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Environmental and health risks associated with reuse of wastewater for irrigation

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KEYWORDS

Al-Rustamia WWTP;
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Abstract The present study focuses on the environmental and health risks associated with the use of treated wastewater produced from Al-Rustamia third extension plant for irrigation. The measured data are used to evaluate comprehensive pollution index (CPI) and organic pollution index (OPI). The average CPI was found as 0.69 which indicated to be slightly polluted for all seasons and a similar result was also obtained with OPI, which is found to slightly vary in the range 1.29–1.60 which indicates as being to be contaminated. Also to evaluate its suitability for irrigation purposes, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP) and Residual Sodium Carbonate (RSC) were calculated following standard equations and found experimentally as (8.70), (74.76) and (2.68) respectively. Irrigation water classes are used for Salinity hazard (EC) and Sodium hazard (SAR) to assess water suitability for irrigation, and it is found that samples in summer and autumn in the class of C3-S1, indicate high salinity and low sodium water, while in spring and winter in the class of C4-S1, they indicate very high-salinity. Furthermore, the data indicate a slight to moderate degree of restriction on the use of this treated wastewater in irrigation due to chloride hazard. RSC value is more than 1.25 at all seasons, indicating that samples in summer and autumn are doubtful for irrigation purposes, while the samples in spring and winter are unsuitable for irrigation.

1. Introduction

Wastewater reuse is an integral part of water demand management, promoting the protection of high quality fresh water and reducing both environmental pollution and overall supply costs. Recent developments in technology and changes in attitudes toward wastewater reuse suggest that there is a potential for Wastewater reuse in the developing world [1,2]. The amount of collected and treated wastewater is likely to increase considerably with population growth, rapid urbanization, and improvement of sanitation service coverage [3–6]. Wastewater generates from domestic, commercial, and industrial sources. In many networks the domestic component is the largest, accounting for as much as 50–80% of the total water use [7,8]. Irrigation with treated wastewater has potential for both positive and negative environmental impacts [9] and with careful planning and management, the use of treated wastewater

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in agriculture can be beneficial to the environment. However, the direct and indirect uses of untreated wastewater in irrigation are increasing as a result of increasing global water scarcity, insufficient and inappropriate wastewater treatment and disposal and escalating fertilizer costs [10–12]. Wastewater is a source of plant nutrients and organic matter [13]. Nevertheless, it may contain undesirable chemical constituents and pathogens that pose environmental and health risks [14]. At the same time, a number of risk factors have been identified in reuse of wastewater; some of them are short term impacts (e.g., microbial pathogens) whereas others have longer-term impacts that increase with the continued use of wastewater (e.g., salinity effects on soil) [15]. The use of treated wastewater for irrigation is one of the methods which are currently widely used [16]. Reuse of treated wastewater helps to alleviate the pressure on traditional water resources by using part of treated wastewater for irrigation and industry. The nutrients in these waters can help plant growth rather than be contaminated as it occurs in the case of discharge into river, as well as the fact that the agricultural sector is the largest consumer of water, consuming about 92% of the amount of water available in Iraq at 1992 after it was 78% at 1980 due to the increase and expansion of agricultural land significantly [17]. Although irrigation with treated wastewater can reduce the utilization of natural water resources, it may also result in environmental problems [18,19]. The Iraqi capital, Baghdad city, has the highest level of sanitation provision with about 80% of the population connected to sewer treatment facilities. The sewerage network that was established between 1960 and 1980 worked on the basis of the separate system, but a combined system has been adopted since 1980. Basic stage was created, which call zero phase (Stage 0), at 1960 with a design capacity (40,000 m^3/day); only 24% of Baghdad's population were served by full sewage treatment. In 1974 was added the first expansion (Stage 1), which partly merge with the basic stage with a design capacity (45,000 m^3/day) and finally, was added second expansion (Stage 2) at 1981 with a design capacity (90,000 m^3/day) and thus became the total capacity of the project (175,000 m^3/day); which serve the East Bank of Tigris River south of the Army Canal. Al-Rustamia plant Stage 3 was operated in 1985 as part of the major expansion of sewage treatment capacity that led to 80% of Baghdad population. Now this stage serves the East Bank of Tigris River north of the Army canal. It was designed to serve a total population equivalent of 1,500,000 [9,20]. The objective of this research focused on the environmental and health risks associated with the use of treated wastewater produced from Al-Rustamia wastewater treatment plant (WWTP) for irrigation and to evaluate its suitability for irrigation purposes as non-conventional water resources.

2. Materials and methods

2.1. Site description

Baghdad city is about 900 km^2 and the approximation number of population for the year 2011 was 7.2 million people. It is a very large city and it is divided by Tigris River to two main parts: the east side (Rusafa) and the western side (Karkh). The city includes 457 sectors where about 82% of the sectors are served by sewerage systems. The Al-Rustamia wastewater treatment plant is located on the Diyala River to the south of Baghdad city at Rusafa Side. Al-Rustamia Project is the oldest sewerage network in Iraq, which provision of services to a third of the population of Baghdad. After treatment, the effluent is discharged into Diyala river and thus into the Tigris River. Al-Rustamia wastewater treatment plants are illustrated in Fig. 1.

2.2. Analysis and data collection

The data used in this study were provided by Al-Rustamia WWTP-Extension3 during 2002. Samples were seasonally collected (twice each season) using clean polyethylene containers before they are thrown to the river. Samples of treated wastewater were analyzed for chemical and physical properties after collection. Procedures followed for analysis have been in accordance with the Standard Method for Examination of Water and Wastewater [21] parameters are electrical conductivity (EC), pH, total dissolved solid (TDS), total suspended solid (TSS), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate (NO_3-N), nitrite (NO_2-N), ammonia (NH_4), phosphate (PO_4^{2-}), sulfate (SO_4^{2-}), boron (B), iron (Fe), and chromium (Cr). The seasonal mean values of parameters are presented in Table 1.

2.3. Assessment methods

The data obtained during laboratory analysis were used in the evaluation of different indices to classify wastewater pollution and to evaluate its suitability for irrigation purposes, the indices are:

2.3.1. Comprehensive pollution index (CPI)

CPI evaluated by using measured concentration of parameters with respect to their permissible limit in irrigation wastewater quality prescribed by Iraqi Fact standard [33], to classify the wastewater quality status and its suitability for irrigation and human use.

$$\mathrm{CPI} = \frac{1}{n}\sum_{i=1}^{n}\mathrm{PI} \quad (1)$$

$$\mathrm{PI} = \frac{\text{measured concentration of individual parameter}}{\text{standard permissible concentration of parameter}} \quad (2)$$

where n: parameters number.

The water quality is ranked in the following categories: clean: (values 0–0.2), sub clean: (values 0.21–0.4), slightly polluted: (values 0.41–1.0), moderately polluted: (values 1.01–2.0), and severally polluted: (values $\geqslant$ 2.01) [22].

2.3.2. Organic pollution index (OPI)

The measured concentration of BOD, COD, Nitrate, and Phosphate is used to evaluate OPI with respect to their permissible limit in irrigation wastewater quality prescribed by Iraqi Fact standard [31], to classify the organic pollution due to organic compounds in the treated wastewater.