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Quality Appraisal of Effluent from Unayzah City Wastewater Treatment Plant for Irrigation Reuse

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ABSTRACT. The suitability of the sewage effluent from Unayzah City (Central Region of Saudi Arabia) wastewater treatment plant for irrigation reuse was assessed during four consecutive years by considering some of its physico-chemical and microbiological characteristics. Processing of the available data and thereafter comparing them with the locally and internationally acceptable quality standards for unrestricted and restricted irrigation reuse revealed that 1) the expected yearly average volume of treated wastewater varies from 26.4×10^5 to 36×10^5 m^3, 2) the effluent under study is marginal with respect to its mean BOD level range (range: 14.3-17.8 mg/L) and mean total suspended solids contents (range: 23.3-25.3 mg/L), 3) electric conductivity (EC) mmhos/cm and pH-value of effluent are within the acceptable quality limits and are not expected to cause severe problems, 4) high total coliform count (48.2×10^2– 137.9×10^2 MPN/100 ml) was evident inspite of achieving between 99.92-99.96% mean removal efficiency which renders the effluent unacceptable for unrestricted irrigation reuse because of public health hazards aspects.

Introduction

Groundwater is the main irrigation water resource in Al-Gassim region of Central Saudi Arabia. The main aquifer which could supply irrigation water in Al-Gassim is the Saq Sandstone (Fig. 1) which contributes about 85% of the present total water use. Due to the rapid growth of irrigated agriculture and high technology of drilling wells, the rate of water withdrawal from the Saq aquifer is about ten times the recommended rate. This over exploitation of the Saq groundwater may lead to severe water shortage for Al-Gassim agriculture in the future. According to Kadaj (1991), a prominent desalination expert and international consultant in advanced water technology, water, not oil, by the year 2000 will be the dominant resource issue of the Middle East. Among the reasons he has cited for an imminent water crisis is the dramatically increased water con-

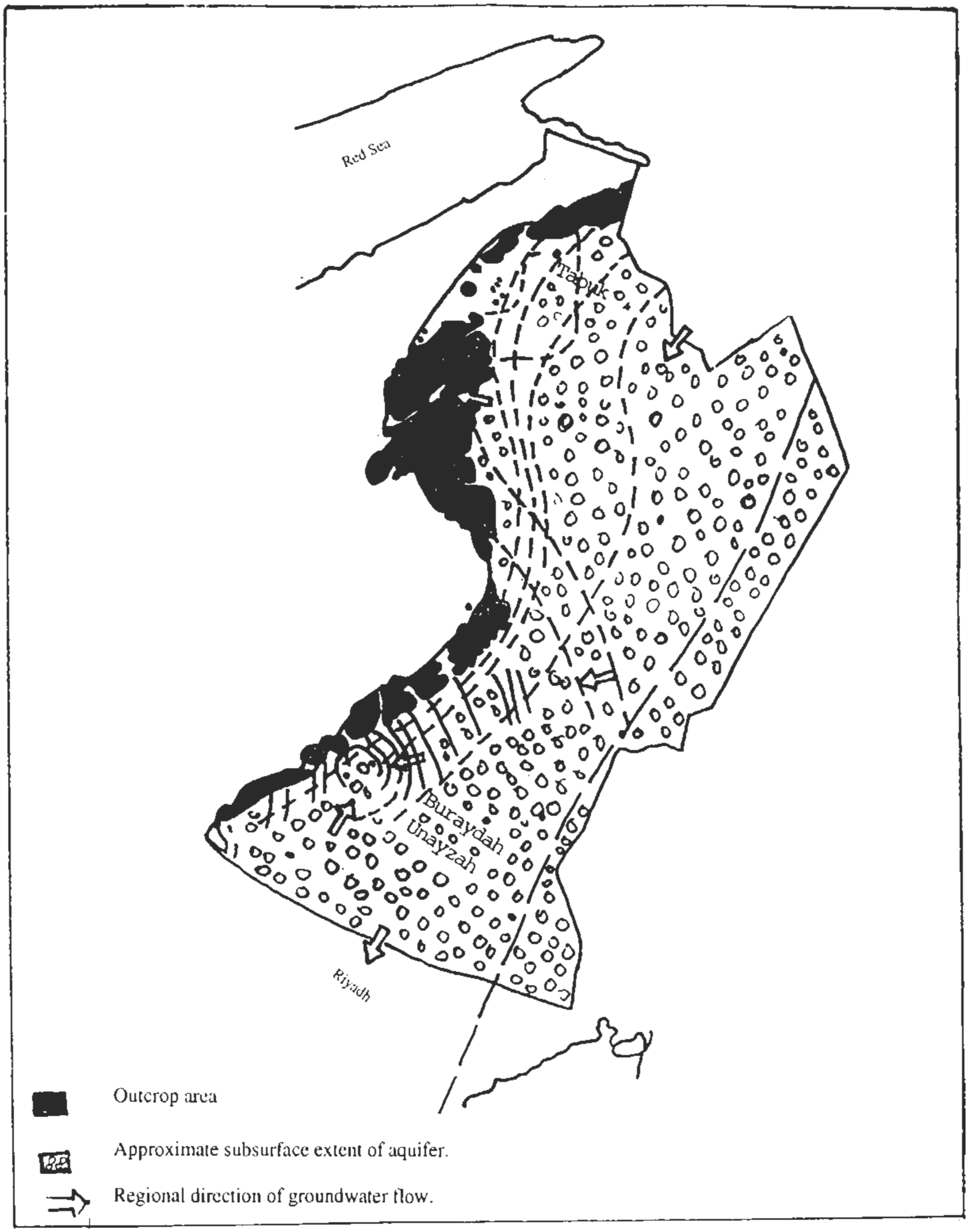

FIG. 1. Map of the Kingdom of Saudi Arabia showing the outcrop and subsurface extent of groundwater flow of the saq aquifer.

sumption caused by the increased urbanization and expansion of agriculture and industry.

In a report about water resources management and conservation in Al-Gassim region Badr (1984) indicated that treated wastewater may make a valuable contribution to the scarce water resources. He estimated the volume of recycled water around 2×10^6 m^3 by the year 2000. Wastewater reclamation and reuse in agriculture has received much attention around the world especially in arid and semi-arid regions (Halpenny 1973, Madancy 1981, Bouwer 1981, Arab Water World 1991). However, reliable data from these areas are often sparse and several components of a water budget, particularly groundwater recharge, may be difficult (Osterkamp *et al.* 1995).

Due to the recent development and population growth, municipalities in Al-Gassim region are faced with the problem of the proper disposing of the ever growing volumes of wastewater that are rich in soil building properties and essential plant nutrients. Moreover, increasing costs of chemical fertilizers have resulted in an upsurge of interest in the use of municipal wastewater and sludge as fertilizer substitutes and soil amendments to facilitate the establishment of vegetation of disturbed lands.

The suitability of sewage effluent for irrigation water and groundwater recharge largely depends on its physico-chemical characteristics and on the type and numbers of microorganisms it contains. Comparing the physico-chemical composition of the effluent with the quality standards for underground native irrigation water, and evaluating the occurrence of microorganisms in the effluent against criteria that have been formulated by public health agencies, will indicate what crops can be irrigated with the effluent in relation to how it is treated before utilization.

The objective of this study is to evaluate some of the physico-chemical and bacteriological characteristics of sewage effluent that limit its reuse for irrigation and to compare them with the locally and internationally acceptable quality standards.

Materials and Methods

The monthly wastewater chemical and microbiological analyses were carried out by the staff of Unayzah City wastewater treatment plant laboratory. Their monthly routine wastewater data were rendered available at the author's request. The compiled data were summarized and processed to extract the most relevant information pertinent to the irrigation reuse of treated effluent. The methods used for wastewater analyses were those recommended by the APHA (1971).

The data listed in Tables 1, 2 and 3 for the influent (inf) and effluent (eff) wastewater quality parameters were calculated from the monthly means for each of four consecutive years, *viz.* 1991/92, 1992/93, 1993/94 and 1994/95.

The efficiencies of removal of the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and total coliform (T.C) were calculated as follows :

a. Efficiency of BOD removal (%) $= \dfrac{BOD_{inf} - BOD_{eff}}{BOD_{inf}} \times 100$

b. Efficiency of COD removal (%) $= \dfrac{COD_{inf} - COD_{eff}}{COD_{inf}} \times 100$

c. Efficiency of TSS removal (%) $= \dfrac{TSS_{inf} - TSS_{eff}}{SS_{inf}} \times 100$

d. Efficiency of T.C. removal (%) $= \dfrac{TC_{inf} - TC_{eff}}{TC_{inf}} \times 100$

The electric conductivity (EC) data shown in Table 2 were obtained by dividing the total dissolved solids (TDS) by 640 according to Rhoades (1982).

Results and Discussion

The existing wastewater treatment plant at Unayzah City of Al-Gassim region, Central Saudi Arabia, consists of stabilization ponds system which provides treatment up to secondary level and thereafter chlorination before the effluent is finally disposed of.

According to Badr (1984) the estimated groundwater usage in Al-Gassim region was 1080×10^6 m^3/year which is an over exploitation of the Saq groundwater and may result in groundwater depletion in years ahead. Therefore, in this situation any additional water into the aquifer will extend its lifetime. The expected yearly average of treated sewage effluent from Unayzah wastewater treatment plant, as calculated from the means shown in Table 1, varied from 26.4×10^5 in 1991/92 to 36×10^5 m^3/year in 1993/94. This volume of treated wastewater although small, yet it is a vital contribution and a first step towards the conservation of this resource, especially in an area where natural recharges are scarce and irrigation water is used irrationally and not judiciously. Previous workers (Badr 1984, Kadaj 1991) called for the utilization of recycled water in agriculture as well as for the protection of the existing groundwater resources to avoid a looming water crisis in years ahead.

TABLE 1. Monthly wastewater influent and effluent volumes at Unayzah wastewater treatment plant*

Parameter	Range	Mean	Median	CV (%)
Total quantity of wastewater ($m^3 \times 10^5$) :		**1991 / 92**		
Influent	2.7 - 3.3	2.5	2.7	8.4
	(24 - 32.4)	(30)	(32.4)	
Effluent	1.9 - 2.5	2.2	2.4	10
	(22.8 - 30)	(26.4)	(28.8)	
		1992 / 93		
Influent	2.5 - 3.2	3.9	3.1	6.2
	(30 - 38.4)	(46.8)	(37.2)	
Effluent	2.5 - 2.8	2.6	2.6	4,7
	(30 - 33.6)	(31.2)	(31.2)	

TABLE 1. Contd.

Parameter	Range	Mean	Median	CV (%)
		1993 / 94		
Influent	1.2 - 3.4	3.0	3.2	22.4
	(14.4 - 40.8)	(36)	(38.4)	
Effluent	2.7 - 3.3	2.2	2.4	8.4
	(32.4 - 39.6)	(36)	(36)	
		1994 / 95		
Influent	2.7 - 3.5	3.1	3.1	9.1
	(32.4 - 42)	(37.2)	(37.2)	
Effluent	2.4 - 3.3	2.9	2.9	9.6
	(28.8 - 39.6)	(34.8)	(34.8)	

*Figures in parenthesis indicate yearly volumes.

Physico-chemical Characteristics

The treated effluent quality parameters studied are shown in Tables 2 and 3. The mean for the BOD of the effluent varied from 14.3 in 1991/92 to 17.8 mg/L in 1994/95 and the mean efficiency of BOD removal varied from 89.3% in 1994/95 to 90.8% in 1991/92. According to Al-Odat and Basahi (1985) and an unpublished Saudi Ministry of Agriculture and Water (MAW) draft standards for maximum contamination levels the quality standard limit for unrestricted and restricted irrigation in Saudi Arabia is a BOD level of 10 and 20 mg/L, respectively. No COD standard limit has been set but it seems that the efficiency of COD removal (range 59.5-71.8%) is lower than that of the BOD (Table 2). The total suspended solids concentration of the effluent, on the average, varied from 23.3 in 1993/94 to 25.3 mg/L in 1994/95 with a mean removal efficiency ranging between 87.7 and 90.5% (Table 2). The Saudi quality standard limit for unrestricted and restricted irrigation is a T.S.S. concentration of 10 and 20 mg/L, respectively. For unrestricted irrigation the Arizona state standards, according to Bouwer and Rice (1981), recommend the reduction of BOD level and T.S.S. concentration both to < 10 mg/L by a tertiary treatment of wastewater. Such effluent may be used to irrigate parks, lawns, school grounds, private yards, sport fields and the like. It is obvious from the data presented in Table 2 that the effluent water under study is marginal with respect to its BOD level and T.S.S. content. Therefore, more detention time of sewage water in ponds is needed to bring the level of both parameters within the range of the national standard quality limits.

The salinity ranges (electric conductivity (EC) mmhos/cm) are shown in Table 2. The values obtained lie within limits of the 3 mmhos/cm (TDS = 1920 mg/L) standard recommended by the FAO (1976). According to Ayers' (1975) guidelines for interpretation of water quality for irrigation no severe problems are expected by using the effluent under study for irrigation. Effluents with TDS concentration of 3400 mg/L (EC = 5.3 mmhos/cm) were used in a similar environment in Qatar to grow fodder for milking cows (Arab Water World 1991). Several classifications were suggested for irrigation waters for salinity hazards ranging from a TDS value of less than about 500 mg/L (no salinity problems) to a TDS of 5000 mg/L (severe salinity problems) (Clark *et al.* 1963, Ayers 1975). The usability of such water will depend, however, on climatic factors, soil type and crop tolerance. The pH-value of the effluent under study presents no problem since it falls within the Saudi standard limits of 6-8.4 for both unrestricted and restricted irrigation (Al-Odat and Basahi 1985).

TABLE 2. Physico-chemical characteristics of influent and effluent water for Unayzah wastewater treatment plant.

Parameter	BOD (mg/L)			COD (mg/L)			Total suspended solids (mg/L)			Total dissolved solids (mg/L)			EC (mmhos/cm)			pH
	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median	Range	Mean	Median	
1991 / 92																
Influent	115 - 189	154.6 (15.8)*	163	324 - 628	402.5 (22.3)	489	176-328	260.6 (18.4)	268	1142 - 1803	1584.4 (10.6)	1522.5	-	-	-	7.2 - 7.4
Effluent	10 - 17	14.3 (17.8)	13.5	110 - 226	163.2 (25.5)	184	21 - 28	24.8 (9.5)	25	1132 - 1720	1382.9	1385.5	1.8 - 2.7	2.2 (14.4)	2.2	7.2 - 7.4
Efficiency (%)	89 - 94.2	90.8 (1.8)	91.7	39 - 75	59.5 (24.3)	62.4	88-92.7	90.5 (1.8)	90.7	-	-	-	-	-	-	-
1991 / 92																
Influent	143 - 193	169.6 (8.3)	181.5	344 - 487	425 (11.5)	362	201 - 288	237.2 (12.7)	259	1195 - 1940	1677.8 (15.4)	1670	-	-	-	-
Effluent	12 - 24	16.4 (23.4)	17	87 - 228	151.5 (35.3)	112.5	22 - 28	24.3 (6.9)	23	1055 - 1674	1413.7 (13.2)	1518	1.6 - 2.6	2.2 (13.6)	2.4	7.3 - 7.4
Efficiency (%)	83.2 92.4	90.3 (3.4)	90.6	53 - 81.6	64.4 (17.1)	68.9	86 - 91	89.9 (1.6)	91.1	-	-	-	-	-	-	-
1991 / 92																
Influent	138 - 226	178.8 (13.6)	168	251 - 490	346 (17)	293.5	181 - 231	203.3 (8.8)	184	1750 - 1872	1821.6 (1.8)	1823.5	-	-	-	-
Effluent	12.9 - 21	16.6 (16.4)	18	89 - 118	100.8 (9.5)	91.5	20 - 29	23.3 (12.3)	21	1436 - 1702	1560 (5.4)	1536	2.2 - 2.7	2.4	2.4	7.2 - 7.4
Efficiency (%)	87.9 - 91.7	90.7 (1.1)	89.3	64.5 - 78	70.9 (4.7)	68.8	-	88.5	88.6	-	-	-	-	-	-	-
1991 / 92																
Influent	103 - 204	167 (2.4)	192	312 - 451	376 (11.8)	379	153 - 229	206.1 (10.9)	221	1627 - 1834	1753 (2.7)	1771	-	-	-	-
Effluent	14 - 21	17.8 (12.6)	19	89 - 112	105.9 (10.5)	110	22 - 33	25.3 (14.4)	22	1439 - 1619	1527 (3.9)	1563	2.2 - 2.6	242	2.4	71 - 7.5
Efficiency (%)	81.9 - 92	89.3 (4.3)	90.1	68.3 - 77.6	71.8 (4.5)	71	83 - 90	87.7 (2.7)	90	-	-	-	-	-	-	-

*Figures in parenthesis indicate coefficient of variation (C.V. %).

Bacteriological Characteristics

The only bacteriological characteristic measured in this study is the total coliform expressed as most probable number (MPN) per 100 ml (Table 3). It may be observed that even after achieving a mean coliform removal efficiency varying from 99.92% to 99.96% the final effluent still contained between 48.2×10^2 and 137.9×10^2 MPN/100 ml which falls within the unacceptable range of bacteriological standards for unrestricted irrigation reuse in USA (Metcalf and Eddy 1979) and in Saudi Arabia (Al-Marshoud and Khan 1982). Bouwer and Rice (1981) indicated that for unrestricted irrigation the state of California requires that the effluent be adequately disinfected so that 7-days median coliform count not in excess of 2.2 MPN/100 ml and 30-day maximum coliform count not in excess of 23 MPN/100 ml.

TABLE 3. Total coliform in influent and effluent water at Unayzah wastewater treatment plant.

Parameter	Range	Mean	Median	CV (%)
Total coliform (MPN/100 ml)				
	1991 / 92			
Influent	$150 \times 10^5 - 265 \times 10^5$	220×10^5	192.5×10^5	13.6
Effluent	$84 \times 10^2 - 160 \times 10^2$	117×10^2	97×10^2	21
Efficiency	99.93 – 99.96	99.95	99.95	0.01
	1992 / 93			
Influent	$176 \times 10^5 - 260 \times 10^5$	219×10^5	220×10^5	9.4
Effluent	$86 \times 10^2 - 165 \times 10^2$	116.2×10^2	112×10^2	21
Efficiency	99.94 – 99.96	99.95	99.95	0.01
	1993 / 94			
Influent	140 × 105 – 265 × 105	182.8 × 105	140×10^5	2.1
Effluent	$102 \times 10^2 - 164 \times 10^2$	137×10^2	122×10^2	19
Efficiency	99.89 – 99.95	99.92	99.91	0.01
	1995 / 95			
Influent	$102 \times 10^5 - 175 \times 10^5$	130.7×10^5	102×10^5	21.7
Effluent	$25.5 \times 10^2 - 85 \times 10^2$	48.2×10^2	40×10^2	37
Efficiency	99.93 – 99.98	99.96	99.96	0.01

The Arizona state requirements for unrestricted irrigation are even more stringent that the effluent should contain a coliform count of 2.2 MPN/100 ml with no single sample to exceed a count of 25 MPN/100 ml. With sufficient control and strict supervision on the irrigation system both California and Arizona states allow the irrigation of fodder, fiber and seed crops and of orchards and vineyards using primary effluent.

Therefore, both agronomic as well as public health aspects must be rigorously considered when effluent water is intended for irrigation use. Most of the previous studies cited in this work (Arab Water World 1991, Shahalam and Abdel Rahman 1986) provided no data to reflect the viral content of treated wastewater scheduled for irrigation reuse. This is especially important since the response of viruses to wastewater treatment and their behaviour in the environment are different from those of bacteria. Berg (1973) indicated that chlorine levels as high as 8 mg/L applied to secondary effluent have little effect on virus concentration. Feachem *et al.* (1978) and Kott *et al.* (1978) indicated that long term detention time of the order of 50 days in ponds, depending on the stage of treatment, may accomplish significant virus removals.

It may be concluded that the suitability of sewage effluent for irrigation reuse depends on its physico-chemical and microbiological characteristics. Therefore, in this study some of the essential quality characteristics of effluent such as BOD, COD, TSS, EC and total coliform count were processed and their levels were compared with the international as well as with the Saudi standards. Moreover, to utilize this resource successfully more work in this direction is warranted.

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تقييم نوعية مياه الصرف الصحي الخارجة من محطة المعالجة بمدينة عنيزة لإعادة استخدامها في أغراض الري

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المستخلص . تم خلال أربعة أعوام متتالية تقييم صلاحية مياه الصرف الصحي المعالجة والخارجة من محطة المعالجة بمدينة عنيزة بالمنطقة الوسطى من المملكة العربية السعودية بغرض إعادة استخدامها في الري وذلك باعتبار خواصها الكيميفيزيائية والميكروبيولوجية . وبعد معالجة البيانات المتاحة ومقارنتها بمواصفات الجودة القياسية المحلية والعالمية الخاصة بإعادة استخدام مياه الصرف الصحي لأغراض الري غير المقيد والري المقيد ، تم ملاحظة الآتي (١) إن متوسط الحجم السنوي لتلك المياه يتراوح ما بين ٤ , ٢٦ × ١٠^{٥} إلى ٣٦ × ١٠^{٥} م^{٣} ، (٢) إن خواص تلك المياه هامشية بالنسبة لمستويات متوسط الأكسجين الحيوي المستهلك (الممتص) (٣ , ١٤-٨ , ١٧ ملجرام/ لتر) ومتوسط المواد الصلبة العالقة (٣ , ٢٣-٣ , ٢٥ ملجرام/ لتر) ، (٣) ليست هنالك ثمة أخطار متوقعة بالنسبة لمستوى التوصيل الكهربائي (الأملاح الكلية الذاتية) وقيمة تفاعل المياه ، حيث إنها تقع في إطار الحدود المقبولة والمسموح بها ، (٤) تحتوى المياه الخارجة على أعداد كبيرة من بكتريا القولون الكلية (٢ , ٤٨ × ١٠^{٢}-٩ , ١٣٧ × ١٠^{٢}/ ١٠٠ مل) ، وذلك رغم المتوسط العالي لكفاءة المعالجة ، والذي يتراوح ما بين ٩٢ , ٩٩-٩٦ , ٩٩٪ ، مما يجعل تلك المياه غير مناسبة للري ، غير المقيد ، وذلك لاعتبارات تتعلق بالخطورة على الصحة العامة .