>Jericho North</td>
<td>Samed</td>
<td>19-14/26a</td>
<td>15.97</td>
<td>15.78 ‰</td>
<td>8.5 ‰</td>
</tr>
<tr>
<td>Jericho East</td>
<td>Abdallah Araikat</td>
<td>19-14/049</td>
<td>30.58</td>
<td>8.14 ‰</td>
<td>3.4 ‰</td>
</tr>
<tr>
<td>Jericho East</td>
<td>Awni Hijazi</td>
<td>19-14/052</td>
<td>34.07</td>
<td>9.99 ‰</td>
<td>4.9 ‰</td>
</tr>
<tr>
<td>Qilt West</td>
<td>Basil Huseini</td>
<td>19-13/018</td>
<td>29.08</td>
<td>8.29 ‰</td>
<td>5.2 ‰</td>
</tr>
<tr>
<td>Qilt West</td>
<td>Basil Huseini</td>
<td>19-13/020</td>
<td>49.38</td>
<td>6.89 ‰</td>
<td>3.4 ‰</td>
</tr>
<tr>
<td>Qilt West</td>
<td>Fahmi Nahas</td>
<td>19-13/047</td>
<td>43.73</td>
<td>6.94 ‰</td>
<td>3.8 ‰</td>
</tr>
<tr>
<td>Qilt West</td>
<td>Fahmi Nahas</td>
<td>19-13/048</td>
<td>41.67</td>
<td>7.42 ‰</td>
<td>3.8 ‰</td>
</tr>
<tr>
<td>Qilt West</td>
<td>Salah Aroui</td>
<td>19-14/012</td>
<td>40.54</td>
<td>8.47 ‰</td>
<td>4.3 ‰</td>
</tr>
<tr>
<td>Qilt West</td>
<td>Sabiru Rantizi</td>
<td>19-13/006</td>
<td>72.71</td>
<td>9.29 ‰</td>
<td>2.3 ‰</td>
</tr>
<tr>
<td>Qilt East</td>
<td>Zuhdi Hashwa</td>
<td>19-13/052</td>
<td>46.55</td>
<td>7.7 ‰</td>
<td>4.3 ‰</td>
</tr>
<tr>
<td>Qilt East</td>
<td>Fahed Hishmi</td>
<td>19-13/015</td>
<td>33.24</td>
<td>8.5 ‰</td>
<td>4.8 ‰</td>
</tr>
<tr>
<td>Jericho East</td>
<td>Arab Project</td>
<td>19-13/069</td>
<td>24.51</td>
<td>10.9 ‰</td>
<td>7.3 ‰</td>
</tr>
<tr>
<td>Qilt East</td>
<td>Iron Factory</td>
<td>19-13/26a</td>
<td>70.13</td>
<td>9.64 ‰</td>
<td>5.2 ‰</td>
</tr>
<tr>
<td>Qilt East</td>
<td>Ibrahim Daek NW</td>
<td>NW</td>
<td>29.68</td>
<td>6.59 ‰</td>
<td>4.9 ‰</td>
</tr>
<tr>
<td>Jericho East</td>
<td>Arab Project</td>
<td>19-14/067</td>
<td>38.86</td>
<td>7.42 ‰</td>
<td>4.5 ‰</td>
</tr>
<tr>
<td>Jericho East</td>
<td>Arab Project</td>
<td>19-14/073</td>
<td>40.41</td>
<td>7.37 ‰</td>
<td>3.9 ‰</td>
</tr>
<tr>
<td>Jericho East</td>
<td>Arab Project</td>
<td>19-14/066</td>
<td>29.69</td>
<td>9.23 ‰</td>
<td>5.7 ‰</td>
</tr>
</tbody>
</table>

Figure 3. $\delta^{18}O_{\text{nitrate}}$ vs. $\delta^{15}N_{\text{nitrate}}$ isotopic composition of major nitrate sources [3].
The $\delta^{15}$N values ranged from $+3.0$ to $+15.78$‰. Oxygen isotope ratios of nitrate were around $+3.3$ to $+8.5$‰ with an exception of two samples having values of 13.9‰ and 14.7‰. These two anomalous signatures belong to samples with very low nitrate contents in the wells (19-14/038) and (19-14/062) north-west of the city.

5 Discussion

The ranges of signature of nitrogen and oxygen isotopes for various sources of nitrate are illustrated in Figure 3 [3]. Comparing with the given results, most of isotopic signatures suggest sewage or manure as the main source responsible for the higher nitrate concentrations, with $\delta^{15}$N values > $+7$‰, and $\delta^{18}$O values between $+3$‰ and $+6$‰. Some samples also show a slight denitrification trend. This process was significant in the Samed well (Figs. 4, 5). This reflects the dry season sampling (end of summer), with nearly no recharge and groundwater may have persisted in the reservoir for several months.

The values in Figures 5a and 5b show slightly increasing $\delta^{15}$N and $\delta^{18}$O with decreasing [NO$_3^-$]. These combined trends point to slight denitrification within the aquifer, where the heavy isotopes $^{15}$N and $^{18}$O are preferentially retained in the remaining nitrate [11].

Sewage is the main source of nitrate because it contains a high amount of urea and other organic and inorganic nitrogenous compounds. Manure under aerobic condition in shallow aquifers is another source of nitrate originating from oxidation processes. The presence of many animal farms, especially in the east of Wadi Qilt and Ein Dyouk areas support these interpretations, in addition, practice of using animal manure as natural fertilizers.

Two wells in the north show relatively small nitrate concentrations and much higher $\delta^{18}$O values (Fig. 5b). This may indicate a different (non-continuous) nitrate source, where nitrate may persist for a long time in the groundwater. The isotopic signature of these wells bears the isotopic signature of chemical fertilizers. The signatures are more isotopically depleted due to mixing with nitrate with different signatures of other sources such as sewage. The source that yields such lower nitrate concentrations also represents the residual nitrate from bacterial denitrification for sewage or manure and gives the high $\delta^{18}$O values, above $+12$‰.

6 Conclusion

- $\delta^{15}$N and $\delta^{18}$O values show that most of the groundwater samples from the wells and springs in Jericho area were dominantly influenced by nitrate derived from septic tanks.
- Sewage and manure appears to be the cause of increased nitrate concentrations.
- The application of fertilizers nitrate is of second importance, but this may vary with seasonal applica-
tion of the pesticides and with chemical composition of the fertilizers.

- Long persistence of nitrate within the groundwater reservoir during the dry season (sampling time) gives a good chance for the beginning of denitrification processes within the aquifer.

- The enriched $\delta^{15}$N$_{nitrates}$ and $\delta^{18}$O$_{nitrates}$ values in the northern wells reflect sources of nitrate other than just sewage. This signature may arise from a mixing trend between chemical fertilizers and the residual nitrate from bacterial denitrification of sewage.

We express our gratitude for the German Federal Ministry of Science and Research (BMBF) (Dr. J. Metzger and Dr. S. Kiefer) for funding this project. Our deep thanks also go to the PHG-Palestinian Hydrology Group in Jerusalem, Palestine, for their logistic and technical support in the field. We thank the group
of Dr. Kay Knoeller, UFZ Department of Isotope Hydrology, for measuring water samples for stable isotopes.

References


Not a single drop of water falling from the sky should go to the sea before serving the mankind....

King Parakrama Bahu
Workshops and Training

- In February 2006, the WSI in cooperation with the Center for Continuous Education (CCE) at Birzeit University organized a training course entitled: “Water Net Design through E-learning” for Palestinian engineers from municipalities, village councils, governmental and nongovernmental institutions working in the fields of water and environment. By the end of the training course, the trainees were able to design a project via computer, which shows a new way of learning away from the known way of class lectures.

- On May 29, 2006, within the activities of WaDImena project, the WSI organized a workshop on “Social and Economic Assessment for Reuse of Treated Effluent from Al-Bireh Wastewater Treatment Plant in Irrigated Agriculture”. After giving a brief description about WaDImena project and the aim of the workshop by the director of WSI – Dr. Ziad Mimi, the project team leader Dr. Maher Abu Madi presented to attendants the research objectives, activities, methodology, expected outcomes and results.

- On May 2, 2006, the WSI started a series of training courses held at the WSI for the third year within the activities of EMWater-MEDA project in cooperation with InWEnt. The series entitled: “Efficient Management of Wastewater: its Treatment and Reuse”, consisted of six blocks that were held between May 2006 and September 2006. The participants in these blocks were Palestinian engineers and professionals working in water/wastewater management as well as in the environmental sectors.

- InWEnt is an international organization for training and human resources development that has been entrusted by the European Commission to implement a project co-funded from the German Ministry for Economic Co-operation and Development (BMZ) entitled “Efficient Management of Wastewater, its Treatment and Reuse in the Mediterranean Countries”. Participating countries of this project include Germany, Italy, Turkey, Jordan, Lebanon, as well as Palestine.

- In July 2006, the WSI at Birzeit University organized a training course entitled: “Vocational Trainings on Water Management in Water and Sanitation Sectors” for Palestinian engineers and professionals working in the fields of water and environment at the Gruppo Di Volontariato Civile (GVC). The training course was funded by the European Commission Humanitarian Aid Office (ECHO) within the framework of the ECHO/-ME/BUD/2005/0105 project.
implemented by Gruppo di Volontariato Civile (GVC) and Palestinian Hydrology Group (PHG) and took place at the WSI from July 29, 2006 until August 17, 2006.

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**New Publications**

- Within the activities of the EMWater project under the MEDA WATER PROGRAMME initiative and funded by the European Union, the WSI at Birzeit University published a book entitled "Efficient Management of Wastewater, its Treatment and Reuse in Four Mediterranean Countries". In addition to the WSI, the following Institutions participated in editing the stated book:
  - Al Al Bayt University – Jordan
  - InWEnt Capacity Building International, Germany
  - Jordan University – Jordan
  - Adelphi Research gGmbH – Germany
  - ENEA – Italy
  - Hamburg University of Technology – Germany
  - Lebanese American University – Lebanon
  - University of Balamand – Lebanon
  - Yildiz Technical University – Turkey

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**Staff News**

- In May 2006, Dr. Rashed Al-Saed has been promoted to Associate Professor at the WSI – Birzeit University.

- Within the framework of staff exchange program of PoWER partnership, Dr. Nidal Mahmoud was hosted by UNESCO-IHE during the period (21 June till 21 August 2006). During his staff exchange visit Dr Mahmoud conducted a comprehensive literature review on leachate characterization and treatment targeting groundwater protection particularly in developing countries. He had given several lectures about Leachate Characterization and Treatment Methods within the international course on Solid Waste Management and Engineering which is offered at UNESCO-IHE for international professionals as well as the regular MSc students. In addition, He had organized and chaired an international face to face workshop on the application of low cost sanitation systems based on onsite anaerobic sewage treatment in UASB-septic tank systems in Africa and in the Arabian Peninsula during the period 24 – 30 July 2006.

- Within the framework of staff exchange program of PoWER partnership, Dr. Maher Abu-Madi spent one month (23 June till 23 July 2006) at UNESCO-IHE Institute for Water Education.
During this period, he developed a research strategy for the 18 partner universities and institutes. He was nominated to present this strategy on the 4th of July 2006 at the Dutch Ministry of Foreign Affairs for potential financial support.

New Funded Projects

- The Partnership for Water Education and Research (PoWER) has funded two new research proposals submitted by the WSI.

The partners in the first proposal which is entitled: “Influence of Urban Development on the Quality of Groundwater. Guidelines Design for Groundwater Protection” are:

- Universidat Blas Pascal, Argentina
- Birzeit University / WSI, Palestine
- Indian Institute of Technology, India

The partners in the second proposal which is entitled: “Community Onsite Anaerobic Sewage Treatment in Hybrid and UASB – Septic Tank Systems” are:

- Birzeit University, Palestine
- WEC- Sana’a University, Yemen
- University of Zimbabwe

New Defended Masters Theses

The following theses were successfully defended at the WSI from March 2006 to September 2006. Hard copies of the theses are available in the main library at Birzeit University.

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