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# Management of Digital Printing Ink Waste with Cotton Fabric using Screen Printing Method

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***Abstract:*** **In India, the textile industry (the second largest sector after agriculture) is undergoing a huge churn due to automation and digitization directed towards the reduction of "carbon footprints." Innovative green solution like digital printing brings water, space, and print-paste waste saving. In the textile digital printing industry, the "piezo technique" is commonly used by most of the print head manufactures. The ink used for printing is discharged through this print head during various maintenance operations, such as suction, purging, purging with positive pressure, or flushing. Considerable amount of ink is wasted per machine. In order to utilize this wasted ink, traditional screen-printing method, using a screen to transfer ink onto a substrate, can be used. Laboratory experimental research was performed to develop a shade that can match with virgin dye printed shade. This was followed by comparative analysis to verify the effectiveness using the International Organizationfor standardization (ISO) test methods. The resultant printed fabric indicated similarity against virgin dye printed fabric within acceptable range of delta ē. The overall results indicated cost reduction, lower waste disposal and environmental impact, with a new product from recycled ink waste.**

***Index Terms:*** **Carbon footprint, Delta(δ) ē, Ink purging, Piezo technique, Screen printing.**

## I. INTRODUCTION

With growing global problems of water and air pollution, it is necessary to employ practices such as digital printing in the textile and garment industry (Wasif, 1998). Further, the demand for digital printers has almost doubled since the 2001 witnessing of the accelerated growth across the value chain (Kalidasan, 2015). Digital printing now covers areas such as apparel, home textile , outdoor/automotive interior, industrial applications, and handicrafts (Malik et al., 2005). Although it is a green technology, some amount of ink waste is still generated as a byproduct of the cleaning operation. Currently, the industry has an option of draining ink into the effluent treatment plant or recycle it. As recycling demands huge cost, the trend is to drain the ink and collect the sludge for further disposal (Hill et al., 1994).

Because the ink is purified, the amount of sludge collected is less but can be reduced further by means of reuse, leading in the reduction of carbon footprint further (Chougule & Sonaje, 2012). This technology is commonly used by integrated mills; therefore, the most common reuse technique used is evading any further set- up cost.

Digital printing is a non-contact digitized image transfer onto a substrate (Tyler, 2005). The printing mechanism consists of the printing heads, inks, a feed system, a drop formation mechanism, nozzles, and ink-supply in tanks or cartridges. The textile inkjet printers usually use a piezo-electric element in the print head (Bowles & Issac, 2012).

Currently, the industry is using "drop-on-demand" (DOD) technology. This technology provides a mechanism for delivery of a drop of the ink through tiny nozzles on the head surface when the piezo-electric element inside the head pushes it on demand of ink. The demand is determined by the printing software according to each pixel, and the instruction is either to fire a drop or not. The drop of ink then falls on the substrate under the influence of gravity and appears as a dot on the substrate surface.If the drop appearing on the surface faces some interruption due to internal or externa l factors, the ink falling pattern appears disturbed and can be seen on test image pattern of nozzles. To get back the clear working nozzles, a cleaning operation is performed by pushing (purging) the ink. The various maintenance operations include suction purging, positive pressure-based purging, or flushing. Considerable amount of ink is wasted because of these operations (Viluksela et al., 2010).



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Waste disposal process is difficult and expensive. Hence, a cost-effective reclamation of waste ink is both economically advantageous and environmentally desirable (Iwasaki et al., 1985). Numerous reclamation systems have been conceived. Some have been implemented, but none have proven very successful. (Leonard & King, 1998). In this study, we aim to use the traditional screen- printing method to utilize this waste ink by employing a screen totransfer ink onto a cotton fabric.

## II. LITERATURE SURVEY

Many researches have been carried out for recycling of inkjet-printed ink waste. But these are either expensive, including big apparatus electronic or mechanical incurring huge cost (Leonard & King, 1998).

As per study done earlier, the system and the method used presently for recycling the inkjet-printing material is very inefficient. The recycled inkjet-printing ink is mixed with the fresh inkjet-printing material to form the reusable inkjet-printing material for the nozzle of the inkjet-printing apparatus. Therefore, the system and the method of the present invention for recycling the inkjet-printing ink can efficiently recycle the unused inkjet wasted inks resulting in great savings inthe inkjet-printing ink and reducing the cost of the inkjet-printing process. In particular, the system and the method of the present invention for recycling the inkjet-printing material is suitable to recycle a high-cost inkjet - printing ink, such as the material of the alignment films (PI Liquid) (Bowles & Issac, 2012).

Another study carried out for offset printing pigment inks was to provide a method of reclaiming waste offset printing ink by removing substantially all entrained water, solvents and solid impurities without a reduction in pigment content, without the need to blend with virgin ink, and with a minimum of operator intervention (Cie, 2015).

The present invention overcomes the deficiencies of the precious processes and achieves its objectives by first subjecting the waste ink to a vacuum distillation procedure whereby substantially all the entrained water and solvents are boiled off under vacuum at a temperature well below wherein the ink is subjected for chemical decomposition. Removal of substantially all the entrained water is paramount towards producing ink with the rheological properties required for the offset printing process. The resulting significant reduction of the viscosity also aids in subsequent handling and processing. Once contaminating liquids have been removed via the vacuum distillation procedure, the solid impurities are filtered out in such a manner so as not to diminish the content of the much finer pigment particles. This is accomplished by using a continually self- clearing filtering device which prevents a build-up of a layer of filtered particles on the filter element thereby precluding any "pre- filtering" of pigment particles. Ink passing through the filter will be devoid of paper dust and lint and will have the pigment content and rheological properties necessary for use in the offset printing process (Leonard & King, 1998).

Depending on above study one more patent was submitted which displayed an improved method for reclaiming waste printing ink are provided wherein waste offset ink is diluted and, later, free water and waste fibrous material are separated through specific gravity differential. A centrifugal method is provided to facilitate separation and to produce an easily disposable waste cake. A heating process is also provided to minimize the quantity of

dilatants necessary to reduce fluid friction. Many reclamation systems have been attempted but none of them are satisfactory. Each system uses some form of agitation to reduce the waste ink viscosity as well as dilution with virgin ink. Then, the waste ink is either strained or filtered by a convenient method (Iwasaki et. al 1985).

## III. RESULTS AND DISCUSSION

Based on the survey results (Table I), it is visible that on an average, minimum 5 ml of ink purge leads to wastage of 20-25 ml per machine which annually results in huge cost (Table II) per machine going into drain. Additionally, the resultant cost saving achieved by re-using the waste ink was 20% (Table III). Therefore, we reused reactive ink from the disposal of textile digital printing ink waste by screen-printing method of application for environmental and economic gains. Resultant product showed fastness properties matching to the original pure inks (virgin) and dyes applied regularly.

Table I. Ink Wastage Survey

| Survey Data | No of Machines Studied Phase-wise | No of cleanings per day | Ink wasted per clean (ml) | Disposal method for ink waste | Machine working hours per day | Machine working days per month |
|---|---|---|---|---|---|---|
| **North** | Users: No 31 | 4-5 | 5 | Drainage | 12–18 | 22–25 |
| | Users: No 63 | 4-5 | 4 | Drain into ETP | 8–12 | 28–30 |
| | Users: No 20 | 3-4 | 5 | Drain into ETP | 8–20 | 28–30 |
| **Central** | Users: No 18 | 2-3 | 5 | Drain into ETP | 20–22 | 28–30 |
| | Users: No 80 | 2-3 | 4 | Drain into ETP | 20-22 | 28–30 |
| | Users: No 60 | 3-4 | 5 | Drain into ETP | 18–22 | 28–30 |
| **South** | Users: No 20 | 4-5 | 5 | Drain into ETP | 18–20 | 28–30 |
| | Users: No 42 | 3-4 | 4 | Drainage | 8–12 | 22–25 |
| | Users: No 64 | 2-3 | 5 | Drain into ETP | 20–22 | 28–30 |

Semi-Industrial machines with Epson head type

Table II. Ink Wastage Cost Calculation

| **Machines** | Industrial | Semi-industrial | Total |
|---|---|---|---|
| Approximate total number in India | 450 | 250 | 700 |
| Number of shifts/day | 2 | 2 | 4 |
| Number of purging's/shift | 2 | 3 | 5 |
| Amount of ink wasted/purge (ml) | 5 | 5 | 10 |
| Total wastage per day (ml) | 9000/ 9L | 7500/7.5L | 16500/16.5L |
| Approximate ink cost per liter (INR) | 1800 | | |
| Total ink wastage cost per day/L (INR) | 16200 | 13500 | 29700 |
| Approximate Ink Waste Cost Per annum (348 days calculated) | **1,03,35,600** | | |

The recipe used for print paste to apply screen printing method is as shown in Table III (Kulube & Hawkyard,1996).

Table III. Recipe for printing method

| **Recipe** | **Original recipe (gm/l)** | **Adjustment** | **Recipe Saving** | **Cost Saving** |
|---|---|---|---|---|
| Reactive print paste | 700 | 700 | - | 8.5 /42.5 X 100 = **20%** |
| Ink waste | - | 250 | - | |
| Orange dye | 35 | 32 | 3 | |
| Black dye | 4 | - | 4 | |
| Red dye | 3.5 | 2 | 1.5 | |
| Water | 257.5 | 16 | - | |
| Total (gm/l) | 1000 | 1000 | 8.5 | |

Based on the assessment study, the color difference value and relative depth obtained using the waste ink sample is as shown in Table IV.

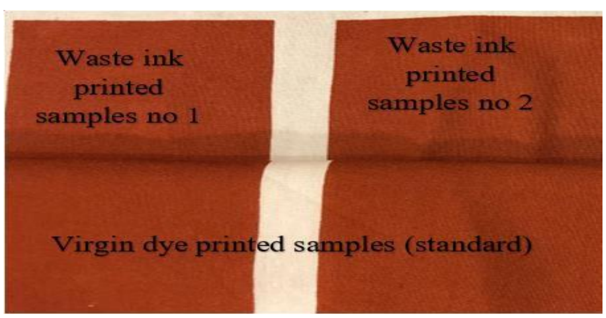


Fig. 1. Reactive printing using screen printing method on cotton

The fastness study results indicated adherence to the standard requirements as shown in Table V.

Table V. Fastness Assessment

| **Substrate: Cotton (Woven)** | **Shade change rating** | |
|---|---|---|
| COLOR FASTNESS TO LIGHT OF TEXTILES WETTED WITH ARTIFICIAL PERSPIRATION ACIDIC: ISO 105 B07 – 2009 | | |
| Reactive Waste ink Sample No. 1 | 4-5 | |
| Reactive Waste ink Sample No. 2 | 4-5 | |
| Virgin dye Printed | 4-5 | |
| COLOR FASTNESS TO LIGHT OF TEXTILES WETTED WITH ARTIFICIAL PERSPIRATION ALKALINE: ISO 105 B07 – 2009 | | |
| Reactive Waste ink Sample No. 1 | 4-5 | |
| Reactive Waste ink Sample No. 2 | 4-5 | |
| Virgin dye Printed | 4-5 | |
| COLOR FASTNESS TO DOMESTIC AND COMMERCIAL LAUNDERING ISO 105 C06 – C2S | | |
| Reactive Waste ink Sample No. 1 | 4-5 | |
| Reactive Waste ink Sample No. 2 | 4-5 | |
| Virgin dye Printed | 4-5 | |
| COLOUR FASTNESS TO RUBBING ISO 105 X 12 | | |
| | **Rating Dry** | **Rating Wet** |
| Reactive Waste ink Sample No. 1 | 4-5 | 3-4 |
| Reactive Waste ink Sample No. 2 | 4-5 | 3-4 |
| Virgin dye Printed | 4-5 | 3-4 |
| COLOUR FASTNESS TO CHLORINATED WATER (SWIMMING POOL- WATER) ISO 105 – E03: 2010 | | |
| Reactive Waste ink Sample No. 1 | 4-5 | |
| Reactive Waste ink Sample No. 2 | 4-5 | |
| Virgin dye Printed | 4-5 | |

Table IV. Color difference value and relative depth

| Standard: 100% Cotton Poplin woven | RD Percentage Waste ink printed sample Illuminant/ Observer D65/10 CIELAB 1976/DIN6174 | | | | |
|---|---|---|---|---|---|
| | RD | dE | dL | da | db |
| | 98 | 0.16 | −0.2 | −0.1 | 0.15 |

RD: Relative Depth

dE- Delta E is the difference between two colors designated as two points in the CIELab colour space.

With the values assigned to each of the L, a, and b attributes of two colors. (SDC,1990) & (AATCC, 1991)

All the fastness evaluation methods could be found in the ISO standard (2015) Technical Manual. After being equilibrated in a conditioning room at 21-250 C and 65% relative humidity for 24 h, the L*a*b* values and DE of printed fabrics were measured by Datacolor spectrophotometer at Raymond Luxury Cotton Lim ited Lab using a D65 illuminant and 10 observations.

The waste ink sample which was used to print on cotton showed similarity in color to the virgin dye as indicated in Fig. 1.

## IV. CONCLUSION

We achieved the aim of saving the cost, reusing disposed waste ink, lowering the environmental impact, and most importantly, obtaining a new product from recycled waste. This will be beneficial in the overall scenario to reduce the carbon footprint.

## V. EXPERIMENTAL SECTION

### *A. Survey*

A market survey questionnaire was used with random selection of users across the country to understand the approximate wastage. Lower working hours contributed similar wastage due to machine stoppage. Ink wastage was then calculated with approximate ink cost per liter. Data was collected for a period of 1 year to ensure consistency of figures at different places across the country.

### *B. Screen printing*

Waste reactive ink collected was used for printing on cotton fabric with screen printing method (cotton poplin 40s × 40s /130 × 80). A screen was used to transfer ink print paste to fabric. A metal rod, squeegee or blade was moved across the screen to fill the open mesh apertures with ink mixed printing paste, and a reverse stroke then caused the screen to touch the substrate momentarily along a line of contact. This caused the print paste to wet the substrate and be pulled out of the mesh apertures as the screen sprang back after the metal rod had passed. Single color was printed at a time . (Fig. 2).

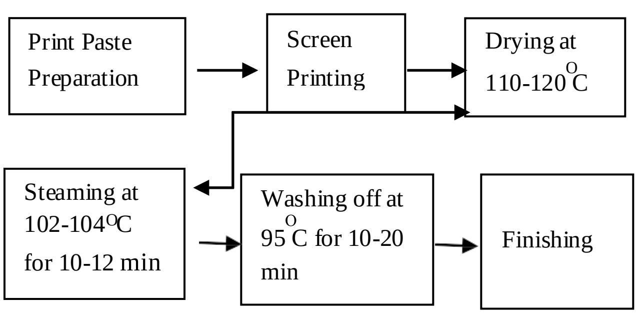


Fig.2. Schematic representation of the process

Waste ink of two different leading manufacturers was collected by using normal plastic tubes attached to the drainage section of the inkjet machine. Both are tested against the virgin dye printed sample.

### *C. Assessment*

The printed sample was further assessed in Spectrophotometer to find the color difference value and relative depth. This was followed by fastness testing to verify the quality parameters using standard test methods as per the international norms as follows: Using test methods by International Organization for Standardization (2015)

1) Perspiration fastness: ISO 105 B07 – 2009

a) Color fastness to light of textiles wetted with artificial perspiration-acidic

b) Color fastness to light of textiles wetted with artificial perspiration-alkaline

2) Washing fastness: ISO 105 C06 – C2S
Color fastness to domestic and commercial laundering

3) Rub fastness: ISO 105
X12 Color fastness to
rubbing

4) Pool water fastness: ISO 105 – E03: 2010
Color fastness to chlorinated water (swimming pool water)

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