Assessment of the Efficiency of Buraydah City Wastewater Treatment Plant

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ABSTRACT

The efficiency of the current sewage treatment plant in Buraydah City (Central Region of the Kingdom of Saudi Arabia) was studied during three consecutive years (1995/1996, 1996/1997 and 1997/1998) by considering some of the physicochemical and bacteriological characteristics of effluent sewage that determine its suitability for irrigation. Processing of the available data and thereafter comparing them with the locally and internationally acceptable quality standards for unrestricted and restricted irrigation revealed that 1) the expected yearly average volume of treated effluent varied from $19.2x10^4$-$26.4x10^4$ m^3. 2) the effluent under study is unacceptable for irrigation reuse with respect to its mean BOD level (range 87-99 mg L^{-1}), mean COD level (range 114-161 mg L^{-1}), mean total suspended solids content (range 98-104 mg L^{-1}), and mean alkalinity level (range 334-365 mg L^{-1}). The data indicated that the efficiency of reducing the levels of the studied parameters using the currently adopted treatment, is low. 3) electric conductivity (EC mmhos cm^{-1}) and pH value of effluent are within the acceptable quality limits and are not expected to pose severe problems. 4) high fecal coliform count (range $3.3x10^4$–$40x10^4$ MPN $100mL^{-1}$) and high total coliform count (range $4.5x10^4$ -$71x10^4$ MPN $100mL^{-1}$) were evident thus indicating a low efficiency of microbial removal which renders the effluent unacceptable for unrestricted and restricted irrigation reuse because of public health hazards as well as evolution of offensive smell to the neighborhood.

INTRODUTION

Groundwater is the main irrigation water resource in Al-Gassim region of central Saudi Arabia. The main aquifer that supplies irrigation water in Al-Gassim is the Saq Sandstone. This aquifer 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 aquifer may lead to severe water shortage for Al-Gassim agriculture in the future (Moghazi and Al-Shoshan, 1999). According to Kadaj (1991), a prominent desalination expert and an 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 consumption caused by the increased utilization 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 to be around 2 x 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, Abdel Magid, 1996, 1999a,b). 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). According to Al-Minhirawi and Hafiz (1997) the World Bank report for the year 1994 indicated that Saudi agriculture alone utilizes 47% of the current available water reservoir and that groundwater is in condition of overdraft.

Abdula'aly and Chammem (1994) indicated that the Kingdom of Saudi Arabia is expected to reach a total consumption volume of water of 16.5 billion m^3 and 20 billion m^3 by the year 2000 and 2010 respectively, 80% of which is being used for agricultural and irrigation purposes. 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 volume of wastewater that are rich in soil building materials 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 the 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 crop can be irrigated with the effluent in relation to how it is treated beforehand.

The objective of this study is to evaluate some of the physico-chemical and bacteriological characteristics that limit the utilization of sewage effluent from Buraydah City Wastewater Plant for irrigation and to compare these characteristics 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 Buraydah City wastewater treatment plant laboratory. Their monthly routine wastewater data were rendered available at the authors' request. The compiled data were checked, 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 (1985). 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 three consecutive years, viz. 1995/1996, 1996/1997 and 1997/1998. The effectiveness of removal of the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (T.S.S.) and total coliform (T.C) were calculated according to Abdel Magid (1996) as follows:

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

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

iii. Efficiency of T.S.S. removal (%) = $\frac{T.S.S._{inf} - T.S.S._{eff}}{T.S.S._{inf}} \times 100$

iv. Efficiency of T.C. removal (%) = $\frac{T.C_{inf} - T.C_{eff}}{T.C_{inf}} \times 100$

v. Efficiency of Alkalinity removal (%) = $\frac{Alk._{inf} - Alk._{eff}}{Alk._{inf}} \times 100$

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

RESULTS AND DISCUSSIONS

Previous workers (Badr, 1984; Al-Saati, 1995 and Moghazi and Al-Shoshan, 1999) indicated that groundwater utilization in AL-Gassim region set the warning for an over exploitation of the Saq aquifer which may result in its depletion in years ahead. Badr (1984) estimated this utilization to be about $108x10^6$ m^3 $year^{-1}$. Moreover, a World Bank report, cited by Al-Minhirawi and Hafiz (1997), revealed that the volume of renewable water resources in Saudi Arabia was estimated at $2.2x10^9$ m^3 $year^{-1}$ whereas the utilization amounts to $3.6x10^9$ m^3 $year^{-1}$ thus resulting in 64% water withdrawal from the subsequent year's water budget. Therefore, in this situation any additional water into the aquifer will extend its lifetime. The expected yearly average of treated sewage effluent from Buraydah wastewater treatment plant, as calculated from the means shown in

Table 1 varied from $19.2x10^4$ m^3 to $26.4x10^4$ m^3 $year^{-1}$. This volume of treated wastewater although a small yet it is a vital contribution and a first step towards conservation of this resource, especially in an area where natural recharge is scarce and irrigation water is used irrationally and injudiciously.

Previous works (Badr, 1984; Kadaj, 1991; Al-Saati, 1995; AL-Minhirawi and Hafiz, 1997 and Abdel Magid, 1999a,b) called for the utilization of recycled water in agriculture as well as for the protection of the existing groundwater resources to avoid water crisis in the near future. It is worth of mentioning that Al-Saati (1995) indicated that the Gulf Cooperation Council countries utilize only 35% of the treated sewage water in both agriculture and industry is used.

Physico-chemical characteristics:

The treated effluent physico-chemical characteristics studied for each of the three consecutive years, viz 1995/96, 1996/97 and 1997/98 were reported in Table 2. The means for the BOD of the effluent varied from 87 mg L^{-1} (range 57-142 mg L^{-1}) in 1995/96 to 99 mg L^{-1} (range 47-124 mg L^{-1}) in 1996/97 and the mean efficiency of BOD removal due to treatment varied from 45% (range 17-58%) in 1997/98 to 64% (range 53-69%) in 1995/96. According to Al-Odat and Basahi (1985) and unpublished Saudi Ministry of Agriculture and Water (MAW) draft statement for maximum contamination levels the quality standard limit for unrestricted and restricted irrigation in Saudi Arabia is a BOD level of 10 mg L^{-1} and 20 mg L^{-1}, respectively. The COD mean of effluent as shown in Table 2 varied from 114 mg L^{-1} (range 104-189 mg L^{-1}) in 1997/98 to 161 mg L^{-1} (range 114-230 mg L^{-1}) in 1995/96.

Table 1: Monthly wastewater influent and effluent volumes (m^3 x 10^4)

wastewater treatment plant:

Total quantity	Mean	Range	S.D
	1995/1996		
Influent	2.5	2.1-2.9	0.24
Effluent	1.6 (19.2)*	1.0-2.6	0.60
1996/1997			
Influent	2.3	2.1-2.2	0.14
Effluent	1.9 (22.8)	1.5-2.2	0.18
1997/1998			
Influent	2.4	1.8-3.0	0.40
Effluent	2.2 (26.4)	1.7-3.1	0.50

* Figures in parenthesis indicate yearly volumes.

Table 2: Characteristics of influent and effluent water at Buraydah wastewater treatment plant.

Parameter		Influent	Effluent	Efficiency (%)	Influent	Effluent	Efficiency (%)	Influent	Effluent	Efficiency (%)
		1995/1996			1996/1997			1997/1998		
BOD (mg L^{-1})	Mean	224	87	64	198	99	46	167	91	45
	Range	121-63	57-142	53-69	157-65	47-124	33-64	124-96	64-149	17-58
	S.D	40	21	4.1	29	20	9	24	22	12
COD (mg L^{-1})	Mean	271	161	42	249	160	36	306	114	63
	Range	248-23	114-30	29-65	230-77	146-77	26-47	296-14	104-89	38-67
	S.D	20	30	10	16	12	7	6	25	8
T.S.S (mg L^{-1})	Mean	201	98	45	126	102	19	146	104	29
	Range	118-61	90-113	14-64	123-29	97-105	16-22	138-51	92-108	26-33
	S.D	66	6.0	21	2.0	3.0	2.0	4.0	5.0	2.0
Alkalinity (mg L^{-1})	Mean	334	365	10	297	334	13	347	339	4.0
	Range	284-80	312-01	4.3-24	265-77	310-85	2.2-8.0	319-87	309-97	0.3-14
	S.D	44	36	6	32	21	7.0	21	25	4.0
EC mmhos/cm	Mean	-	2.1	-	-	2.2	-	-	2.4	-
	Range	-	1.8-2.6	-	-	1.6-2.6	-	-	2.2-2.7	-
	S.D	-	2.2	-	-	2.4	-	-	2.4	-
PH	Mean	7.6	7.8	-	7.6	7.8	-	7.4	7.8	-
	Range	7.3-7.8	7.5-7.9	-	7.4-7.9	7.6-8.1	-	7.2-7.6	7.4-8.5	-
	S.D	0.14	0.14	-	0.13	0.14	-	0.13	0.29	-

The efficiency of COD removal varied from 36% (range 26-47%) in 1996/97 to 63% (range 38-67%) in 1997/98. No COD, standard has been set by the Saudi Authorities but it seems that the mean efficiency of COD removal (range 36-63%) is similar to that of BOD (Table 2). The low efficiency of both BOD and COD removal indicates that the sewage under study suffers from oxygen depletion which is vital for the stabilization (oxidation) of organic materials in sewage as follows:

$$CHONSP + O_2 + H_2O \xrightarrow[\text{Microorganisms}]{\text{Aerobic}} NO_3^- + PO_4^{--} + SO_4^{--} + CO_2 + H_2O$$

The total suspended solids (T.S.S.) concentration of the effluent, on the average, varied from 98 mg L^{-1} (range 90-113 mg $^{-1}$) in 1995/96 to 104 mg L^{-1} (range 92-108 mg L^{-1}) in 1997/98 with a mean removal efficiency ranging between 19 and 45% (Table2). The Saudi quality standard limit for unrestricted and restricted irrigation is a T.S.S concentration of 10 and 20 mg L^{-1}, 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 less than 10 mg L^{-1} by a tertiary treatment of wastewater. Such effluent may be used to irrigate parks, lawns, school grounds, private yards, sport fields and the like. On the other hand, the means for the alkalinity of the effluent varied from 334 mg L^{-1} (range 310-385 mg L^{-1}) in 1996/97 to 365 mg L^{-1} (range 312-401 mg L^{-1}) in 1995/96.The mean efficiency for alkalinity removal varied from 4% (range 0.3-14%) in 1997/98 to 13% (range 2.2-8%) in 1996/97. Such low efficiency of alkalinity removal implies high concentration of CO_3^{--} and HCO_3^- ions which have an indirect effect on water quality by the precipitation of Ca^{2+} and Mg^{2+} and thus increasing the exchangeable sodium percentage. Mahida (1981) indicated that waters with more than 2.5 meq L^{-1} of residual sodium carbonate are not suitable for irrigation.

It is evident from the data presented in Table 2 that the effluent water under study is of an unacceptable quality with respect to its BOD, T.S.S. and alkalinity levels. Therefore, more detention time of sewage water in ponds is needed to bring the level of these parameters within the range of the national as well as the international standards quality limits. Disposing of such effluent water in the sand dunes within the vicinity of Buraydah City as is currently practiced warrants more careful planning and attention since these materials endanger the groundwater quality as well as the likelihood of evolution of offensive smells to the neighborhood.

The salinity ranges as indicated by the electrical conductivity (EC) mmhos cm^{-1} are shown in Table 2. The values obtained lie within the limit of the 3 mmhos cm^{-1} (TDS = 1920 mg L^{-1}) 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 purpose. Water with EC value of 5.3 mmhos cm^{-1} (TDS = 3400 mg L^{-1}) was 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 an EC value of less than 0.78 mmhos cm^{-1} (TDS = 500 mg L^{-1}-no salinity problems) to an EC of 7.8 mmhos cm^{-1} (TDS = 5000 mg L^{-1} -severe salinity problems) (Clark et al., 1963; Ayers, 1975 and Mahida, 1981). The suitability of such water will depend, however, on climatic factors, soil type and crop tolerance. The pH value of effluent under study pose no problem since it falls within the Saudi standard limit of 6-8.4 for both unrestricted and restricted irrigation (Al-Odat and Basahi, 1985).

Bacteriological Characteristics:

The bacteriological characteristics measured in this study are the fecal coliform and the total coliform expressed as the most probable number (MPN) per 100 ml (Table 3). It may be observed that after achieving a fecal coliform and total coliform removal of 82 to 95% and from 84 to 95%, respectively, the final effluent still contained between $3.3x10^4$ and $40x10^4$ MPN $100mL^{-1}$ fecal coliform count and between $4.5x10^4$ and $71x10^4$ MPN $100mL^{-1}$ total coliform count which falls within the unacceptable range of bacteriological standard for unrestricted irrigation reuse in Saudi Arabia (AL-Marshoud and Khan, 1982; and AL-Odat and Basahi, 1985) and in U.S.A. (Metcalf and Eddy, 1979). Bouwer and Rice (1981) indicated that for unrestricted irrigation the state of California requires that the effluent to be adequately disinfected so that 7-day median coliform count not in excess of 2.2 MPN $100mL^{-1}$ and 30-day maximum coliform count not in excess of 23 MPN $100mL^{-1.}$ The Arizona State requirements for unrestricted irrigation are even more stringent that the effluent should contain a coliform count of 2.2 MPN $100mL^{-1}$ with no single sample to exceed a count of 25 MPN $100mL^{-1}$. With sufficient control and strict supervision on irrigation system both California and Arizona States allow the irrigation of fodder, fiber and seed crops and orchard 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

Table 3: Fecal and total coliform bacteria content of influent and effluent water at Buraydah wastewater treatment plant.

Parameter (MPN 100 mL^{-1})	Fecal coliform			Total coliform		
	Mean	Range	S.D	Mean	Range	S.D
	1995/96					
Influent ($x10^6$)	7.7	1.3-25	8.6	68	1.5-205	92
Effluent ($x10^4$)	40	2.6-92	41	71	3.8-187	84.6
Efficiency (%)	93	51-99	13	95	57-99	12
1996/97						
Influent ($x10^6$)	1.5	0.5-4.0	1.0	2.0	0.30-4.0	1.1
Effluent ($x10^4$)	6.1	3.2-11	2.9	7.1	3.1-15	3.7
Efficiency (%)	95	86-98	3.5	94	82-98	6.0
1997/984.5						
Influent ($x10^6$)	3	1.4-16.5	4.5	4.9	1.4-25	6.7
Effluent ($x10^4$)	3.3	1.5-4.5	1.1	4.5	3.2-5.4	0.8
Efficiency (%)	82	70-97	9.1	84	73-98	7.0

scheduled for irrigation reuse. This is especially important since the response of viruses to wastewater treatment and their behavior in the environment are different from those of bacteria. Berg (1973) indicated that chlorine levels as high as8 mg L^{-1} 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, T.S.S. , alkalinity , EC and fecal and total coliform counts were processed and their levels were compared with the international as well as with the national Saudi standards. Moreover, to utilize this resource successfully more work in this direction is warranted.

Recommendations:

1. Effluent should not be disposed of on lands in the proximity of urban areas or bodies of running or recreational water as it is well below the required standards.
2. Effluent should not be utilized for irrigation.
3. Re-evaluation of sewage treatment is warranted.
4. Construction of a modern and an efficient sewage plant is deemed necessary

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تقييم كفاءة محطة معالجة مياه الصرف الصحي بمدينة بريده

هجو محمد عبد الماجد و سعود سبيل العود

قسم التربة والمياه -كلية الزراعه والطب البيطري فرع جامعة الملك سعود بالقصيم - بريده ص ب ١٤٨٢ - المملكة العربية السعودية

الخلاصة:

تم خلال ثلاثة أعوام متتالية (١٩٩٦/٩٥م، ١٩٩٧/٩٦م و١٩٩٨/٩٧م) تقييم كفاءة محطة معالجة مياه الصرف الصحي بمدينة بريده بالمنطقة الوسطى من المملكة العربية السعودية بغرض إعادة استخدامها في الري وذلك باعتبار خواصها الكيموفيزيائية والبكتريولوجية .وبعد معالجة البيانات المتاحة ومقارنتها بمواصفات الجودة القياسية المحلية والعالمية الخاصة بإعادة استخدام مياه الصرف الصحي لأغراض الري غير المقيد والري المقيد ، تم ملاحظة الأتي :

١) إن متوسط الحجم السنوي لتلك المياه يتراوح مابين ١٩,٢x١٠^{٤} الى٢٦,٤x ١٠^{٤}م^{٣}، ٢) ان خواص تلك المياه غير مقبولة بالنسبة لمستويات متوسط آلا كسجين الحيوي المستهلك (٨٧-٩٩ملجرام/لتر)،متوسط مستوى الأكسجين الكيميائي المستهلك (١١٤-١٦١ملجرام/لتر) ،متوسط محتوى المياه من المواد الصلبة العالقة (٩٨-١٠٤ملجرام /لتر) ومتوسط مستوى القلوية (٣٣٤-٣٦٥ملجرام/لتر) .النتائج تشير إلى تدني كفاءة طريقة المعالجة المستخدمة حاليا في خفض مستويات المعالم آلتي تم دراستها، ٣) ليست هنالك ثمة أخطار متوقعه بالنسبة لمستوى التوصيل الكهربائي (الأملاح الكلية الصلبة الذائبة) وقيمة تفاعل المياه، حيث أنها تقع في إطار الحدود المقبولة والمسموح بها،٤) احتواء المياه،بعد المعالجة على أعداد كبيره لكل من بكتيريا القولون البراز يه (٣,٣x١٠^{٤}-٤٠x١٠^{٤} /١٠٠مل) وبكتيريا القولون الكلية (٤,٥x١٠^{٤}-٧١x١٠^{٤} /١٠٠مل) يعد مؤشرا على تدني كفاءة إزاحة الميكروبات من المياه المعالجة مما يجعلها غير مناسبة لأغراض الري غير المقيد وذلك لاعتبارات تتعلق بالخطورة على الصحة العامة بالاضافه إلي انبعاث الروائح الكريهة عند استخدامها.