

Water Pollution Control - A Guide to the Use of Water Quality Management Principles

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Case Study XII* - Kingdom of Jordan

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XII.1 Introduction

This case study focuses on the management and control of wastewaters and water pollution sources in the Hashemite Kingdom of Jordan in order to increase the available supply of waters of suitable quality on a sustainable basis. Although applicable to the whole of Jordan, special emphasis is placed on the Amman-Zarqa region because of its high level of population and economic activity. Due to low rainfall and increasing water supply demands, Jordan has to consider all possible methods of water conservation and reuse.

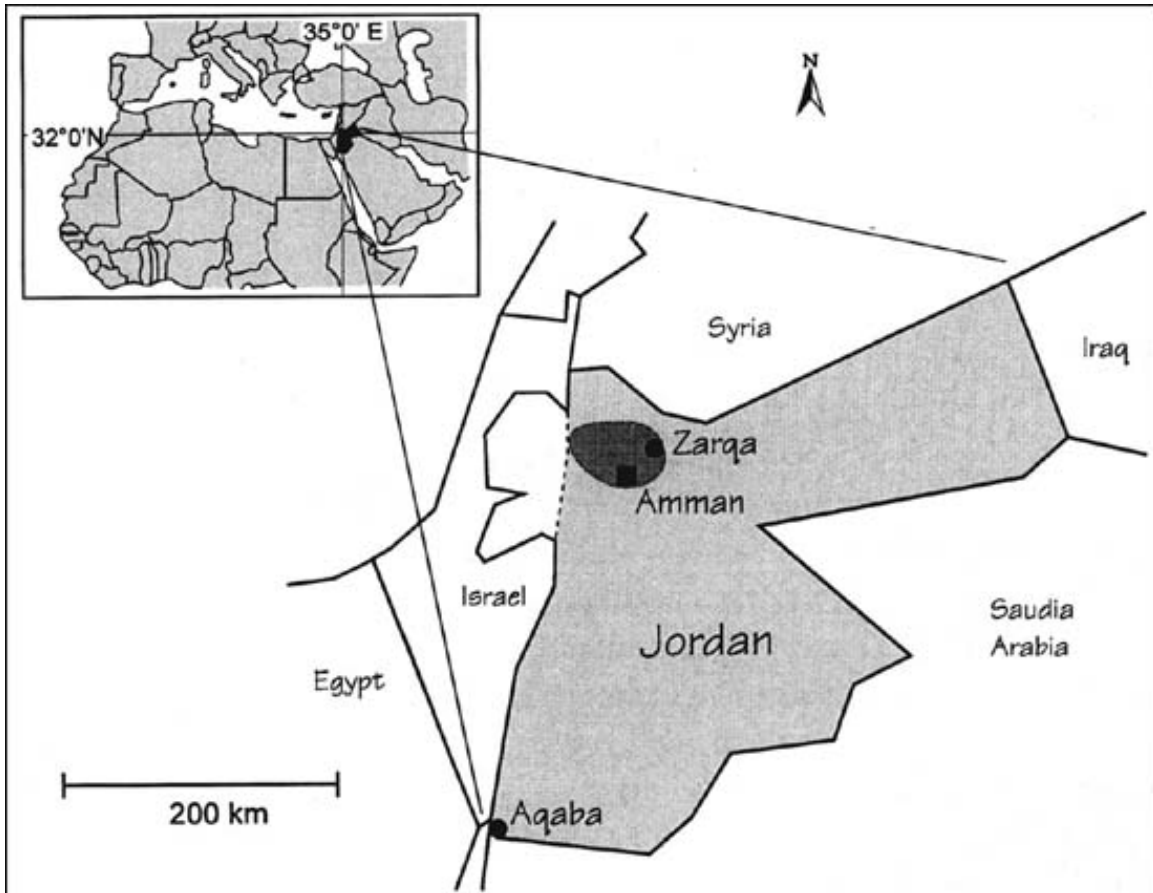
This case study presents an analysis of the water pollution problems in Jordan and identifies some solutions. The basic information and data presented here were gathered by the author, with the assistance of others, during a consulting assignment in Jordan under a contract through the United States Agency for International Development (USAID) in 1992.

XII.2 General information on Jordan and Greater Amman

Jordan is typical of countries in the Middle-East (Figure XII.1) facing population and development growth, while still limited by their water resources. Figure XII.2 shows rainfall distribution in Jordan as isohyets for a normal year. The more acute water problems occur in the more highly populated areas of Jordan, including Amman and Zarqa (see Figures XII.1 and XII.2). Figure XII.3 shows monthly and mean annual rainfall data for an Amman rainfall station. Typically, rainfall occurs from October to April, with over 75 per cent occurring during the four months of December to March.

According to a Greater Amman Planning Report published in 1990, the total population of Jordan was estimated at 3,112,000, of which 2,177,000 (70 per cent) were urban (10 per cent in refugee camps and informal areas) and 935,000 (30 per cent) were rural. Assuming an increasing urban population, the total population in the year 2005 is projected to be 4,139,000, of which 3,158,000 would be urban and 981,000 would be rural.

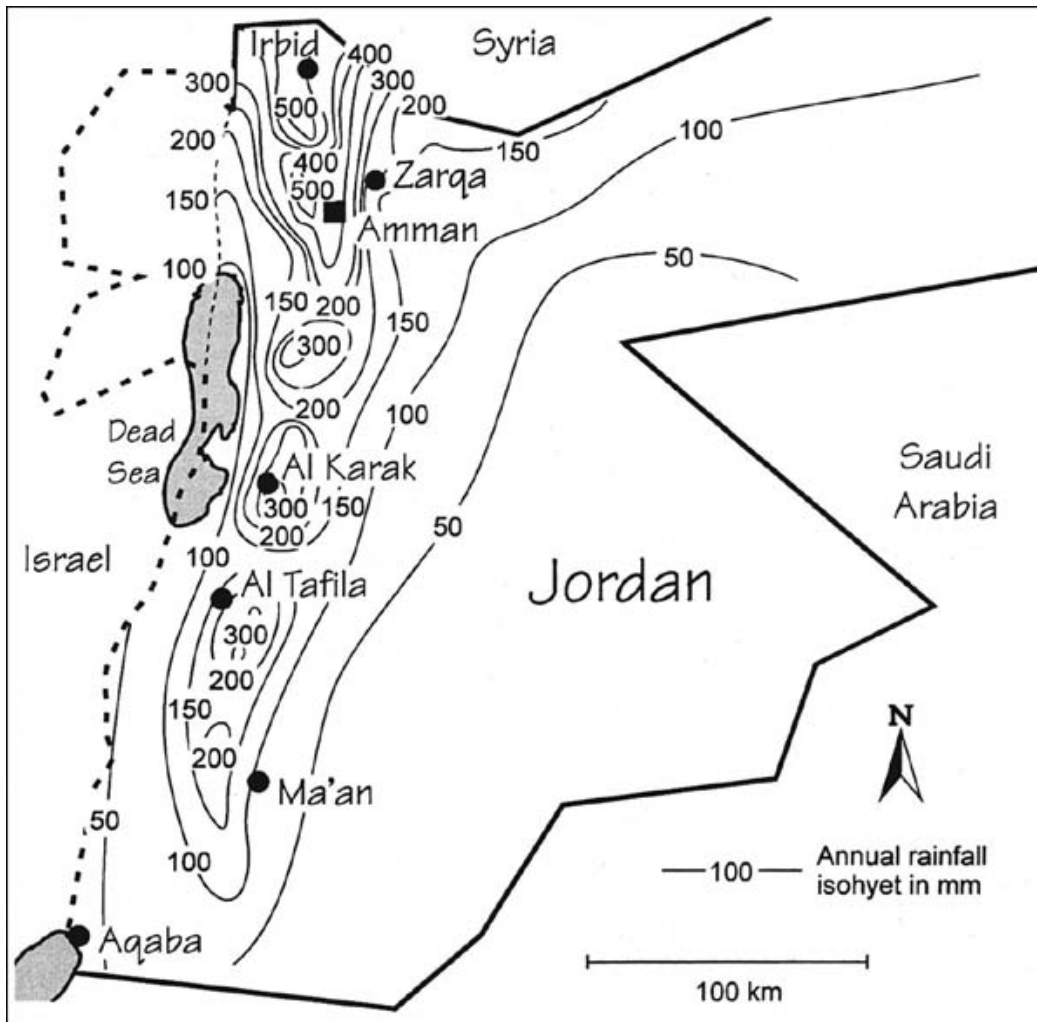
Figure XII.1 Location map of Jordan, indicating Amman and Zarqa where some of the more acute water shortages occur



In 1985, the population of Greater Amman was 900,990. There were 144,708 households of which 141,000 occupied dwellings and 16,000 buildings were vacant. Low-rise apartment buildings accounted for 60 per cent, one or two story villas and houses accounted for 30 per cent and single story buildings dwellings accounted for 10 per cent of dwellings. The projected population for the year 2005 is 2,000,000.

Figure XII.4 shows the projections for water supply and demand in Jordan between 1990 and 2015 as determined in a water management study for USAID (USAID/Jordan, 1992). The projected shortage represents a formidable deficit. The study concluded that no single supply management method could solve this shortage, but that a combination of management alternatives would probably prove to be the best solution. Some of the wastewater control alternatives considered are discussed in this case study.

Figure XII.2 Rainfall distribution as isohyets for a normal year (long-term average) for Jordan



XII.3 Wastewaters and water pollution control

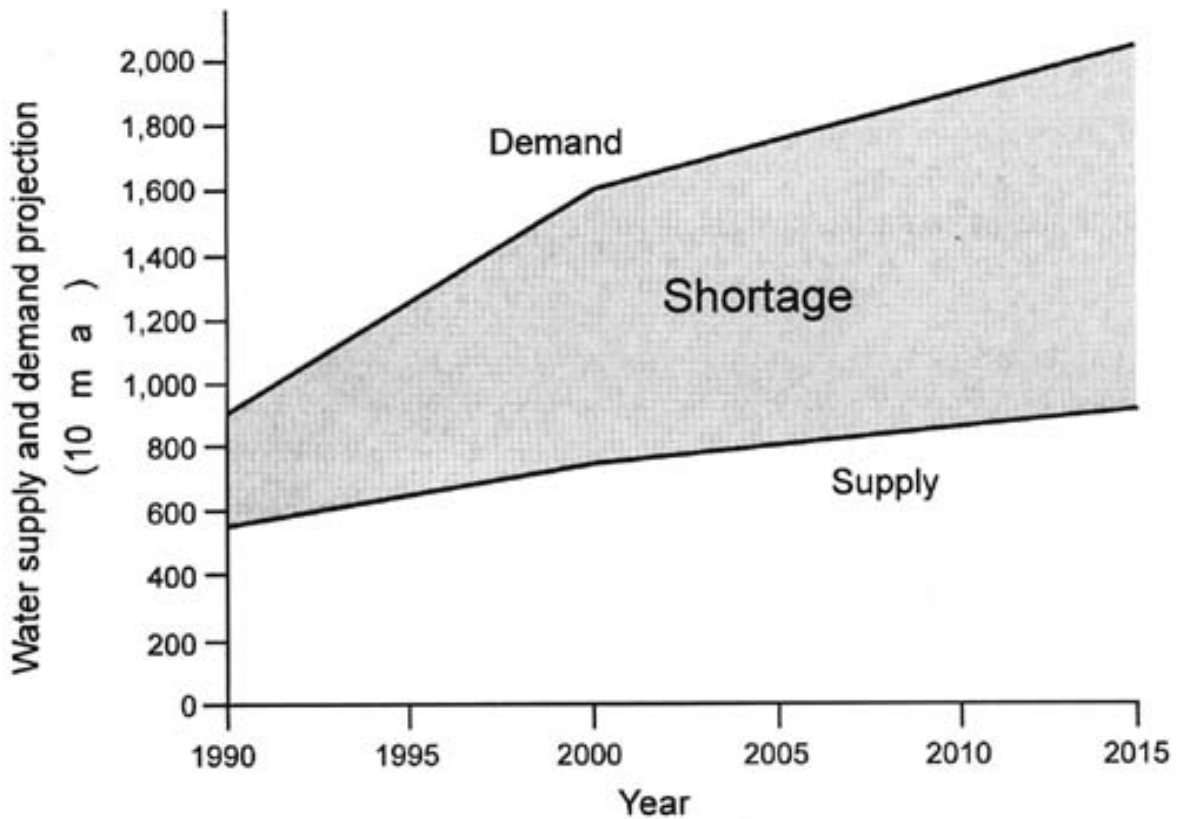
The major discharges of wastewaters are from municipal treatment plants and industrial and commercial operations. The largest contributors are concentrated in the Zarqa River Basin, including the Amman-Zarqa region. There are 14 major wastewater treatment plants (WWTPs) operating in Jordan. The As-Samra plant, serving Amman and Zarqa, has the greatest capacity with a current flow of about 100,000 m³ d⁻¹. Other existing and proposed plants include a range of treatment processes, but waste stabilisation ponds are the most common method used.

There are more than 100 major wet-type industrial operations (i.e. those industries which use water in some form of processing and which produce wastewater, such as the chemical industry, pulp and paper mills and food and drink processing) in the Amman-Zarqa region, as well as hundreds of additional smaller industrial operations and commercial shops which discharge small amounts of wastewaters. Of a total of 108

- The Ain Ghazal WWTP being taken out of service and its load being transferred to As-Samra.
- Increased wastewater loads and diversions to As-Samra.
- Increased septic tank dumpage (sewage pumped from septic tanks and dumped into the pond influent for further treatment).

The original wastewater treatment ponds were designed to handle an average of 68,000 m³ d⁻¹ but current flows are about 100,000 m³ d⁻¹ or greater. In 1991 the average annual flow to the As-Samra ponds was 97,471 m³ d⁻¹. The chemical oxygen demand (COD) of the influent was 1,574 mg l⁻¹ and the biochemical oxygen demand (BOD) was 703 mg l⁻¹. The effluent had 180 mg l⁻¹ of suspended solids and a BOD of 104 mg l⁻¹ effluent (equivalent to an 85 per cent removal). The effluent is usually high in nutrients (as ammonia nitrogen and phosphorus) and high in coliform bacteria (total and faecal). Consequently, downstream water quality, in the Wadi Zarqa, River Zarqa and King Talal Reservoir, has been deteriorating continuously. Studies by Engineering-Science, Inc. (1992) have shown that nutrients in the Wadi Zarqa averaged 4 mg l⁻¹ N and 0.3 mg l⁻¹ P during the one year period, 1989-90.

Figure XII.4 Water supply and demand for Jordan projected from 1990 to 2015 (After USAID/Jordan, 1992)



Emergency standby handling and containment facilities are needed at all WWTPs, including municipal and industrial plants, in order deal with spills and discharges during equipment failures. There is also an urgent need for such a system for the Ain-Ghazal/As-Samra siphon-pump where overflows into a nearby wadi occurred during storms in 1992. A further threat is the possible failure or rupture of the 39 km long, 1,200 mm diameter, siphon to the WWTP ponds.

The control of toxic and hazardous wastewaters and sludges is urgently needed. Sources of toxic and hazardous wastewaters include WWTPs and industrial wastes which are discharged to sewers, to receiving streams and to stormwater run-off as a result of spills. This is a problem of major concern in the Zarqa river basin where contamination in the food chain exceeds acceptable health limits. Studies on hydrochemical pollution of the Amman-Zarqa basin by Hanaineh-Abdeinour *et al.* (1985) during 1979-81 showed an "*obvious increase in trace elements*". The study classified the Amman-Zarqa waters at that time as "*weakly to heavily polluted*". Heavy pollution was mainly caused by: Cd, NO₃, SO₄, Cl, K and Na. Several trace elements were also observed to be increasing, including Fe, Pb, Mn, Zn, Cu and Cr.

Significant increases in elements normally associated with industrial discharges were also identified as follows: Cl showed a 6.5 fold increase, NO₃ showed a 2.2-fold increase, SO₄ showed a 5.0-fold increase and TDS showed a 2.2-fold increase. Although these results do not present a complete inventory of elements in all the possible toxic and hazardous industrial wastes being discharged, they do show an emerging pattern of concern. It is expected that these concentrations will have continued to increase since the study was carried out. A central toxic and hazardous waste treatment facility is needed for the handling and disposal of these wastes.

Inadequate on-site, pre-treatment of industrial wastewaters is a prevalent problem. Although many industries have on-site treatment facilities, they are generally inadequate as indicated by the discharges being directed to the As-Samra WWTP. Data show that the COD and the total suspended solids (TSS) concentrations in the influents are extremely high at all of the 14 major plants in Jordan, largely due to the discharge of industrial wastes. Ordinary domestic sewage in Jordan typically has BOD values in the range of 600-700 mg l⁻¹, but industrial discharges may drastically increase these values, such as at the Irbid plant where the influent has a BOD of around 1,140 mg l⁻¹. Available data show that all of the 14 major WWTPs are receiving industrial discharges, and for nine out of the 14 plants the treatment efficiencies are reasonable, giving 90 per cent BOD removal or more. Nevertheless, the discharges are still exceeding desired limits. Effluents should have less than 30 mg l⁻¹ BOD, 30 mg l⁻¹ TSS and 60-100 mg l⁻¹ COD. Several of the plants are achieving these results but most are not, particularly the As-Samra waste stabilisation ponds at their current load.

Government instructions for discharging industrial and commercial wastewater into public sewers, as published in the official newspaper of the HKJ on 17 September 1988, Edition No. 3573, prescribe the following limits: 800 mg l⁻¹ BOD, 1,100 mg l⁻¹ TSS, 2,100 mg l⁻¹ COD, 50 mg l⁻¹ P and 50 mg l⁻¹ fat, oil and grease (FOG). Although these are relatively lenient limits and regulations, a survey of municipal WWTP concentrations indicated that a large number of industries were not complying with them. In order to bring WWTP effluents into a desired range of compliance, there is a need for much higher level of on-site, pre-treatment by all industries, together with consistent monitoring.

Waste minimisation measures are needed. Although certain private organisations, such as the Chamber of Industries, are available to promote the activities of industries and commercial operations, there is a lack of effort to minimise waste discharge in an organised way.

A more direct and effective method of technical assistance to industries in relation to WWTP requirements is needed. In most cases, managers and WWTP operators are willing to provide proper treatment facilities, but are uncertain about the actual treatment facilities required. Industries in the same proximity should also be encouraged to combine their needs into a mutual WWTP for greater efficiency.

A more effective and responsive approach is needed for monitoring and compliance. At present, industries may be informed of non-compliance by the discharges from their WWTP effluents, but they need further information on the proper technical approach for rectifying the problem. There is a need for a more responsive "link" between monitoring and compliance.

Basin-wide comprehensive water quality management programmes and an environmental protection agency are needed in order to cross environmental boundaries and to follow the effects of a range of environmental emissions, not only in water but also in other media such as air, solid waste, soil and sediments. Table XII.1 gives, as an example, the trends between 1987 and 1989 in average values for selected toxic elements in the reservoir sediments of the King Talal Reservoir. The results were reported by Gideon (1991) from data compiled from reservoir suspended sediment annual reports.

In the same study, selected boreholes (water wells) in the Amman-Zarqa catchment area in 1990 showed heavy contamination with TDS, Na, Cl and NO₃. Although polluted water discharges are largely responsible for this gross contamination of resources, there are associated emissions in other media (e.g. air) which should be investigated in a co-ordinated way.

Table XII.1 Average concentrations of toxic elements in sediments of the King Talal Reservoir, 1987-89

Variable	1987	1988	1989
Iron (mg kg ⁻¹)	17,392	19,094	25,110
Aluminium (mg kg ⁻¹)	12,275	17,869	22,077
Arsenic (mg kg ⁻¹)	2.80	1.53	4.36
Cadmium (mg kg ⁻¹)	11.80	6.66	8.78
Chromium (mg kg ⁻¹)	36.0	36.0	42.3
Lead (mg kg ⁻¹)	35.0	41.0	44.0
Manganese (mg kg ⁻¹)	362	413	442
Zinc (mg kg ⁻¹)	90	97	108

Source: Gideon, 1991

Training programmes in basic water pollution control awareness and WWTP operation and maintenance are needed immediately. Although many water pollution control professionals within the government and involved in WWTP operation and maintenance have impressive educational backgrounds, there is a need to focus more closely on practical problems in the field. For example, although university educated engineers are expected to be capable in the basic aspects of wastewater management, they very often lack practical experience, especially where financial resources are extremely limited. Seminars and symposiums are excellent for drawing attention to problems. In addition, continuous workshop-type training is needed for all operational personnel in both government and industry.

XII.5 Management solution alternatives

In this section management alternatives for solutions to the problems discussed above and their associated needs are considered in the same order as above. Water conservation and sustainable quality effects are also noted.

Expansion and improvements in the Ain-Ghazal/As-Samra wastewater treatment system are believed to be in progress in order to alleviate the major problems in this area. This expansion should meet all current and future effluent requirements through to the year 2015. Assuming that the existing As-Samra waste stabilisation pond system will be expanded and improved, there will be some increase in evaporation losses from the ponds. These losses could be partially off-set by covering the anaerobic ponds with floating Styrofoam sheets or other floating material. These ponds do not need to be open to the atmosphere. Based on an area of 18 ha of anaerobic ponds with an evaporation rate of approximately 2.0 m a^{-1} , covering the ponds would save approximately $360,000 \text{ m}^3 \text{ a}^{-1}$. Covering the other ponds, i.e. aerated, facultative and maturation ponds, is not recommended because it would interfere with the treatment processes and because the costs of such untried methods would be uncertain. The bottoms of the ponds can be sealed thereby eliminating seepage losses equivalent to about 5 per cent of the pond inflow. Seepage losses for a flow of $100,000 \text{ m}^3 \text{ d}^{-1} \text{ a}^{-1}$ at 5 per cent loss would be $1.8 \times 10^6 \text{ m}^3 \text{ a}^{-1}$. Such a water loss is worth recovering using a low cost method such as bottom sealing.

An alternative also worth investigating is the possible development of a small hydro-power station using the flow and head of the pond effluent. A suitable site could be downstream on the Zarqa river where heads in the range of 50-100 m may be available. Based on a flow of $100,000 \text{ m}^3 \text{ d}^{-1}$, the following power generation could be possible:

- For a head of 50 m: approximately 600 horsepower or 400-500 kW.
- For a head of 100 m: approximately 1,200 horsepower or 800-1,000 kW.

Although the power that could be generated is not great, there would also be some water quality benefits downstream. In fact, the most important effect of the As-Samra treatment system improvements will be realised in downstream water quality improvements in a range of water resources.

Emergency standby handling and containment facilities for all WWTPs and industrial plants are needed to contain spills and accidental discharges. The Ain-Ghazal siphon-pump system is currently causing the most concern. The benefits of installing such

facilities include the prevention of water quality degradation in rivers and streams. These benefits could be quantified using risk analysis techniques.

Control of disposal of WWTP sludges and industrial toxic and hazardous materials is required. Municipal WWTP sludges are normally not considered to be hazardous and therefore may be used as a soil conditioner in certain restricted areas. Although they have some fertiliser value, it is generally not worth further processing to market as a cost-recovery product. Waste stabilisation pond systems produce very little sludge, which is one of their major advantages. The existing As-Samra anaerobic ponds require de-sludging only after intervals of several years of operation. In addition, the sludge quantities produced are relatively small. The other ponds, employing facultative and maturation processes, never need to be de-sludged if properly operated.

The disposal of industrial sludges, including toxic and hazardous materials, is a much more difficult problem requiring special handling and disposal methods. A hazardous waste treatment facility for the Amman-Zarqa industrial complex is currently in the planning stage through the World Bank Industrial Waste Unit. This will allow industries to use a central service and should prevent indiscriminate disposal and miscellaneous discharges into the sewers and streams. Similar facilities in other governorates may be needed as industrial development increases.

As far as possible, all industries should be required to connect to the sewer system and to provide on-site, pre-treatment which will control effluents according to standards. As an economy measure certain industries in close proximity could combine their discharges for treatment in a common facility. An industrial waste discharge fee system, based on quantity and quality, would also encourage on-site pre-treatment and compliance because of the costs incurred for violations. However, this approach must be combined with an efficient monitoring and enforcement mechanism.

By instituting a fee system, based on quantity and quality, it is expected that industries will be much more responsive to reductions in water use and waste disposal, mainly because of the possible cost associated with non-compliance. Coupling this system with an industrial waste minimisation programme is expected to reduce industrial water demand by 50 per cent within an 8-year period. Vast improvements in water quality control could also be expected. Further, the collection of fees would help to fund better monitoring and enforcement.

Industrial waste minimisation is the application of low-cost, low-risk alternatives for reducing and reusing waste materials. A broad range of cost savings is possible for conservation of water as well as for conservation of other valuable materials. A typical industrial waste minimisation programme should include the following management initiatives: waste audits, improved housekeeping, substitute materials, and recycling and re-using wastes.

In wet-type industries, water savings can be dramatic in well-managed programmes, with savings in water consumption up to 70 per cent or more in certain industries over an 8-year period (Center for Hazardous Materials Research, 1991). Although difficult to quantify, improvements in the water quality of industrial effluents can be expected to be even more dramatic than those achieved in water conservation, especially for toxic discharges. Many of the industrial chemicals in waste streams can be recovered and

reused, e.g. chrome in tannery wastes, with considerable cost recovery benefits to the industry. Benefits may also occur in reduced wastewater effluent charges under the industrial waste discharge fee system.

Industrial managers have expressed the need to be more closely advised on their WWTP requirements so as to be more responsive to the discharge regulations. An alternative approach to this problem would be to arrange for direct technical assistance through existing private industrial support agencies in close co-ordination with the governmental ministries in charge of monitoring and compliance. This technical assistance should be closely coupled with monitoring results obtained by the appropriate Ministry. Although not possible to quantify, long-term improved technical assistance should accrue significant benefits.

Consistent and effective monitoring is fundamental to the enforcement of compliance with effluent standards. Currently, the system only identifies non-complying WWTPs and industries sporadically and often problems are not corrected. Therefore, in order to be more effective in correcting problems, it has been suggested that non-compliance notifications should be coupled with immediate technical guidance either from the appropriate ministry or from a private industrial support agency, together with a deferred time period in which to make corrections and to achieve compliance. Although such measures can be expected to enhance water quality, the benefits cannot be measured directly.

Comprehensive water quality management programmes are required through river basin authorities. A wide range of environmental emissions occur, particularly in industrial areas such as the Zarqa river basin, and therefore it has been suggested that water quality management and monitoring should be co-ordinated to trace contamination in the full range of water resources and environmental media. This would include flowing surface waters, impoundments, water supplies, drinking waters, irrigation waters, groundwaters, wells, soil contamination, irrigation use, pesticide applications, pollution from urban run-off, non-point pollution sources, air pollution and solid waste disposal. Such a basin-wide programme is best accomplished through river basin authorities or through an environmental protection agency which would cross ministerial boundaries but could still integrate the efforts of various ministries. Through this approach, problems can be traced and corrected more responsively. These new authorities or the environmental protection agency should have certain enforcement powers.

River basin authorities have been highly successful for water pollution control in various developed countries; examples include Ruhr Verbands in Germany and River Commissions in the USA. The expected benefits include enhancement of water quality and enforcement efforts that will be more responsive and better co-ordinated.

Certain training programmes have been recommended as being required immediately and could be the key to most of the problems discussed above. The most immediate need is for the training of appropriate government engineers and scientists, WWTP managers and operators of municipal and industrial plants. Beyond this initial need, a broader training programme should include other government water resource control management personnel, private sector industrialists, selected consultants and industrial service company principals. The subjects that could be included in the training programme, depending on the personnel to be trained and their needs, are as follows:

- Basic water pollution control.
- Point-source pollution.
- Non-point source pollution.
- Pollution prevention and waste minimisation.
- Pollution measurement and monitoring.
- Industrial water conservation.
- Pollution control audits and feasibility studies.
- WWTP design and equipment requirements.
- WWTP operation and maintenance.
- Equipment requirements, costs and project financing.

Along with the proposed training programmes, two demonstration facilities should be set up for use in connection with the training programme. These would be a typical industrial plant with a WWTP and a typical municipal WWTP.

The overall objective of the broader training concept programme is to produce an environmental awareness which will form the basis for establishing higher priorities in water conservation and quality control throughout the country. Although the benefits of these training programmes are not directly measurable, they will be immediate and far reaching.

XII.6 Recommendations and possible results

The major discharges of wastewaters in Jordan are from municipal and industrial WWTPs, with the largest plants located in the Amman-Zarqa region. The effluents from the As-Samra waste stabilisation pond system and from over 100 wet-type industries in this region constitute by far the largest portion of the total available wastewater flows that require water conservation and quality management. The most immediate priority recommendations for achieving benefits in water conservation and water quality are:

- An improved Ain-Ghazal/As-Samra treatment system.
- Implementation of an industrial waste discharge fee system.
- Implementation of an industrial waste minimisation programme.
- Training programmes in water pollution control and WWTP operation and maintenance.
- Investigation into a small power station using the As-Samra effluent.

Longer-term water conservation and water quality effects will result from the following actions:

- Basin-wide water quantity and quality management through river basin authorities or an environmental protection agency.
- Effective water quality monitoring and compliance.
- Technical assistance to industrial waste dischargers.

- A central toxic and hazardous waste handling and treatment facility.
- Emergency handling and containment facilities for all WWTPs and industrial waste dischargers.

The above recommendations will result in significant water conservation savings, but the greatest effects are expected to be achieved in water quality enhancement. Although the benefits of water quality improvements are difficult to quantify, the effects of the improvements become quantifiable in terms of water available for reuse for a variety of purposes. Thus water quality improvements will have far reaching benefits for overall water use throughout Jordan.

XII.7 References

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