Journal of Cleaner Production xxx (2015) 1–9

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Scope of reusing and recycling the textile wastewater after treatment with gamma radiation

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ARTICLE INFO

Article history:
Received 19 October 2014
Received in revised form
6 October 2015
Accepted 7 October 2015
Available online xxx

Keywords:
Textile wastewater
Gamma irradiation
Cotton fabric
Reusing
Recycling

ABSTRACT

Fresh water is a precious natural resource that has been currently facing a severe stress because of its growing consumption by the industrialised civilisation. The global scarcity of fresh water has warranted an increasing demand for the treatment, recycling and reusing of wastewater for industrial purposes. This paper investigates the use of high energy gamma radiation to degrade and decontaminate combined textile wastewater and its potential application in textile wet processing and reuse for irrigation purposes. The treatment was carried out using a Cobalt-60 gamma radiation source at 10 kGy irradiation dose with a dose rate of 13 kGy/h. The change in pH, decolouration percentage, reduction of total suspended solids, total dissolved solids, biological oxygen demand and chemical oxygen demand, variation of electrical conductivity and heavy metal content of irradiated wastewater were extensively investigated. Then the treated wastewater was recycled for cotton fabric processing and reused in the irrigation of Malabar spinach plant. The detailed experimental results demonstrated that the irradiated wastewater can be satisfactorily used as an alternative to fresh water for scouring-bleaching and dyeing of cotton fabric. The risk to human health of fabric dyed with irradiated wastewater was also investigated. Carcinogenetic risk analysed by Gas chromatography–mass spectrometry showed the presence of banned amine in dyed fabric under the detection limit of 10 ppm and the absence of formaldehyde, signifying the non-toxicity of the fabric for human health. In case of a potential use in irrigation, treated wastewater was applied to Malabar spinach plant and compared with a controlled planting using the underground fresh water for irrigation. The plant irrigated with irradiated wastewater exhibited a better growth in terms of leaf count, root length and plant growth. It was further revealed that degradation of the textile dyes by gamma radiation led to an increase in nitrogen content in the irradiated wastewater that itself acted as a biofertiliser providing additional nutrient for a better growth of the aforementioned plant. So it can be concluded that gamma irradiation is a promising tool for the degradation and decontamination of textile wastewater for its safe recycling in textile wet processing and reuse as irrigation water having fertilising properties. Furthermore, the effectual reusing and recycling of irradiated wastewater demonstrated in this research work bear its scientific credibility in application field where consumption of million litres of fresh water per day and concurrently discharging same amount of effluent could be reduced considerably in a single textile dyeing industry.

1. Introduction

The textile industries are one of the major sources of water pollution in terms of releasing highly coloured waste stream in surface water bodies. The wastewater generated in textile processing plants is contaminated with toxic synthetic colourants and various perilous chemicals. The processing of textile materials is carried out in aqueous medium and creates a large volume of wastewater (Khatri et al., 2015). Nearly 70–150 L water is required for the processing of 1 kg cotton fabric (Allegre et al., 2006). Again during dyeing, only a certain amount of dyestuff is retained by the

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http://dx.doi.org/10.1016/j.jclepro.2015.10.029
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fabric. As a result, a considerable amount (10–40%) of unfixed hydrolysed dyes remains in textile wastewater, causing highly coloured effluent discharge (Rosa et al., 2015; Cooper, 1993). The problems associated with the discharge of coloured water from dye houses have concerned both industrial and academic scientists over the last four decades in most industrialised countries.

Treatment of textile wastewater is complicated due to the varying concentrations of both organic and inorganic compounds (Libra and Sosath, 2003). High levels of biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS) and the nonbiodegradable nature of organic dyes in wastewater make it difficult for ordinary treatment technologies (Asghar et al., 2015; Badani et al., 2005; Kim et al., 2002) to effectively remove organic pollutants and colour from it. Though conventional techniques have some degree of effectiveness, all of these generate secondary waste which needs to be tackled further (Rauf and Ashraf, 2009). Complete colour removal is not possible with biological treatment technology (Bes-Piá et al., 2002) as dyes are not readily degraded under aerobic conditions. In addition, in order to ensure the fastness requirements, textile dyes are generally made up of a high degree of chemical and photolytic stability which further increase its resistance to biological treatment. Membrane technologies like ultrafiltration and nanofiltration techniques are found to be effective for the removal of all classes of dyestuffs (Marmagne and Coste, 1996). However, a significant energy consumption coupled with the high costs of membrane and its relatively short life have limited the use of these techniques for dye house effluent treatment (Christie, 2007).

In this regard, ionisation radiation technology is the promising technique to decolourise and decompose the textile wastewater (Getoff, 1999). The radiation technology normally utilise a strong oxidising species such as hydroxyl radicals (•OH) which have a high electrochemical oxidation potential and trigger a sequence of reactions resulting in the breakdown of the dye macromolecules into smaller and less harmful substances (Bhuiyan et al., 2014a,b). Various active species are generated as a result of interaction between gamma rays and water such as hydroxyl radical (•OH), hydrogen radical (H•), hydrated electron (e^-_{aq}), and hydrogen peroxide (H_2O_2) and so on (Rauf et al., 2007). Hydroxyl radical attacks the conjugated double bond of the dye particle and breaks it. Thus the coloured dye molecules produce colourless smaller molecules which results in the decolouration of the effluent.

The reuse and recycling of textile wastewater has drawn the attention of the researchers around the globe because of the pollution of existing water bodies as well as the depletion of the groundwater level by the textile industry. These conditions will make life unsafe and will not support the sustainable development of the textile industry. The industry has to face the pressure to recover and reuse its wastewater as to fulfil the demand of increasing population or face the danger of being shut down (Tang and Chen, 2002). The reuse of wastewater for irrigation is practised in many countries of the world. The effluent contains mainly organic and inorganic nutrients and can input a greater amount of minerals that can help better growth of crops (Jolly et al., 2009). The use of industrial wastewater for irrigation purposes can lessen the increasing stress on surface water and dependency on groundwater for irrigation purposes. In addition, textile wastewater can be recycled in textile processing after removal of the colour by efficient treatment.

The main objectives of this study were to degrade the dye molecules and organic pollutants of textile wastewater by using gamma irradiation followed by the investigation of physicochemical parameters of the irradiated water as well as looking into the scope for using treated wastewater for irrigation and dyeing purposes.

2. Experimental

The wastewater samples of this study were collected directly from the equalisation tank of Effluent Treatment Plant (ETP) of Divine Textiles Mills Ltd, Gazipur, Bangladesh. Wastewater samples were collected and irradiated in 500 ml plastic bottle. The test of chemical oxygen demand (COD) of wastewater was performed by using higher range COD (HR COD) vials having range 0–1500 mg/L that was supplied by HACH, USA. The reagents used for the digestion of wastewater for the determination of heavy metals were collected from Merck, India and standard stock solutions of known concentrations of different heavy metals were supplied from Scharlau Chemi, Spain.

For the recycling of irradiated wastewater in fabric processing, 100% cotton knit fabric of 120 GSM (grams per square metre) was used to run the pretreatment and dyeing operation. The fabric was knitted in single jersey structure from 26^S combed yarn. The scouring and bleaching treatment of fabric was performed by adding a mix of chemical agents: wetting agent (Imeron PCLF), peroxide stabiliser (Stabiliser SOF liquid) and peroxide killer (Bactosol SAF liquid) from Clariant, Bangladesh. Hydrogen Peroxide (H_2O_2), acetic acid (CH_3COOH), and caustic soda (NaOH) from Merck, India and sequestering agent from Dysin, Bangladesh.

The dyeing of fabric was carried out by using commercial reactive dye, Novacron Red FN2BL from Swiss Colours Ltd. Bangladesh. Auxiliary chemicals like detergent (Imeron PCLF) and levelling agent (Drimagen E3R) were collected from Clariant, Bangladesh. Glauber salt ($Na_2SO_4 \cdot 10H_2O$), sodium acetate (CH_3COONa), soda ash (Na_2CO_3) and acetic acid (CH_3COOH) were brought from Merck, India.

2.1. Sample collection and irradiation

The wastewater samples in this study were obtained directly from the equalisation tank of Effluent Treatment Plant (ETP) of a knit dyeing industry. Samples were collected in 500 ml plastic bottles, packed in polyethylene bags and sealed for the safety prior to being subjected to gamma irradiation. The wastewater samples were submitted to Cobalt-60 gamma radiation source provided in the Institute of Radiation and Polymer Technology (IRPT), Atomic Energy Research Establishment, Savar, Dhaka. The irradiation was performed with 10 kGy radiation dose of dose rate 13 kGy/h without any further treatment or dilution. The radiation dose was determined by Amber Perpex dosimeter.

2.2. Physicochemical analysis of raw and treated wastewater

The Physicochemical parameters of wastewater samples were analysed before and after irradiation. The pH of the raw and irradiated wastewater samples was measured directly by Ecoscen digital pH metre, (Model 1161795 from Eutech Instruments Pte Ltd., Singapore). Chemical oxygen demand (COD) values were measured by spectrophotometer (DR 2800 from HACH, USA). The test was carried out by dichromate method, adding 2 ml of wastewater sample to a solution of a strong oxidising agent (potassium dichromate) in a strongly acidic medium (H_2SO_4) containing a silver sulphate catalyst and the sample was refluxed at 150 °C for 2–3 h.

Biological oxygen demand (BOD_5) was measured by dilution method. A 300 ml airtight glass bottle was filled with wastewater sample and incubated it 20 °C for 5 days. Dissolved oxygen (DO) of incubated wastewater was measured by DO metre (HQ40d from HACH, USA) initially and after incubation, and the BOD_5 was calculated from the difference between initial and final DO.

The test of total suspended solids (TSS) was performed by filtering the wastewater through a fibre pad filter and then

Please cite this article in press as: Bhuiyan, M.A.R., et al., Scope of reusing and recycling the textile wastewater after treatment with gamma radiation, Journal of Cleaner Production (2015), http://dx.doi.org/10.1016/j.jclepro.2015.10.029