Development of Light Weight Liquid Absorbent Filter Paper for Application in Gold Immunochromatography Assay

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ABSTRACT

In order to obtain low weight filter paper with good liquid absorbency, cotton pulp, softwood pulp and mercerized pulp were used as raw fibrous materials, and filter paper of 200g/m^2 was made by changing fiber composition and beating degree of pulp. Pore structure of filter paper, capillary liquid absorbing height and surface water absorbency were used to characterize the water absorbency of filter paper, and fiber quality analyzer (FQA) was used to observe the surface morphology of filter paper. Results show that the water absorbing capacity and thickness of the finished filter paper would be 580-590g/m^2 and 0.4mm, respectively, which meet the requirements of the low weight liquid absorbent filter paper when the mixed pulp was comprised of 65% softwood pulp, 20-25% mercerized pulp and 10-15% cotton pulp, and the beating degree of mixed pulp was at about 19°SR.

Keywords: *Liquid Absorbent Filter Paper, Low Weight, Liquid Absorbency, Pore Size, Mercerized Pulp.*

Introduction

Gold immunochromatography assay (GICA) is a kind of solid phase membrane immune analysis method developed in the 1980's, which combines colloidal gold immune technology and chromatography technology (Shyu et al., 2002). GICA developed very rapidly and is widely used in the detection field of medical (Liu et al., 1995; Lin et al., 2004), food (Sun et al., 2005; Chen et al., 2007; Deng et al., 2007), livestock production (Lin and Wang, 2005; Xu et al., 2010) and plant virus (Ohki and Kameya, 1996; Ohki et al., 1992).

Colloidal gold immunochromatography rapid assay indicator paper is especially suitable for family disease self-inspection and is very popular in Europe and America, and there are over 300 self-inspection products in these countries(Shanghai Bioengine Laboratory Co.,Ltd, 2012). Liquid absorbent filter paper located at the end of colloidal gold immunochromatography rapid assay indicator paper is the water absorbent material, which provides the capillary force for the rapid assay indicator paper. When colloidal gold immunochromatography rapid assay indicator paper is in use, the measured liquid is eventually absorbed by liquid absorbent filter paper through the capillary action of base material, so the liquid absorbency, absorption rate and absorption uniformity of liquid absorbent filter paper has direct influence on the detection precision of colloidal gold immunochromatography rapid assay indicator paper. At present, expensive high purity cotton pulp is the main raw material of good performance liquid absorbent filter paper, and the filter paper must have higher basis weight and thickness so as to ensure its liquid absorbency and absorption rate. Generally, the basis weight is as high as 360g/m^2, and the thickness up to 0.64mm. With the popularization of family disease self-inspection, thin colloidal gold immunochromatography rapid assay indicator paper is a development tendency, and liquid absorbent filter paper of 200 g/m^2 and 0.40mm is required to meet the requirements of liquid absorbency and assembly thickness. In order to reduce the use of expensive high purity cotton pulp and ensure the liquid absorbency of filter paper, it is necessary to develop low weight liquid absorbent filter paper using various fibrous materials. This paper studied the changes in pore structure and liquid absorbency of filter paper at different fiber compositions and different beating degrees, so as to obtain good performance light weight liquid absorbent filter paper.

Experimental

Raw Materials.

Cotton pulp from Anhui Xuelong Chemical Fiber Co., Ltd (with original beating degree of 14-15°SR); softwood pulp from Weyerhaeuser Canada Ltd (with original beating degree of 13-15°SR); softwood mercerized pulp from Buckeye Company, USA (with original beating degree of 11-12°SR) were used in the present study.

Methods.

100% cotton pulp, mixed pulp consisting of cotton pulp and softwood pulp, and mixed pulp consisting of cotton pulp, softwood pulp and softwood mercerized pulp were beaten in Valley beater. The pulp consistency was adjusted to 3% and the final beating degree was set as 15 °SR, 17°SR, 19°SR, 21°SR, 23°SR and 25°SR.

The beaten pulps were diluted to 0.1%-0.2% consistency. The filter papers of 200g/m^2 were made on a 300mm width trial paper machine.The basis weight, thickness, water absorbency and other physical properties of the liquid absorbent filter papers were measured according to Tappi standard methods.

To make the description easier, paper made from 100% cotton pulp was defined as paper A; paper made from 30% cotton pulp and 70% softwood pulp was defined as B; paper made from 15% cotton, 65% softwood pulp and 20% softwood mercerized pulp was defined as paper C.

Pore Size Meter PSM165 (TOPAS company, Germany) was used to determine the maximum and mean pore size of filter paper. The test procedure is fully automated, measurement results may be presented in customized reports using PSM Win software. The testing fluid used is Topor (perfluoro compound, Topas specific testing fluid), the pressure drop is 350 mbar, sample adapter is 11mm, test area is 10 cm^2, the test duration is 5-15 minutes (depends on samples). XWY-V1 Fiber Quality Analyzer (FQA) of Zhuhai Warren Papermaking Technology Company was used to characterize the surface structure of the filter papers.

Results and Discussion

Effect of Beating Degree of Pulp and Fiber Composition on the Pore Size of Liquid Absorbent Filter Paper.

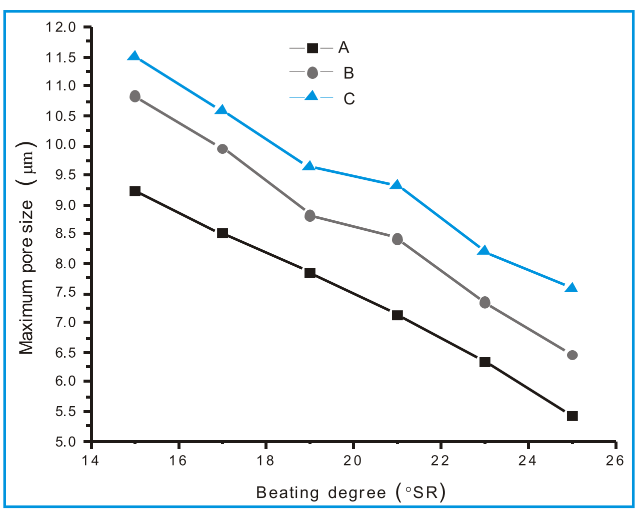


Fig.1. Effect of beating degree on the maximum pore size of filter papers

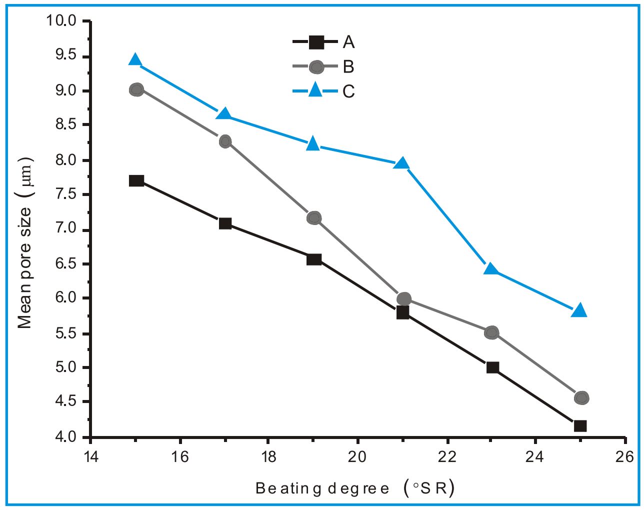
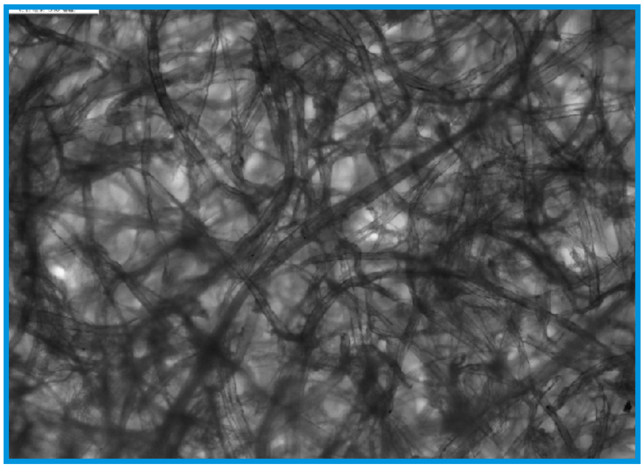


Fig.2. Effect of beating degree on the mean pore size of filter papers

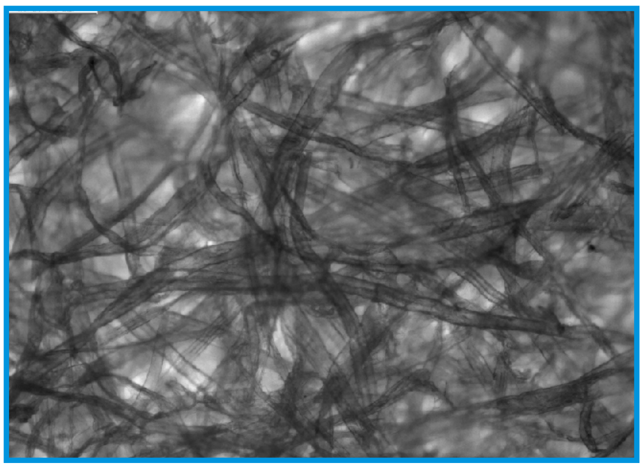
Effects of beating degree of pulp on the maximum and mean pore size of papers A, B and C are shown in Fig.1 and Fig.2.

It can be seen from these figures that the maximum and mean pore size of liquid absorbent filter papers decreased with the increase in beating degree of pulp at different fiber compositions, because both cotton fibers and softwood fibers would absorb water, swell and fibrillate during beating, and there were more hydroxyl groups exposing on fiber surface with the increase of beating degree, which resulted in more hydrogen bonds and strengthened fiber bonding (Lu, 2008), thereby improving the density and reducing the pore size of paper. At the same beating degree, both maximum and mean pore size of paper B were larger than that of paper A, but were smaller than that of paper C. The average diameter of cotton fiber is 20μm, while the average diameter of softwood fiber is about 50μm, and paper made from thicker fiber has very loose fiber network structure and larger pore size (Jin et al., 2003), so filter paper made from thin cotton pulp fiber is more compact and had smaller maximum and mean pore sizes. Mercerization treatment reduces the fines content in softwood pulp and improves the length uniformity and smoothness of softwood pulp fiber (Xu et al., 2003), which reduces the contact area between fibers and loosen the fiber bonding (Zhao and Tu, 2006), so liquid absorbent filter paper containing mercerized pulp has higher porosity and larger pore size.

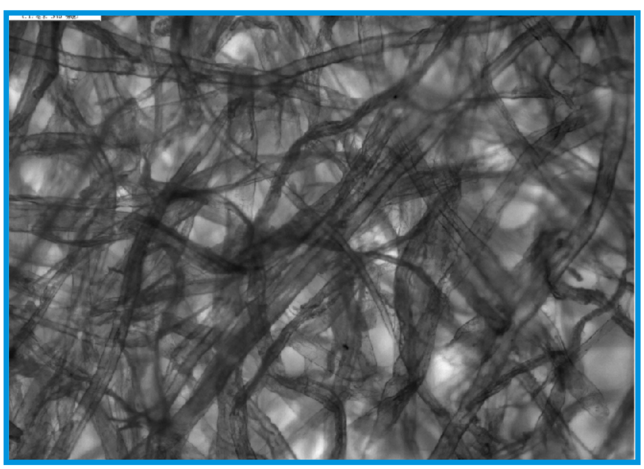
Pore structure of liquid absorbent filter paper can be characterized by its maximum pore size and mean pore size, generally, if the maximum pore size is close to the mean pore size, the filter paper would have uniform pore size and stable capillary liquid absorbency, which is helpful to improve the detection precision of colloidal gold immunochromatography rapid assay indicator paper. The maximum pore size of paper A is near to its mean pore size at different beating degrees, and their trends are stable and consistent, that is, thin cotton fiber is suitable for making uniform liquid absorbent filter paper. The difference between maximum and mean pore size of paper B at



(a) Surface pore structure of paper A



(b) Surface pore structure of paper B



(c) Surface pore structure of paper C

Fig.3. Surface pore structure of filter paper made from different fiber compositions

different beating degrees is greater than that of paper A, so the pore size uniformity of paper B is worse than paper A, which has adverse effect on the liquid absorption uniformity of liquid absorbent filter paper. The maximum and mean pore size of paper C is also larger than that of paper A, however, the maximum and mean pore size of paper C is near to that of paper A when the beating degree is in the range of 19 -21°SR, that is, within this range of beating degree, paper C has good pore size distribution and has good liquid absorbency.

Fig.3 shows the surface pore structure of paper A, paper B and paper C, in which the beating degree of pulps was 19°SR. At the same beating degree of pulp, the pore size of paper A was smaller and well-distributed due to the thinner cotton fibers, while the pore size of paper B was larger and was not well-distributed, since paper B consisted of 70% thicker softwood fibers. For paper C, the pore size was also very large, but the pore size distribution was better than that of paper B.

Effect of Beating Degree of Pulp and Fiber Composition on the Water Absorbency of Liquid Absorbent Filter Paper.

Water absorbency of paper A, B and C at the set beating degree were shown in Fig.4 and Fig.5.

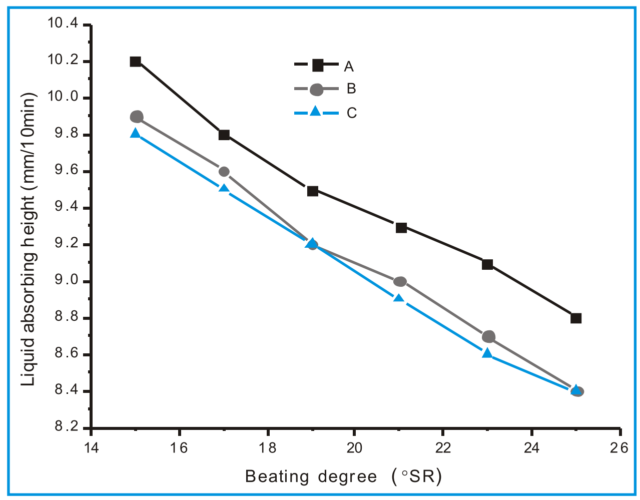


Fig.4. Effect of beating degree on the liquid absorption rate of filter paper

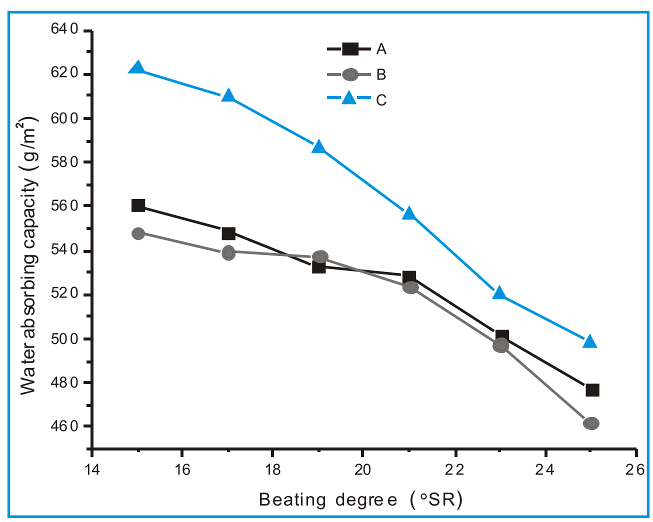


Fig.5. Effect of beating degree on the water absorbing capacity of filter paper

For liquid absorbent filter papers, the liquid absorbing height in 10 minutes is referred as their liquid absorption rate. It can be seen from Fig.4 that the liquid absorbing height of liquid absorbent filter papers with different fiber compositions were quite different, but they had the same trends. According to capillary action, the capillary liquid absorption rate is inversely proportional to capillary diameter. Paper A was denser and had smaller pore size and thinner capillary, so the liquid absorption rate of paper A was obviously higher than that of paper B and paper C. It can be seen from Fig.5 that water absorbing capacity was not directly related to liquid absorption rate, the water absorbing capacity of paper C was higher than that of paper A and paper B, which were close to each other and different at different beating degrees, because the addition of mercerized pulp improved the bulk and porosity of filter paper, which made it easier to absorb more water. Liquid absorbing capacity is the most pivotal index of liquid absorbent filter paper used as colloidal gold immunochromatography rapid assay indicator paper, and liquid absorption uniformity and liquid absorption rate are in the second place. Paper A had good liquid absorption uniformity, so it had high detecting precision, but its liquid absorbing capacity is not large enough, so it is necessary to increase the basis weight to achieve high liquid absorbing capacity, and this will raise the cost of paper greatly. According to the requirements of low weight liquid absorbent filter paper, generally, the liquid absorbing capacity of filter paper should be in the range of 580g/m^2-590g/m^2, and the basis weight and corresponding thickness of paper should be about 200 g/m^2 and 0.4mm. It can be seen from Fig.5 that it was difficult for paper A to meet the requirements of water absorbing capacity, and paper A had bad formation and thickness of only 0.38mm, which is not thick enough to meet the requirement of assembly. After adding mercerized pulp, the water absorbing capacity of paper C improved greatly and can meet the requirements of water absorbing capacity at the beating degree of 19 °SR. The thickness and formation of paper were also good enough to meet the requirements.

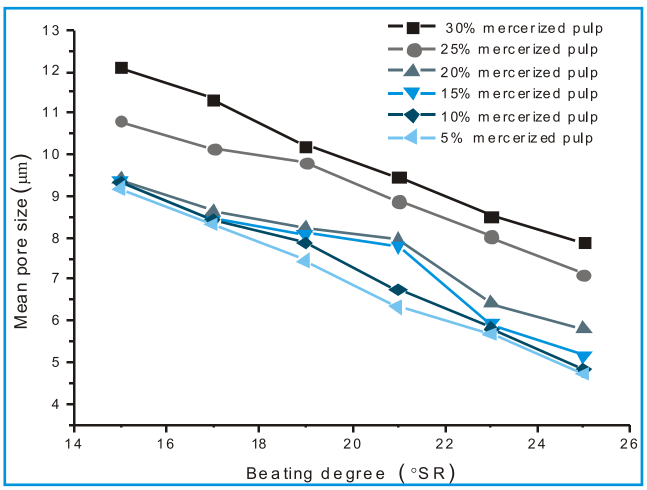


Fig.6. Effect of amount of mercerized pulp on pore size of liquid absorbent filter paper

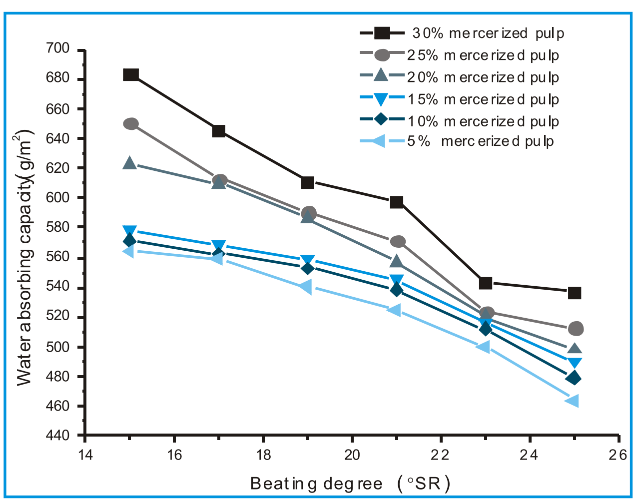


Fig.7. Effect of amount of mercerized pulp on water absorbency of liquid absorbent filter paper

Effect of Mercerized Pulp Content on the Performance of Liquid Absorbent Filter Paper.

After the addition of mercerized pulp, the water absorbing capacity of liquid absorbent filter paper was improved. When the amount of softwood pulp is fixed to 65%, and the amount of mercerized pulp and cotton pulp were changed, the pore size and water absorbency of liquid absorbent filter papers are shown in Fig.6 and Fig.7.

It can be seen from Fig.6 that with the increase of mercerized pulp content, the pore size of liquid absorbent filter paper augmented at the same beating degree, but the augment was not obvious until the amount of mercerized pulp was more than 15%, and it indicated that the loose structure of liquid absorbent filter paper would be assured only when the amount of mercerized pulp reached a certain value. Fig.7 showed that water absorbing capacity of liquid absorbent filter paper was directly related to the amount of mercerized pulp, and it was difficult for filter paper to meet the requirement of water absorbing capacity when the amount of mercerized pulp was less than 15%, and it was difficult to control the beating degree of pulp to meet the requirements of water absorbing capacity and thickness when the amount of mercerized pulp was more than 30%. Therefore, 20-25% of mercerized pulp with beating degree of 19 °SR were suitable for making low weight liquid absorbent filter paper, and under these condition, the thickness of paper could be controlled in the range of 0.39-0.41mm.

Conclusions

At the same beating degree, the maximum and mean pore size of liquid absorbent filter paper made form 30% cotton pulp and 70% softwood pulp was larger than that of filter paper made from 100% cotton pulp, but was smaller than that of filter paper made from 15% cotton pulp, 65% softwood pulp and 20% softwood mercerized pulp.

The maximum pore size of filter paper made from 100% cotton pulp was close to its mean pore size at different beating degrees, and the tendency was stable and consistent. After the addition of softwood pulp, the maximum pore size of filter paper was very different from its mean pore size. Both the maximum and the mean pore size of filter paper made from 15% cotton pulp, 65% softwood pulp and 20% softwood mercerized pulp were larger than that of filter paper made from 100% cotton pulp, but they were close to each other when the beating degree was in the range of 19-21°SR, and the pore size distribution was relatively uniform in this range of beating degree.

Liqiud absorption rate of the filter paper made from 100% cotton pulp was apparently higher than that of filter paper made form mixed pulp, and the liquid absorption rate of paper made from pulp containing mercerized pulp was the lowest. When the basis weight of paper was 200g/m^2, the water absorbing capacity of paper made from 100% cotton pulp was lower, and its thickness and water absorbing capacity could not meet the requirements of low weight colloidal gold immunochromatography rapid assay indicator paper. After adding mercerized pulp, the water absorbing capacity of filter paper improved, and filter paper made from 65% softwood pulp, 20-25% mercerized pulp and 10-15% cotton pulp can meet the requirements of water absorbing capacity and thickness when the beating degree of pulp was controlled at about 19 °SR.

Acknowledgements

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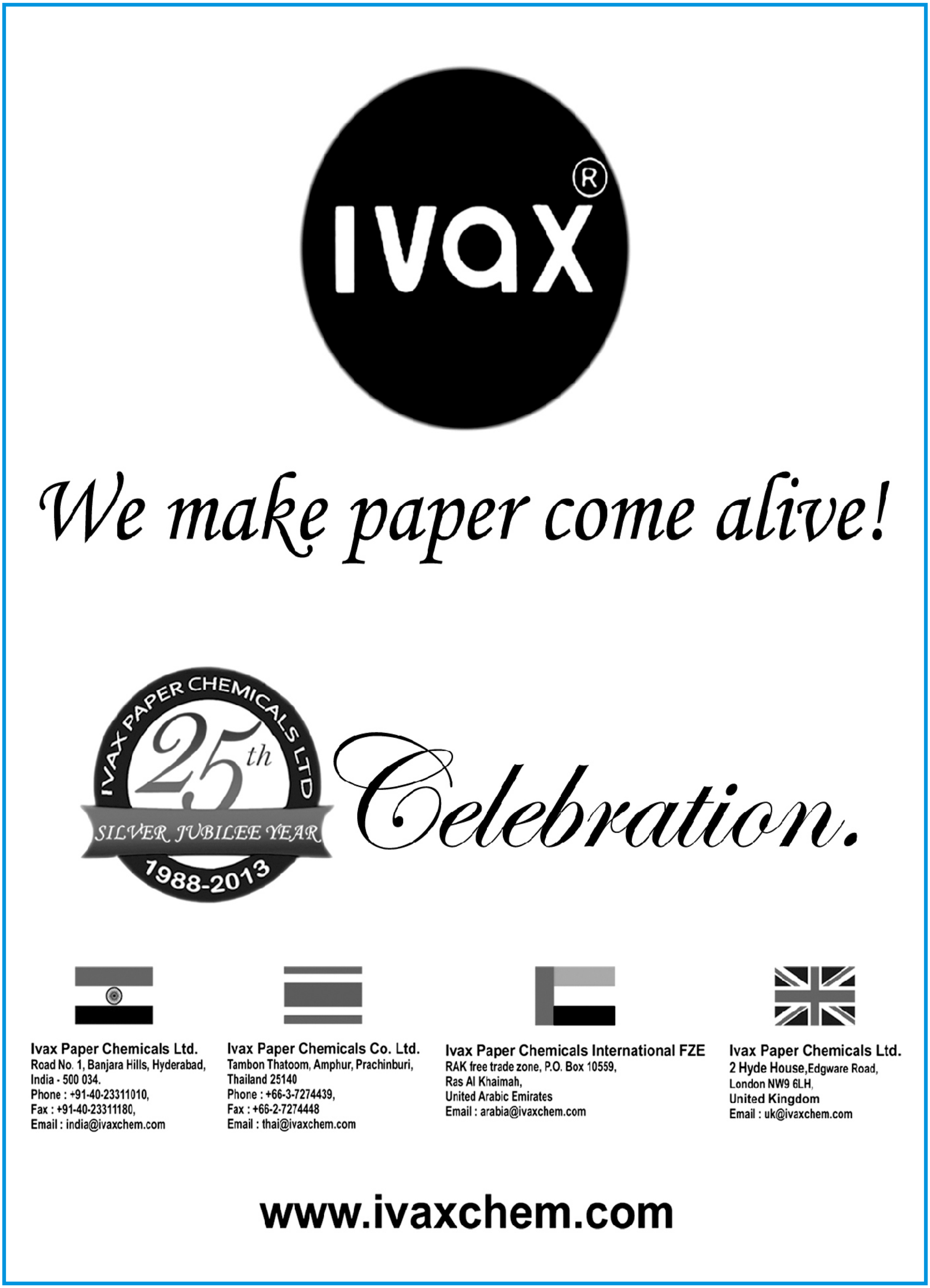
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