INTRODUCTION

Paper is more than an industrial product and it is the cultural barometer of the nation. The term paper is derived from the Latin word ‘papyrus’ (the name of the reedy plant) and French ‘papier’ (chewed paper) (Kulshrestha, 1988). The paper forms an integral part of our lives today. The new millennium is going to be the millennium of the knowledge. Paper is one of the significant discoveries that changed the history of the world around. The use of paper by mankind dates back to several centuries. Pulp and paper constitute one of the most important segments of India’s industrial economy and is treated as a basic sector. Paper impregnates all sectors of our daily activity from book to bullets and from newspapers to nuclear technologies. Paper has played a key role in the evolution of our civilization. Diversity of uses of paper & its products makes its importance very obvious in the modern life.

It is a basic medium of communication and dissemination of information. It is required for the growth of education, reading, writing, storing, knowledge, quality of life, culture, marketing, supply and other sectors of the economy. All human beings are using paper either directly or indirectly and it is very difficult to imagine modern life without paper (Reddy et al, 2003). Paper is made up of cellulosic fiber obtained from plants. Starch and other plant products are used as auxiliary material in the paper production process. Paper is a web composed of fibers, roughly oriented and matted together to form sheets.

Presently, the modern paper industries are designed to run on pulp made from wood, agricultural residues and recovered paper, consequently, the composition of the fiber consumed by paper industry has changed over the past decade. However, some significant changes are also made in the international flows of the raw materials (pulp logs, wood chips and recovered paper) to be used to make paper (Honnold, 2009). The percentage share of total fiber from domestically produced wood and non-wood pulp has fallen, while the percentage recovered paper has risen sharply (Jain, 2015).

The global paper and paperboard industry is dominated by North America, Europe and Asia. Global paper and paperboard production was cited at around 404 million tons in 2014, Asia leading with over 180 million tons and accounting for nearly a 45% of the world’s production. Asia was followed by Europe with 27% production and North America with 21%
of the total world production. Per capita paper consumption in US is 300 kg and 35 kg in Asia (13.2 kg in India). In India writing and printing segment accounts for 26% of the global paper consumption, while packaging, tissue & sanitary, and newsprint accounts for 37%, 8% and 7% respectively (Jain, 2015).

The paper industry in India is one of the most thriving industries in the country. The Indian paper industry produces 15.0 million tons paper per annum, around 3.7% of the total world production in 2014. As compared to international capacities, India lag far behind. Scandinavian countries, USA, the Russian Federation, China, Indonesia and Japan are the major players in the field of pulp and paper. These countries have some of the best available raw materials for paper production and cutting edge technologies to control the global trade (Chaudhery, 2011). The Indian paper Industry mainly produces 38% writing and printing 8% newsprint grade and 54% industrial grade paper ((Devotta, 2014).

The writing and printing grade of paper comprised mainly of uncoated varieties such as cream wove; map litho branded copier is mainly produced from wood based raw materials with a little share from agro and recycled waste paper whereas the industrial paper viz. kraft paper, white board, Machine glazed (MG) poster, duplex board and grey board, is mainly produced by the small and medium sized recycled waste paper based mills. Newsprint grade paper is produced by mills utilizing mainly recycled waste paper as well as agro residues as major raw material (Bajpai, 2015). The distribution of Indian paper industry based on the type of raw material used for paper making is as 35% wood based, 10% agro residues based and 55% recycle/waste fiber based (Jain, 2015).

After consumption of the paper, it often makes its way to trash bins and thus, termed as ‘waste paper’. This waste paper when recovered becomes the reclaimed cellulose fiber base suitable for paper making. Today the term ‘recycled fiber’ is used to refer the post consumer paper that has been collected and reused to make paper. Use of recycled fiber for paper making has been picking up the world over, including India. The recycled fiber/waste paper as a raw material is the best suited for newsprint, duplex board and kraft paper. The availability of indigenous waste paper is inadequate and as a result industries rely heavily on waste paper imports to meet the demand of raw materials. Presently around 3.0 million tons of waste paper is sourced indigenously and 4.0 million tons is being imported. The share of imported waste paper is 57% of total recycled fiber requirement.
The use of waste or recycled paper as the raw material for paper production has been increased during the last few decades and some paper mills depend almost completely on waste paper. The main benefit of the recycling is a double decrease of the environment loading, first in the form of conservation of the natural resources used as the manufacturing process inputs (Hossain and Ismail, 2015) and the second, reduction in environmental pollution by way of decreased production of harmful compounds as the manufacturing process output (Cabalova et al., 2011).

The current environment awareness and legislation is forcing us for maximum recycling of waste paper. The paper industry is the exclusive user of waste paper as a secondary source of raw material. Without recycling of the waste paper, the fiber supply in the world cannot be full filled with increasing demand of paper. The paper production from the recycled fibers consumes less energy; conserves the natural resources viz. wood and decreases the environmental pollution.

Over the last few years, as a result of attraction of the consumers and the successful development of recycling processes, the use of recycled fibers in newsprint, tissues and in higher quality paper grades is significantly increased. The main difficulty for the recycling of recovered printed paper such as old news paper, mix office waste, laser waste, magazine paper etc. is deinking (i.e., removal of ink) and the strength of recycled paper. There are two major phases in deinking of the paper: the disintegration of printed paper and the separation of ink particles and contaminants from the fibrous suspension by washing or flotation (Sanchez, 2000) and it is commonly done in an alkaline medium using chemical substances (Ferguson, 1992). Because of the use of chemical agents such as NaOH, H₂O₂, Na₂SiO₂, surfactants during the process of deinking, pH value rises relatively high and pollution load generated from the mill effluent is increased to high levels. Also, high value of pH negatively affects the optical properties. Alternative to this conventional process is the enzymatic deinking. By enzymatic treatments the ink particles adhering to the paper surface are released and separated by floatation. The use of cellulases and hemicellulases bring about partial hydrolysis of carbohydrate molecules on the fiber surface resulting in the detachments of ink from the latter.

Technological advances in repulping and deinking (removing the ink from the paper) have improved the quality of the secondary fiber. Finally, growing demand for recovered paper has stimulated investment in the infrastructure to collect and process paper in many countries. Paper that heretofore would have ended up in a landfill is now being collected.
processed and exported (Stafford, 2007). The paper, which is produced after recycling, has been increasingly produced in various grades in the paper industry. Paper recycling is increasingly important for the sustainable development of the paper industry.

The pulp and paper industry is the fourth-largest energy user worldwide, consuming about 5% of total global industrial energy consumption (IEA, 2011). In India, the pulp and paper industry is positioned seventh (BEE, 2010-11) among the highest energy consumers using stubbornly high amount energy compared to mills in the developed countries (Panda and Keswani 2008). Energy is the second largest cost component accounting approximately 25% of the total manufacturing cost of pulp and paper industry in India. Major part of the energy i.e. 18-25% is used during refining of pulp for paper making.

Refining is a mechanical treatment which increases the surface area of fibers, fiber to fiber bonding and thus strength properties of paper. Refining of pulp by cellulase enzyme modifies the pulp properties such as improved fiber strength (Gupta et al., 2015). Cellulase helps to soft the fibers and breaks the primary wall. Fiber becomes easy to refine by addition of enzyme because of digestion of small fiber fraction. Cellulase enhances fiber strength along with reduction in required refining energy and increases inter-fiber bonding fibrillation, while increasing drainage rates and avoiding fiber breakage. The small amounts of enzyme provide the same function as large amounts of chemicals and that enzymatic processes generally require less energy inputs (Nielsen et al., 2007).

Microbial cellulases have become the focal biocatalysts due to their complex nature and wide spread industrial applications (Kuhad et al., 2011). Cellulases have been commercially available for more than 30 years and are the target for both academic as well as industrial research (Singh, 1999; Singh et al., 2007). Basic and applied studies on cellulytic enzymes have demonstrated their biotechnological potential in various industries including food, animal feed, brewing and wine making, agriculture, biomass refinery, pulp and paper, textile and laundry.

Cellulases are inducible enzymes synthesized by a large diversity of microorganisms including both fungi and bacteria during their growth on cellulosic materials. Microorganisms excreting cellulase play an important role in nature, due to their ability to decompose lignocellulosic residues, establishing a key link in the carbon cycle.

Over the years, a number of organisms, particularly fungi, possessing cellulose-degrading enzymes have been isolated and studied extensively. Fungi are the most important
microorganisms for the decomposition of organic matter. The ability of the fungi to grow and survive under adverse conditions is well documented (Kumar, 2011). The ability to accumulate micronutrients is high in fungi (Standburg et al., 1981; Gadd, 1986). By virtue of their greater biomass production, extensive hyphal growth, aggressive sporulation, spreading in environment and high surface: cell ratio of the filaments is likely to perform better than bacteria.

The fungal cellulases are mainly produced from soft rot fungi (Aspergillus, Fusarium, Humicola, Penicillium, Trichoderma, Chaetomium, Neurospora and Paecilomyces), brown rot fungi (Coniophora, Lanzites, Poria, Tyromyces, Fomitopsis) and white rot fungi (Phanerochaete, Sporotrichum, Trametes, Agaricus, Pleurotus, Phlebia). One of the most extensively studied fungus is Trichoderma reesei, which converts native cellulose and its derivatives to glucose by the action of cellulolytic enzymes. Beside Trichoderma several fungi like Humicola, Penicillium and Aspergillus can metabolize cellulose as an energy source, but only few strains are capable of secreting a complex of cellulase enzymes, which could have potential application in the enzymatic hydrolysis of cellulose.

Most of the commercial cellulases (including β–glucosidase) have been produced from the Trichoderma, Penicillium and Aspergillus genera however many other microorganisms including aerobic bacteria (Acinetobacter, Acidothermus, Bacteriodes, Eubacterium, Geobacillus, Microbispora, Paenibacillus, Rhodothermus, Bacillus, Psuedomonas), anaerobic bacteria (Acetivibrio, Butyrovibrio, Clostridium, Fibrobacter, Ruminococcus) and actinomycetes (Cellulomonas, Streptomyces, Thermomonospora, Actinomucor) are also known to be good producers of cellulase.

Several investigators worldwide are working on cellulase production with the rejuvenated interest created due to its application in lignocellulose conversion (Sukumaran et al., 2005). Production of low titers of cellulase has always been major concern and researchers are trying to improve the production of high titers by adopting multifaceted approaches, which include the use of better bioprocess technologies. Use of cheaper or crude raw materials as substrate for its production makes the process further cost effective (Sukumaran et al., 2005).

The cellulase has been produced by both submerged fermentation (SmF) and solid state fermentation (SSF). The production of cellulase at industrial scale is usually carried out by SmF using different microbial strains. However, in nature, degradation of cellulose by
cellulase producing aerobic microorganisms probably resembles solid-state fermentation than a liquid culture (Holker et al., 2004; Zhu et al., 2009). It is also found that high levels of proteins can be obtained in SmF but production of proteins grown on solid substrates might be more advantageous (Holker et al., 2004). Moreover, until now, research has mostly focused on hydrolytic activities of proteins present in extracts of filamentous fungi grown on solid substrates that have direct application in biotechnological processes neglecting the identity of proteins involved.

Solid state fermentation holds tremendous potential for the production of enzymes. It can be of special interest in those processes where crude fermented product may be used directly as enzyme source. SSF is an attractive process to produce fungal microbial enzymes using lignocellulosic materials from agro-industrial wastes due to its lower capital investment and lower operating cost (Haltrich et al., 1996). Solid substrate fermentation has a great perspective for the bioconversion of lignocellulosic biomass. Crop residues (straw, corn by-products, bagasse, etc.) are particularly suitable for this purpose, since they are available in large quantities in processing facilities (Pandey et al., 2001).

Cellulase enzyme is a complex in nature and it act in synergistic action of endoglucanase, exoglucanase and β-glucosidase activity. Cellulase is used in various different industry such as food and feed, ligno-cellulosic conversion into bioethanol, textile, detergent, beverages, agriculture and solid waste management. In recent past, interest in the application of cellulases in the pulp and paper industry has increased considerably. The mechanical pulping processes such as refining and grinding of the woody raw material leads to pulps with high content of fines, bulk, and stiffness (Kuhad et al., 2011).

The cellulase enzyme is used in pulp and paper industry mainly in two of its processes i.e. deinking and refining. By adopting the enzyme technology, there will be less consumption of chemicals and thus environmental pollution can be reduced in the generated effluent.

Keeping in view the above discussion, the role of cellulase and its demand in pulp and paper industry, the present research has been planned for efficient production of cellulase enzyme from fungi with the following objectives:

1. Isolation of cellulase producing fungi from different sources
2. Screening of isolates for efficient cellulase producer
3. Characterization of selected isolate
4. Optimization of different conditions for enhanced cellulase production

5. Purification and characterization of cellulase

6. Utilization of lignocellulosics as substrate for cellulase production

7. Applications of cellulase enzyme in pulp and paper industry in the area of enzymatic deinking and refining of waste paper