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SEWAGE WATER QUALITY OF UNAYZAH WASTEWATER TREATMENT PLANT AND ITS SUITABILITY FOR IRRIGATION

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ABSTRACT

The Suitability of the sewage effluent from Unayzah City (Central Region of Saudi Arabia) wastewater plant for irrigation purposes was assessed during three consecutive years (1999/2000, 2000/2001, and 2001/2002) by considering some of its biochemical, physiochemical and microbiological characteristics. Processing of the available data and thereafter comparing them with the locally and the internationally acceptable standards for unrestricted and restricted irrigation revealed that: 1) the expected yearly average volume of treated sewage effluent varied from $10.9X10^5$ to $38.3X10^5$ m^3 which raises a high concern to the authorities regarding its disposal. 2) The effluent under the study is unacceptable for irrigation reuse in respect to the following: a) The mean BOD (range 25-34 mgL^{-1}), in spite of a relatively high BOD removal efficiency (range 83-87%), b) The mean COD level, which varied from 115 to 135 mgL^{-1}, c) The mean alkalinity level (range 290 - 298 mgL^{-1}). d) The mean total suspended solid contents (range 42 - 135 mgL^{-1}). 3) The mean electric conductivity (EC mmhose Cm^{-1}) (range 1.65-1.85) and the mean pH value (7.3) of the effluent, however, are within the acceptable recommended quality limits for restricted irrigation. 4) The high fecal coliform count (range $1.6X10^3$ - $1.2X10^4$ MPN 100 ml^{-1}) and the high total coliform count (range $2.2X10^3$ - $101X10^4$ MPN 100 ml^{-1}) were evident thus indicating low efficiency of and incomplete microbial removal which renders the effluent unacceptable for restricted and unrestricted irrigation because of environmental and public health concern.

INTRODUCTION

Due to the recent development and population growth, municipalities and the water and sewage department in Al-Qassim Region of Central Saudi Arabia are faced with the problem of proper disposing of the ever growing volumes of wastewater that are rich in soil building properties and essential plant nutrients. The disposal sites suggested by the authorities, like Wadi Al-Ruma, were faced with intense criticism in the daily press reflecting the public opinion and concern about environmental problems in the vicinity. Previous investigators (Badr, 1984; AbdelMagid, 1996 and AbdelMagid and Al-Oud, 2000) have drawn the attention to the large amounts of treated sewage water resulting from the sewage treatment plants at Unayza and Buraydah cities. Wastewater reclamation and reuse in agriculture has received much attention either locally (Roy, 1988; Al-Saati, 1995; Al-Fassi et al, 2003), regionally (Arab Water World, 1991) or internationally (Halpenny, 1973; Madancy, 1981, Bouwer, 1981; WHO, 1990). Moreover, AbdelMagid (1999) has drawn the attention to the indispensability of treated water in the strategies of the Saudi

Arabia water security and its importance for agriculture. He based some of his arguments on a World Bank Report (1994) indicating that sewage water represents only 0.8% of the Kingdom water needs inspite of a yearly water deficit reaching 64% in the renewable water recourses. Abdula'aly and Chammem (1994) indicated that the Kingdom of Saudi Arabia is expected to reach a total consumption of water of 20 billion m^3 by the year 2010, 80% of which is being used for agricultural and irrigation purposes.

Recently , The Ministry of Water (MW) (2002) considered the reuse of treated sewage water. Legislative rules and standards governing the reuse are currently underway.

The objective of this study is to evaluate the biochemical, the physiochemical and the bacteriological characteristics of treated effluent from Unayzah City Wastewater Plant for irrigation reuse according to the locally and the 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 upon the authors' request. The methods used for wastewater analyses are those recommended by the APHA (1992). The complied data were checked, summarized and possessed to extract the most relevant information pertinent to the irrigation reuse for treated effluent recommended by the APHA (1992). The data listed in Tables 1, 2, and 3 for the influent (inf) and the effluent (eff) wastewater quantity and quality parameters were calculated from the monthly means for each of the three consecutive years used in this study, viz. 1999/2000, 2000/2001, and 2001/2002. The effectiveness of removal of the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), alkalinity (Alk), and total coliform (TC) and fecal coliform (FC) were calculated according to AbdelMagid (1996) as fallows:

i. Efficiency of BOD removal (%) $= \dfrac{BODinf - BODeff}{BODinf} \times 100$

ii. Efficiency of COD removal (%) $= \dfrac{CODinf - CODeff}{CODinf} \times 100$

iii. Efficiency of TSS removal (%) $= \dfrac{TSSinf - TSSeff}{TSSinf} \times 100$

iiv. Efficiency of alkalinity removal (%) $= \dfrac{Alkinf - Alkeff}{Alkinf} \times 100$

$$\text{iv. Efficiency of TC removal (\%)} = \frac{TCinf - TCeff}{TCinf} \times 100$$

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 DISCUSSION

Previous workers (Badr, 1984; AL-Saati, 1995; Moghazi and Al-Shoshan, 1999; AbdelMagid and AlOud, 2000; and AbdelMagid, 1999, 2001) have drawn the attention to the fact that the irrational and injudicious groundwater utilization in AL-Qassim region of Saudi Arabia has set the warning for over exploitation of the Saq aquifer which may result in its depletion in years ahead. Recently, a World Bank report cited by Al-Minhirawi and Hafiz (1997) and AbdelMagid (1999, 2001) revealed that the volume of the renewable water resources in Saudi Arabia was estimated at $2.2X10^9$ m^3 $year^{-1}$ whereas the actual utilization amounts to $3.6X10^9m^3$ $year^{-1}$ thus resulting in 64% water withdrawal from the subsequent year's water budget. This sets the warning for an imminent water crisis due to the dramatically increased consumption caused by the increased urbanization and expansion of agriculture and industry (Kadaj, 1991 and Abdula'aly and Chammem, 1994). Al-Saati (1995) called for the utilization of recycled water in agriculture as well as for the recharge and protection of the existing groundwater resources to avoid water crisis in the near future. He revealed that the Gulf Cooperation Council Countries utilize only 35% of the treated sewage water in both agriculture and industry. In this study the expected yearly average volume of the treated sewage effluent from Unayzah wastewater treatment plant as shown in Table 1 varied from $10.9X10^5$ m^3 $year^{-1}$ in 200/2001 to $38.3X10^5$ m^3 $year^{-1}$ in 2001/2002. Similarly, AbdelMagid (1996) obtained an effluent mean volume ranging from $26.4X10^5$ m^3 $year^{-1}$ in 1991/1992 to $36X10^5$ $year^{-1}$ in 1993/1994 for the same treatment plant. Likewise, AbdelMagid and AL-Oud (2000) obtained a mean volume of treated effluent ranging from $19.2X10^4$ $year^{-1}$ in 1995/1996 and $26.4X10^4$ m^3 $year^{-1}$ in 1997/1998 for Buraydah wastewater treatment plant. This voluminous amount of sewage effluent is raising a high degree of concern for the authorities regarding its disposal which may involve both health and aesthetic problems in the vicinity. In spite of its comparatively small volume the treated effluent produced in Unayzah and Buraydah plants may contribute significantly to recharging the exploited groundwater storage, especially in an area where irrigation water is used irrationally and injudiciously. Treated sewage effluent has been used for sprinkler irrigation in Bahrain (Al-Aradi, 1986), in Saudi Arabia (Roy, 1988), and in Qatar (Arab Water World, 1991; AbdelMagid, 2001) without causing any environmental problems.

Table (1): Monthly wastewater influent and effluent volumes (m^3X10^5) wastewater treatment plants

Total quality	Mean	Range	SD
	1999/2000		
Influent	3.4 (41.3)	3.2-3.7	0.18
Effluent	2.7 (31.2)	1.2-2.8	0.12
	2000/2001		
Influent	1.1 (13.1)	0.99-1.2	0.12
Effluent	0.92 (10.9)	0.81-1.01	0.08
	2001/2002		
Influent	4.5 (51.3)	3.6-4.6	0.44
Effluent	3.2 (38.3)	2.8-3.4	0.16

Biochemical and physiochemical characteristics

The biochemical and physiochemical characteristics of the treated effluent wastewater studied for each of the three consecutive years viz. 1999/2000, 2000/2001, and 2001/2002 are reported in Table 2. The mean BOD of the effluent ranged between 25mgL^{-1} (range 19-40 mgL^{-1}) in 1999/2000 and 34mgL^{-1} (range 22-41 mgL^{-1}) in 2000/2001, and the mean efficiency of BOD removal due to the current treatment varied from 83% (range 75-92%) in 2000/2001 to 87% (range 82-90%) in 2001/2002. Previous assessment of the treated sewage quality of the same treatment plant (AbdelMagid, 1996) during the years 1991/1992 to 1994/1995 showed relatively lower values for the effluent BOD varying from 14.3 mgL^{-1} in 1991/1992 to 17.8 mgL-1 in 1994/1995 and an efficiency of BOD removal that varied from 89.3% in 1994/1995 to 90.8 in 1991/1992. This variation in the BOD and its removal efficiency magnitudes may be accounted for by the dramatic changes taking place in the style of living in the region over the years. According to Al-Odat and Basahi (1985), AbdelMagid (2001) and an unpublished Saudi Ministry of Agriculture and Water (MW) draft statement for maximum contamination levels the quality standard limit for the unrestricted and restricted irrigation is a BOD level of 10 mgL^{-1} and 20 mgL^{-1}, respectively. However, the MW in 2002 prepared, according to a Royal Decree, a provisional legislative act to govern the utilization of treated sewage effluent for irrigation. According to these legislative rules the highest permissible limits for unrestricted and restricted irrigation is a BOD level of 10 mgL^{-1} and 40 mgL^{-1}, respectively.

The COD means of the effluent as shown in Table 2 varied from 115 mg L^{-1} (range 90-127 mgL^{-1}) in 1999/2000 to 135 mgL^{-1} (range 131-142 mgL^{-1}) in 2001/2002. The efficiency of the COD removal varied from 65% (range 57-71%) in 1999/2000 to 70% (range 60-77%) in 2001/2002. It has been shown that the BOD of waste is almost always lower than the COD and generally only 50-70% of the UOD (Ultimate Oxygen Demand, which assumes the oxidation of all species in the waste to their oxidized stable forms) (Dupont et al, 2000). However, the COD removal efficiency is always less than that of the BOD (Table 2). No COD standard has been set by the Saudi authorities either recently (MW, 2002) or in the past. This may be attributed to the fact that the knowledge of COD level is particularly relevant only when industrial wastes are considered and where toxicity to biological systems, as evidenced by low or no BOD, is suspected (Dupont, et al, 2000). Moreover, it may be inferred from the data for both the BOD and COD in Table 2 that the efficiency of their removal is low which implies that the sewage under study suffers from oxygen depletion which is vital for the stabilization (oxidation) of organic materials in sewage.

The total suspended solids (TSS) concentration of effluent, on the average, varied from 42 mgL^{-1} (range 34-52 mgL^{-1}) in 1999/2000 to 135 mgL^{-1} (range 130-145 mgL^{-1}) in 2000/2002 with a mean removal efficiency ranging between 69% (range 57-74%) in 2000/2002 and 77% (range 63-84%) in 1999/2000. The mean values of TSS obtained in this study, however, are higher than the means obtained by AbdelMagid (1996) for the same treatment plant during 1991/1992 to 1994/1995. The proposed Saudi standard limits for unrestricted and restricted irrigation is a TSS of 10 mgL-1 and 40 MgL-1, respectively (MW, 2002). Moreover, for unrestricted irrigation the Arizona state standards, according to Buwer and Rice (1981), recommend the reduction of both BOD and T.S.S levels to <10 mgL^{-1} by tertiary treatment of wastewater. Such effluent may be used to irrigate shrubs, lawns, school grounds, private yards, sport fields and the like. It may be observed that (Table 2) the effluent under study is generally well above the highest recommended levels by the proposed Saudi Standards (MW, 2002). Therefore, it may be recommended that more detention time of sewage water in ponds is needed to bring the levels of both TSS and BOD within the range of the standard national and international quality limits. The means for the alkalinity of the effluent, as shown in Table 2, varied from 290 mgL^{-1} (range 276-298mgL^{-1}) in 2001/2002 to 298 mgL^{-1} (range 270-308 mgL^{-1}) in 2000/2001. The mean efficiency for alkalinity removal varied from 15.3 mgL^{-1} (range 8.5-23 mgL^{-1}) in 2000/2001 to 18.2 mgL^{-1} (range 17.7 – 22 mgL^{-1}) in 2001/2002. Similarly, AbdelMagid and Al-Oud (2000) obtained low levels for the alkalinity removal efficiency in Buraydah wastewater treatment plant. Such low efficiency of alkalinity removal implies high concentration of CO_3^{2-} and HCO_3^- ions which have an indirect impact on sewage water quality by the precipitation of Ca^{2+} and Mg^{2+} and thus increasing the exchangeable sodium percentage. Mahida (1981) indicated that waters containing more than 2.5 mgL^{-1} residual sodium carbonate are not suitable for irrigation. It is worth of notice that the Saudi proposed Standard (MW, 2002) licensing sewage water utilization for irrigation ignored the role of CO_3^{2-} and HCO_3^- as important diagnostic tools for irrigation water quality and suitability.

The salinity ranges of the effluent as indicated by the electrical conductivity (EC) mmhos $cm^{-1}$are shown in Table 2. The means of the EC of the effluent under study varied from 1.65 mmhos cm^{-1} (TDS 1056 mgL^{-1}) in 2001/2002 to 1.85 mmhos cm^{-1} (TDS 1184) mgL^{-1}) in 1999/2000.

Table (2): Characteristics of influent and effluent water at Unayzah wastewater treatment plant

Parameter		Influent	Effluent	Efficiency (%)	Influent	Effluent	Efficiency (%)	Influent	Effluent	Efficiency (%)
		1999/2000			2000/2001			2001/2002		
BOD mg L^{-1}	Mean	181	25	85	213	34	83	233	31	87
	Range	141-267	19-40	84-89	141-327	22-41	75-92	181-310	34-25	82-90
	SD	35	4.6	1.35	54	8.3	5.1	41	2.5	2.3
COD mg L^{-1}	Mean	329	115	65	418	117	70	440	135	69
	Range	282-385	90- 127	57-71	230-851	81-148	60-77	308-541	131-142	57-75
	SD	19.4	9.7	2.3	133	17.8	6.0	54	3.5	4.0
TSS mg L^{-1}	Mean	197	42	77	158	68	75	439	135	69
	Range	228-264	34-52	63-84	130-387	32-112	57-91	308-541	130-145	57-74
	SD	43	4.4	6.3	73	21	8.2	54	3.5	4.0
Alkalinity mg L^{-1}	Mean	365	296	17.0	349	294	15.3	355	290	18.2
	Range	324-380	270-308	8.0-27	312-382	264-321	8.5-23	301-372	276-298	17.7-22.0
	SD	12.5	7.3	3.5	16.2	8.1	3.1	12.1	5.5	2.1
EC mmhose cm^{-1}	Mean	2.15	1.85	-*	2.1	1.67	-	2.19	1.65	-
	Range	2.08-2.31	1.7-2.04	-	1.95-2.3	1.68-1.84	-	2.11-2.26	1.54-1.74	-
	SD	0.05	0.03	-	0.15	0.02	-	0.02	0.01	-
pH	Mean	7.2	7.3	-	7.4	7.3	-	7.2	7.3	-
	Range	7.1-7.4	7.2-7.4	-	7.2-7.6	7.1-7.4	-	7.1-7.4	7.1-7.4	-
	SD	0.01	0.01	-			-	0.01	0.01	-

* Not determined

The salinity levels obtained in this work are within the salinity limit 3 mmhos (TDS= 1920 mgL^{-1}) recommended by the FAO (1976) and the salinity limit of 2.34 (TDS=1500 mgL^{-1}) and 3.1 mmhos (TDS=2000 mgL^{-1}) recommended by MW (2002) for unrestricted and restricted irrigation, respectively. According to Ayers' (1975) guidelines for interpretation of water quality for irrigation no severe problems are expected from using the effluent under study for irrigation. Water with EC value of 5.3 mmhos cm^{-1} (TDS=3400 mgL^{-1}) was used in a similar environment in Qatar to grow fodder for milking cows (Arab Water World, 1991). Maas (1990) and Gratten and Oster (1993) indicated that the threshold irrigation water salinity for a 100% yield potential for tree crops varied from 1 mmhos cm^{-1} (TDS=640 mgL^{-1}) for salinity sensitive crops to 2.7 mmhos cm^{-1} (TDS 1728 mg L^{-1}) for salinity tolerant crops such as date palm. Moreover, several classifications were suggested for irrigation waters for salinity hazards ranging from an EC value of 0.78 mmhos cm^{-1} (TDS=500 mgL^{-1}- no salinity problems) to an EC value of 7.8 mmhos cm^{-1} (TDS= 5000 mgL^{-1}- severe salinity problems) (Clark et al, 1963, Ayres, 1975 and Mahida, 1981). The suitability of such water, however, will depend on climatic factors, soil type and crop tolerance.

The pH value of the effluent under study, as shown in Table 2, ranged from 7.1 to 7.4 with a mean value of 7.3 for all years of study. These values are within the standard limits of 6-8.5 for both unrestricted and restricted irrigation (Al-Odat and Basahi, 1985 and MW, 2002).

It is evident from the data presented in Table 2 that the effluent under study is of an unacceptable quality with respect to its BOD, T.S.S and alkalinity levels. Therefore, more detention time is needed to bring the levels of these parameters within the range of the national as well as the international standards and may accomplish significant virus removal as well (Feachem et al, 1978 and Kott et al, 1978). It may, therefore, be mentioned that disposing of such effluent in the vicinity of cities in wadis, as is currently practiced, warrants more attention in view of the environmental, health and aesthetic problems encountered.

Bacteriological characteristics:

The bacteriological characteristics measured in this study are the fecal coliform and the total coliform population expressed as the most probable number(MPN) per 100ml (Table 3). It may be observed that even after achieving a mean removal of 99.99% for both the fecal and total coliforms, the final effluent still contained between $1.6X10^3$ and $1.2X10^4$ MPN100 ml^{-1} fecal coliform count and between $2.2X10^3$ and $1.1X10^4$ MPN100 ml^{-1} total coliform count. The counts of both total coliforms and fecal coliforms fall within the unacceptable range of bacteriological standard for unrestricted and restricted irrigation reuse of sewage water as proposed by Saudi authorities (Al-Marshoud and Khan, 1982; AL-Odat and Basahi, 1985 and MW, 2002). In USA Bouwer and Rice (1981) indicated that for unrestricted irrigation the State of California requires the effluent to be adequately disinfected so that 7-day median coliform count not in excess of 2.2 $MPN100ml^{-1}$ and 30-day maximum coliform count not in excess of 23 MPN $100ml^{-1}$.

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

Parameter (MPN $100L^{-1}$)	Fecal coliform			Total coliform		
	Mean	Range	SD	Mean	Range	SD
	1999/2000					
Influent	$8.5X10^7$	$8X10^6$-$1.1X10^8$	$4.9X10^7$	$8.5X10^7$	$1.1X10^7$-$1.3X10^8$	$4.9X10^7$
Effluent	$1.1X10^4$	$1.1X10^3$-$2X10^4$	$1.2X10^4$	$1.1X10^4$	$2.2X10^3$-$4X10^4$	$1.2X10^4$
Efficiency (%)	99.99	99.97-99.99	0.07	99.99	99.92-99.99	0.03
	2000/2001					
Influent	$8.2X10^7$	$2.6X10^6$-$9X10^7$	$7.3X10^7$	$8.2X10^7$	$7.1X10^7$-$3X10^8$	$7.3X10^7$
Effluent	$1.2X10^4$	$8X10^2$-$1.1X10^4$	$1.9X10^4$	$1.1X10^4$	$2.1X10^3$-$9X10^4$	$1.9X10^4$
Efficiency (%)	99.99	99.95-99.99	0.09	99.99	99.5-99.99	0.02
	2001/2002					
Influent	$7.1X10^7$	$2.7X10^8$-$8X10^6$	$6X10^7$	$6.5X10^8$	$1.7X10^7$-$9X10^9$	$1.8X10^9$
Effluent	$1.6X10^3$	$7X10^2$-$2X10^3$	$3.8X10^2$	$2.2X10^3$	$1.1X10^3$-$2.6X10^3$	$4.2X10^2$
Efficiency (%)	99.99	99.96-99.99	0.07	99.99	99.7-99.99	0.02

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 the irrigation system both California and Arizona States allow the irrigation of fodder , fiber, and seed crops and orchard and vine yards using primary effluent.

It may be concluded that the salient features of the findings of this work imply that the effluent water studied is of an unacceptable quality with respect to its BOD, T.S.S., and alkalinity levels as well as its bacteriological characteristics. Therefore, it is recommended that the shortcomings pointed out in this study must be taken into consideration by the authorities before effluent water is used for irrigation or disposed of on lands or in wadis in the vicinity of urban areas. Re-evaluation of sewage effluent treatment warrants needs more attention in order to avoid environmental, health, and aesthetic problems.

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نوعية مياه الصرف الصحي المعالجة في محطة عنيزة ومدى صلاحيتها للري الزراعي

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في هذا البحث تم تقييم مدى صلاحية مياه الصرف المعالجة في محطة الصرف الصحي في محافظة عنيزة بالمنطقة الوسطى من المملكة العربية السعودية للري الزراعي خلال ثلاث سنوات متتالية هي 1999/2000، 2000/2001 و 2001/2002 وذلك باعتبار خواص المياه المعالجة الكيموحيوية والكيموفيزيائية والبكتريولوجية ومقارنتها بالمواصفات القياسية المحلية والعالمية. دلت البيانات المتحصل عليها بعد معالجتها ومقارنتها بالمواصفات القياسية المحلية والعالمية للري الزراعي على مايلي: 1) أن الحجم السنوي للمياه الخارجة من محطة المعالجة يتراوح من $10.9X10^5$ إلى $38.3X10^5$ m^3 الأمر الذي يقلق المسؤولين بالنسبة لطريقة التخلص منها. 2) المياه المعالجة تحت الدراسة غير صالحة للري الزراعي المقيد وغير المقيد بالنسبة للقياسات التالية: a) قيم متوسط الأكسجين الحيوي المتطلب (BOD) والذي تراوح من 25 إلى $34mgL^{-1}$ والذي يجعل هذه المياه غير صالحة للري الزراعي المقيد وغير المقيد بالرغم من ارتفاع كفاءة إزالة BOD من المياه المعالجة الذي تراوح من 83 إلى 87%. b) متوسط الأكسجين الكيميائي المتطلب (COD) (والذي تراوح من 115 إلى mgL^{-1} 135). c) قيم متوسط القلوية (290 إلى $298\ mgL^{-1}$). d) قيم متوسط الأملاح الكلية الصلبة المعلقة والتي تراوحت من 42 إلى $135\ mgL^{-1}$. 3) أما قيم متوسط التوصيل الكهربائي (EC) (والتي تراوحت من 1.65 إلى $1.85\ mmhos\ cm^{-1}$) وقيم متوسط pH (7.3) فانها كلها متطابقة مع مواصفات الري المقيد. 4) أشارت النتائج إلى وجود أعداد كبيرة من بكتريا القولون البرازية والذي تراوحت من $1.6X10^3$ إلى $1.2X10^4$ MPN $100ml^{-1}$ وكذلك وجود أعداد كبيرة من بكتريا القولون الكلية تراوحت من $2.2X10^3$ إلى $101X10^4$ $MPN100ml^{-1}$ والتي تدل بوضوح على انخفاض كفاءة إزالة الميكروبات من مياه الصرف الصحي وبالتالي على عدم صلاحيتها للري الزراعي المقيد وغير المقيد لما تسببه هذه المياه من أخطار على البيئة والصحة العامة.