Application of Ionizing Radiation for Sustainable Textile Effluent Treatment Plant

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Abstract. In the rapid growing world, the demand for clothing especially the readymade garment is one of the key economy factors for the developing countries where cheap manpower is available. But, although having a vital role in the total economy, the textile industry development is not sustainable in the South Asian region causing serious degradation to the environment for its high ground water consumption and large waste discharge. In this research the amount of effluent production was reduced by the application of irradiated chitosan which modify the cotton surface and facilitate it to absorb more color at a lower dye concentration. Raw textile effluent was also treated by gamma radiation and physico-chemical properties were measured. Textile effluent treated by gamma radiation was used for the coloration of cotton fabrics with reactive dyes in exhaust method at 60°C where fresh water served as control. Color fastness to wash, rubbing and perspiration were evaluated. Samples showed very high competitiveness with control samples thus opening a new era for of textile effluent reuse. Irradiated effluent also showed excellent plant growth when irrigated to Malabar spinach plants (80% more dry weight) where raw effluent showed significant growth retardation. Minerals content of the plant was also studied and significant increase of minerals content was found in the samples irrigated with treated effluent than the samples irrigated with fresh water. So, this paper represents a very promising technique for the sustainable development in the textile sector leading to zero waste production facility.

Keywords: Radiation treatment, Recycle, Reduce, Reuse, Textile effluent, Zero waste technology

1 INTRODUCTION

In Bangladesh Ready Made Garments (RMG) is the thrust sector in earning foreign currency. About 75% foreign currency is earned by exporting readymade garments every year. To support the RMG division a large number of backward linkage industry i.e. textile dye houses have grown countrywide. These industries produce a huge amount of polluted water which are extensively coloured, highly alkaline and contain refractory organic materials (Noman et al. 2013 and Momani et.al. 2002). They mainly use reactive dyes for the coloration of cellulosic fibre and disperse dye for synthetic polyester fibre. Besides synthetic dyes, textile industries use enormous organic synthetic chemicals in different stage of fabric processing. These chemicals used in several processes such as demineralization, scouring, bleaching, dyeing, washing, fixing and softening. Huge amount water is used for the coloration and washing off process and this consequently produces large volume of effluent with non-biodegradable dyes and chemicals. As a result, this sector is one of the most environmentally polluted sectors and a real threat to our agriculture. The major source of the pollution is the textile dye effluent, which is very often discharged to the environment without any treatment by the industrialists. In addition, approximately all dye houses in Bangladesh depend mainly on ground water for dyeing and washing purpose. This huge ground water extraction (~60 L water is required to dye 1 kg cotton fabric) is leading to a ghastly disaster in the Dhaka city, the capital of Bangladesh as the city is sinking for this massive extraction. A report showed that Dhaka is sinking over half an inch a year on average because of excessive extraction of groundwater and inadequate space for recharging (website: a, March 2013). So, there is no alternative without recycling and reusing the extracted ground water as a profitable sector like textile industry cannot be ignored. Although there are established effluent treatment plants (ETP) in some textile industries based on conventional effluent treatment techniques e.g.

chemical, biological or electrocoaguation, these are not a solution of the burning issue as the treated water cannot be recycled and reused. Huge space, numerous chemicals and physical agents e.g. mechanical stirring, high power demand etc. requirement and production of secondary waste (sludge) are the major drawbacks of conventional effluent treatment techniques. Chemical and power generation needed to input daily which results in the vast amount of cost cumulatively. Moreover, the management of sludge is very complicated and difficult issue. On the other hand, radiation technology can be utilized to develop zero waste production facilities.

The most common steps of wastewater treatment directed towards removal of pollutants with least effort involve screening, primary sedimentation, biological treatment, secondary sedimentation and disinfection (Shah et al. 2001). Sedimentation both before and after biological treatment generate sewage sludge (Wei and Liu 2005). Production of sewage sludge has reached an alarming dimension with the growth of urban population, the improvement of human life quality and the development of industry and agriculture (Shah et al. 2001). It is estimated that worldwide approximately 26 kg of sludge is generated per person per year, on a dry weight basis (Borrely et al. 1998).

Gamma radiation is an ionizing radiation and degrades stable dye molecules. The ionizing radiation-induced oxidation of organic pollutants has been extensively studied in radiation processing of water and wastewater in the past few years (Cooper and Obien, 2001 Wang and Hu 2005, Abdel-Gawad et al. 2001, Graino 2001). Ionizing radiation has been demonstrated as an effective way to oxidize organic pollutants. Although the effect of radiation on a specific pollutant in sewage sludge has not been investigated in the past, the radiation-induced degradation of organic pollutants is well acknowledged in aqueous medium. So from this perspective, the oxidation of these organic pollutants and conversion of them to more biodegradable ones may be expected. A few researchers examined the effect of ionizing radiation on bulk parameters such as chemical oxygen demand (COD) (Meeroff 2001). Generally, COD exhibited a decreasing trend with radiation, which indicated the occurrence of the oxidation and degradation of some organic pollutants.

In this experiment textile effluent is decontaminated using gamma radiation and the treated water is successfully used as biofertilizer and as well as the water source of dyeing process to evaluate the possibility of recycling. Besides, the ultimate effluent yield is also reduced by improving dye absorption capability of the cotton fabric.

2 METHODOLOGY

Reduction of Effluent Yield

Chitosan, a positively charged biomolecule was extracted from prawn shell waste by chemical method in Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission and irradiated by gamma radiation at different doses. Jute fabric was soaked in irradiated chitosan solution for surface modification. Modified jute fabric was then dyed and compared with dyed untreated fabric.

Recycle of Textile Effluent

Textile effluent was irradiated using gamma radiation for decolourization. Treated effluents were then used to dye cotton fabric by reactive dyes using exhaust method at 60°C where fresh water served as control. Three types of reactive dyes e.g. Novacron Blue FNR (Huntsman), Novacron Red FN 2BL (Huntsman) and Kiractive Yellow 150 (Orient chemtex) were used. Samples were then analyzed for color matching using color matching Spectrophotometer Data Color 650. Color fastness to wash , rubbing and perspiration were measured according to ISO 105 C02, ISO 105 X12, 1995 and ISO 105 E04 respectively.

Reuse of the Treated Effluent as Liquid Fertilizer

Samples was irradiated by gamma rays from Co-60 source at different radiation doses (10, 15, 20, 25 kGy) at a dose rate of 13 kGy/h. Treated wastewater was irrigated into Malabar Spinach to observe the fertilizing effect of irradiated wastewater. Twelve plots have prepared where, the plants were successively nourished by water, untreated effluents and the irradiated wastewater.

3 RESULTS AND DISCUSSION

Radiolysis of Textile Effluent

In water, wastewater as well as sludge matrix, the principal component is water. Therefore, it would be expected that the effect of ionizing radiation may be dominated by the interaction of radiation and water (Abdel-Gawad, E. 2001). As far as pure water is concerned, when exposed to ionizing radiation, the radiolysis of water can be presented as following equation:

$H_2O \rightarrow [2.7]OH^{*} + [2.6]e^{-}_{aq} + [0.6]H^{*} + [2.6]H_3O^{+} + [0.7]H_2O_2 + [0.45]H_2$

Surface Modification of Fabric

Irradiation led lower viscosity of chitosan solution. This is due to the degradation of large polymeric chain of chitosan and hence increases binding units at a distinct volume. Chitosan is positively charged molecule and binds with –OH groups that present in fibre. This interaction leads to improved dye binding capability of fabric. **Table 1** represents the experimental data.

Table 1. Dye absorption of chitosan treated samples where untreated samples (U.T.S) served as control.

Color		K/S		
	Chitosan%	T.S.	U.T.S	λm
Novacron Red FN2BL 1% shade	0.5	9.9	6.4	540nm
	1	12.6		
	2	13.7		
Novacron Yellow FN2R 1% shade	0.5	23	18.8	460nm
	1	23.2		
	2	24.2		
Novacron Blue FNR 1% shade	0.5	19.2	19.02	620nm
	1	21.2		
	2	21		

Dye absorption and colour strength were evaluated according to Kubelka-Munk equation. The relationship between reflectance (R) percentage, adsorption (K) and the scattering (S) of dyes in a dyed sample is expressed as K/S represent the color strength of a dyed material i.e how much dye contain the material. Higher the K/S values higher the color strength. In our experiment jute fabric is modified with chitosan solution where modified samples showed improved dye absorption. This resulted diluted effluent production which is less toxic and requires less extensive treatment for decolourization.

Treated Effluent as Dyeing Water Source

Gamma radiated effluents were used as dyeing water source. Color matching tests suggested that there was no significant difference between the shades prepared from dye preparation of treated effluent and dye preparation of fresh water. Samples were also passed in the analysis of Datacolor software (**Fig. 1**).

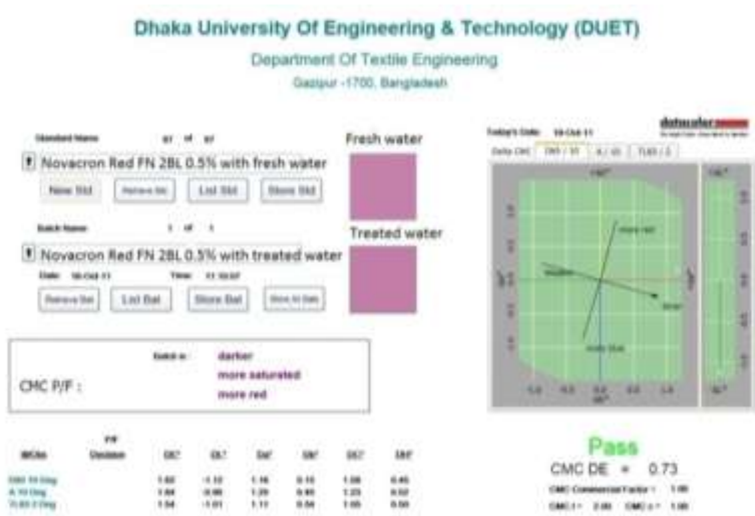

Fig. 1. Color matching between the cotton fabric dyed by fresh and radiation treated water (Dye pigment: Novacron Red FN 2BL (0.5%))

Besides, color fastness to wash, to rubbing and to perspiration were evaluated the shade quality. No significant difference was found between the color fastness changes of the samples dyed with fresh water medium and samples dyed with treated effluent medium.

Reuse of the Treated Effluent as Liquid Fertilizer

Dye molecules are mainly nitrogenous molecule. Gamma radiation degrades dye molecules to develop water soluble nitrogenous compound which can be used as biofertilizer. In the experiment, 270% increase of water soluble nitrogenous compound (-NH_4^+) was observed at 15 kGy gamma radiation dose. Malabar Spinach plants irrigated with this showed significant growth stimulation (**Table 2**). Malabar Spinach plants irrigated with treated dye effluent were also showed 80% more dry weight than the plants irrigated by fresh water (**Fig. 2**). Root length of the plants was also found to increase at a percentage of fifty.

Significant increase of minerals content was found in the analysis of 'Tandem accelerator' in the samples irrigated with treated effluent than the samples irrigated with fresh water. Concentration of Zinc, Manganese, Calcium, Potassium and iron were found 74, 70, 26.5, 7 and 25 percent increased respectively (**Table: 3**).

Table 2. Morphological characters of malabar spinach at different days after sown (DAS).

Sample ID	Plant height average (cm)						No. of leaf average					
	20 DAS	27 DAS	34 DAS	41 DAS	48 DAS	55 DAS	20 DAS	27 DAS	34 DAS	41 DAS	48 DAS	55 DAS
Control	**5**	**9.8**	**21**	**24**	**29.1**	**37.5**	**5**	**7**	**12**	**19**	**24**	**28**
0kGy	5.2	8.16	12.6	18.6	22.4	29.3	6	7	10	14	16	19
10kGy	**5**	**13.5**	**23.3**	**35.5**	**48.3**	**62.4**	**5**	**11**	**21**	**28**	**34**	**45**
15kGy	5.1	12.5	22.3	31.3	36.7	50.3	5	9	16	22	29	39
20kGy	5.3	12.2	20.2	28.3	35.2	48.6	6	9	14	19	27	35
25kGy	5.2	9.8	17.6	25.7	32.8	44.7	5	8	14	21	25	30

Table 3. Mineral content (in ppm) in plant.

Samples	Mn	Zn	K	Ca
Control plant	101	38	11417	20082
Raw effluent treated plant	108	52	5529	11843
10kGy gamma radiated effluent treated plant	172	66	12185	25347

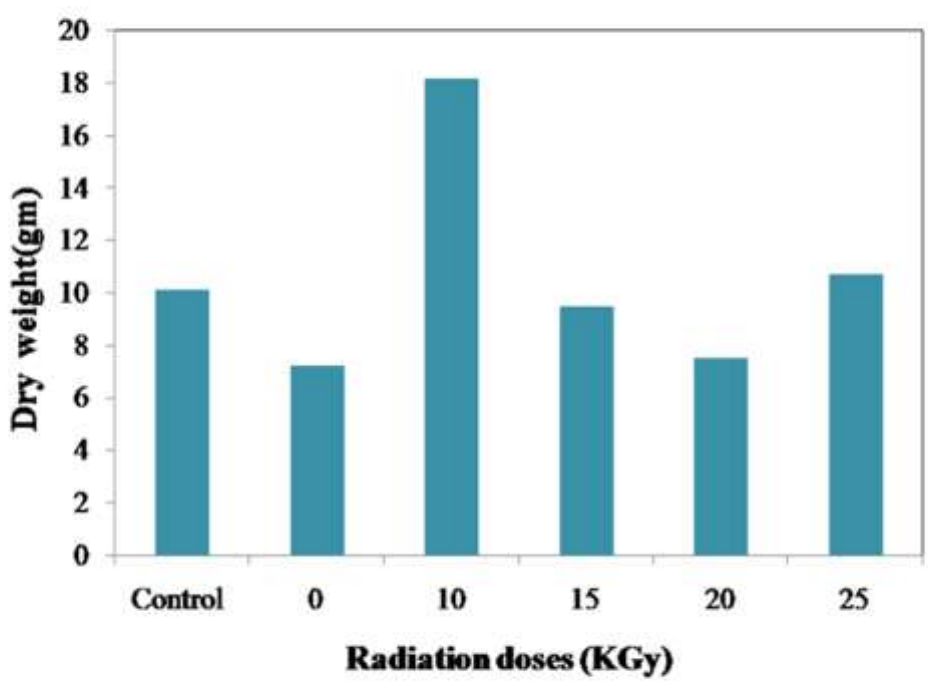

Fig. 2. Dry weight of Malabar spinach plant irrigated by treated textile effluent.

Encouraging Government Policies and Laws in Bangladesh

Textile sector is very essential for the economical development of Bangladesh. It appears much of the socio-economic development in the first decade of the twenty-first century for the country. Bangladesh is now the 2nd of the exporter of RMG in the world and earns 17123.29 million US$ from this sector. Besides, this sector has made employment opportunities of approximately 1.5 million women workers. On the other hand, negative impacts of this sector are also alarming. Rivers are dying; lands are losing their fertilities due to the pollution of its waste. As the country is still depending most in the agriculture-based economy, it could not bear such development with the cost of degrading agriculture. Conserving natural environment for the next generation is also a vital issue. So, the Government of Bangladesh has taken strict policies and supervision plan for the sustainable development of textile sector. Following laws and order can be mentioned here.

The Bangladesh Environment Conservation (Amendment) Act, 2010

Under section.12 of the Bangladesh Environment Conservation (Amendment) Act, 2010, an industrial unit or project shall not be established or undertaken without obtaining an environment clearance certificate from the Director General in the manner prescribed by the Bangladesh Environment Conservation Rules, 1997 & other essential conditions mentioned in the said provision. This provision also directed that any industrial unit or project which was established before the enactment of the said Act, are also bound to take again an environment clearance certificate in compliance with the said section of the said Act. Under section. 15 of the Bangladesh Environment Conservation (Amendment) Act, 2010, if anyone violates the provisions mentioned in the section.12 of the said Act, he shall be punished with imprisonment of any description which may extend to five years but not less than two years or with fine which may extend to five lac taka in Bangladeshi currency but not less than one lac taka (1 million taka = 10 lac) or with both.

The Environment Court Act, 2000

Under section.4 of the Environment Court Act, 2000, an environment court shall be constituted with one judge in the rank of Joint District Judge of the judicial service of Bangladesh. Under section.5 of the Environment Court Act, 2000, such judge shall try & dispose all offences & cases for compensation under environmental laws. Under section.5A of the Environment Court Act,2000, if any person violates the order of the Environment Court, such court may impose him a penalty prescribed for that offence or to an imprisonment not exceeding three years or to a fine not exceeding three lac taka or to both.

4 CONCLUSION

Gamma radiation breaks the stable dye molecules and thus decolorizes and decontaminates the textile effluent which can be further utilized by recycling and reusing it. The results of the present study suggest that gamma radiation can be employed effectively to treat textile effluent for the sustainable development of zero waste production facility. Besides, treated effluent can be utilized as biofertilizer for increased agricultural production, although we should ensure the application of heavy metal free dyes as radiation has no effect on heavy metal reduction.

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Biography

Jahid M M Islam is working as Research Coordinator of Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Bangladesh. He received his BSc. and MS degrees in Biochemistry & Molecular Biology from the University of Dhaka, Bangladesh in 2007 and 2008, respectively. He has also received MSc. degree in Biotechnology and Genetic Engineering from University of Development Alternative, Bangladesh. He is the author/coauthor of more than 20 international papers and has written three book chapters. His current research interests include polymers of biomedical importance, green composites, biodegradable packaging materials, application of natural resources for sustainable development etc.

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