Investigating the Amount of Water Consumption, Costs of Water Output and Lost Fibers in the Effluent Stream of an OCC Recycling Company in Iran

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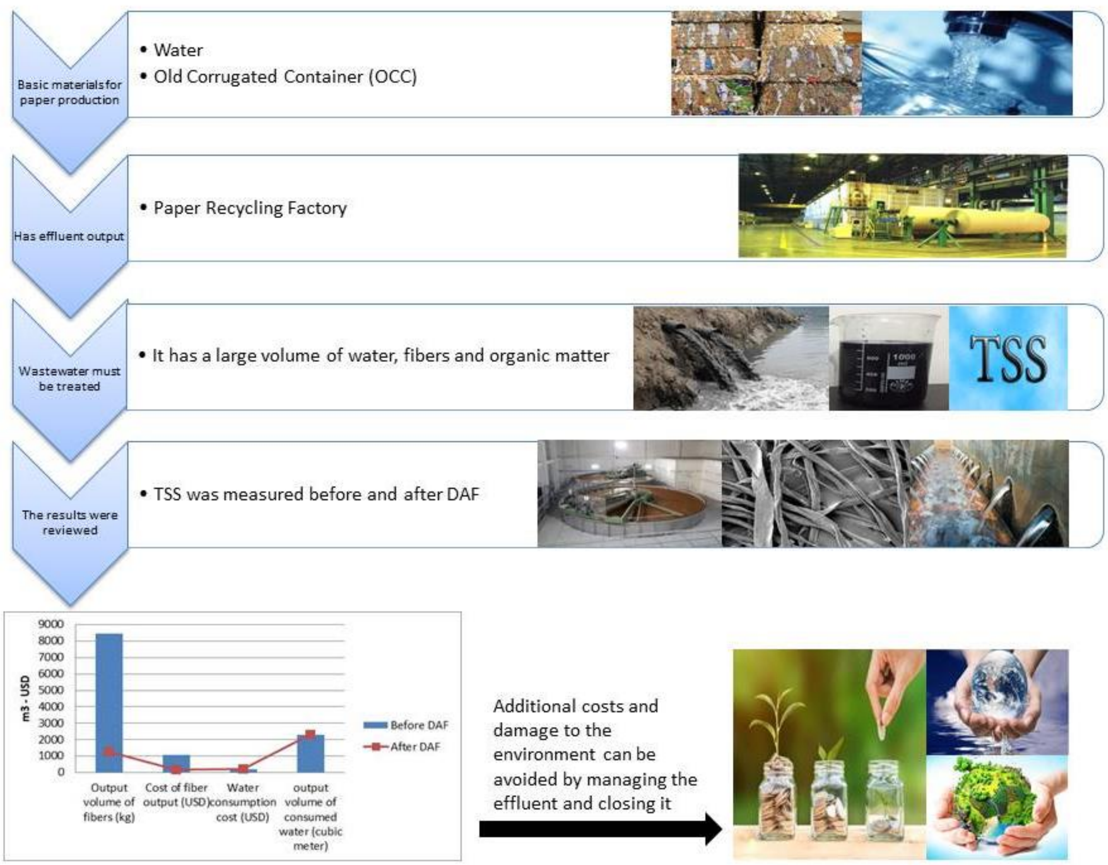
GRAPHICAL ABSTRACT



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Paper production is a process based on using water. Most of the industrialized countries set strict standards to protect the environment, and all industrial wastewater output must be based on such standards. Because of their economic value, recycled fibers must be separated from the effluent and returned to the system when the effluent leaves the factory. The purpose of this study was to investigate and measure the amount and costs of water consumption and the amount of fiber wastage in the controlled and uncontrolled output of the desired factory effluent. From observations of a local OCC recycling factory, the amount of water consumption and effluent output and the amount of fibers in the effluent output of this factory before pre-treatment and after pre-treatment were investigated. It was observed that if the water intake was not controlled and if pre-treatment was not used, a significant amount of fibers was thrown away along with the wastewater, which was 8,440 kg per 391 tons of production in one month based on total suspended solid.

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Keywords: OCC recycling; Wastewater; Environment; Water consumption; Fiber output cost

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INTRODUCTION

Water is the source of life, and all life reactions take place in water. The pulp and paper industry is water-use-intensive, ranking third after the metal and chemical industries in terms of worldwide freshwater consumption. Water consumption by this industry reaches 15 to 60 m^3 per finished tons of paper. High freshwater consumption and the accumulation of contaminants during the paper manufacturing process contribute to the large volume of effluent from paper mills. It has been estimated that the effluent of the pulp and paper industry is responsible for 50% of all industrial wastes and that the effluent volume and chemical oxygen demand (COD) discharged by this industry can reach 38.5 m^3 and 7.5 kg per tonne of paper, respectively (Chen *et al*. 2015).

Therefore, it is not surprising that water pollution is a major environmental concern (Mandeep *et al*. 2020). Because paper production is a process that consumes a lot of water, the use of water in this process should be carefully examined. Wastewater recovery, integrated management, reclamation, reuse, and recycling can be used as tools for the better management of water resources and most importantly to attract stakeholders, scientists, and policymakers into this very important issue (Maryam and Buyukgungor 2019).

Nowadays, the conjuncture of water scarcity, restricted environmental laws, and rising costs of energy and effluent treatment have guided the industries to adopt strategies of water management (Eghuikwem *et al*. 2021). The area of process integration allows the development of methodologies for process optimization, focusing on the reduction of water consumption and the environmental impacts related to these activities (Manago *et al*. 2018). The practice of water and wastewater reuse is an important option for water resources management in the industry, aiming to reduce water consumption and hence their effluent generation (Francisco *et al*. 2014; Tram Vo *et al*. 2014). In addition to reducing effluent generation, pulp mills seek to generate effluents with lower organic and inorganic loads (Nascimben Santos *et al*. 2020).

In the discussion of recycling, fibers should be separated from non-fibrous materials, and because water is a suitable substrate for fibers in various stages of cleaning and screening, the water flow inevitably carries along unwanted materials (Mandeep *et al*. 2019). These unwanted materials are separated from the fibers and can add to the waste load (substances in the wastewater) (Patel *et al*. 2021). Although most of these materials come from recycled paper, when it is made from recycled paper fibers, the complexity of the paper structure prevents the reuse of all the materials in the original paper. For example, there is a coated layer containing porcelain clay and glue in administrative papers, which is broken after kneading and cannot be used again as a coating layer on the surface. As it is an undesirable material for inclusion in the recycled paper, it is discarded. Other types of unwanted materials are those that are added to paper during the conversion process. For example, ink, glue, and other materials that are unintentionally introduced during the collection of wastepaper and its delivery to paper (such as food residue, fat, *etc.*) are among them. The presence of these and similar materials interferes with papermaking operations and hurts to quality of paper made from recycled fibers. As a result, it is necessary to separate these materials. Most of the separated non-fibrous materials will be suspended or dissolved in water. To avoid problems caused by contamination, these materials must be separated before the water exits the recycling plant, and therefore there is a need for wastewater treatment (Mandeep *et al*. 2020).

METHODS

This research was conducted in the local OCC recycling factory. The width of the paper making machine was 130 cm, the speed of the production line was 90 meters per minute, and the product type was liner paper with a weight of 135 g/m^2.

All the calculations were made based on the amount of water production and consumption of the OCC recycling plant in Iran. To calculate and check the amount of water consumed in this factory, several factors were considered, which are as follows:

- The water consumed during a month (calculated through the period water bill)
- Amount of working hours during this period
- Amount of paper production in the same month under review
- Amount of production line stops in the desired month
- Investigating factory effluent and TSS levels before and after DAF

The TSS values are determined by weighing the solid matter filtered from a water sample onto a tared piece of standard filter paper composed of glass fibers (APHA 2540 2016) standard method (Hubbe *et al*. 2016).

The OCC recycling plant in question had two water meters that showed a total of 3096 cubic meters of water consumed for one month based on the bill issued in one month.

RESULTS

Amount of Working Hours in a Month

The amount of working hours in a month was examined based on the date that the water consumption bill was issued in the same period, and the hours of these days were added together and a total of 672 hours were obtained, which is considered to be 28 working days in terms of days became.

The Amount of Paper Production in One Month

The amount of paper production during the mentioned periods was collected based on tons, and its amount for 28 working days was 390,651 tons.

The Relationship between Water Consumption and the Amount of Production

The amount of water consumed during 28 working days was 3,096 cubic meters, which was calculated for one day and 110.6 cubic meters were obtained. The amount of production during 28 working days was 390.7 tons, which was calculated for one day and its amount was 14.0 tons per day.

Based on the amount of daily production and daily water consumption that was obtained, the amount of water consumption for one ton of paper was calculated and its amount was 7.9 cubic meters per ton of production, which was calculated as follows:

$$\begin{cases} 13.96\ Tons\ of\ paper\ per\ day \\ 110.57\ cubic\ meters\ per\ day \\ 1\ ton\ of\ paper = \chi\ cubic\ meters \end{cases}$$

$$\chi = \frac{110.57 \times 1}{13.96} = 7.9\ cubic\ meters$$

From 7.9 cubic meters of water used to produce one ton of paper, ¼ of it evaporates, which was obtained by dividing 7.9 by 4, several approximately 2, which was obtained by subtracting 2 from 7.9 to 5.9 cubic meters. That is, for every ton of production, 9.5 cubic meters of water must be removed from the system. According to the results of the experiments, based on the TSS value before and after the DAF, the amount of fiber that leaves the DAF system and the amount that returns to the system through the DAF can be calculated. Furthermore, by obtaining the amount of output water per ton of production that leaves the system, it can be calculated for a month based on the amount of production:

$$\begin{cases} 1\ Tons\ of\ production\ paper \\ 5.9\ cubic\ meters\ of\ water\ output \\ 390.7\ tons\ of\ production\ per\ month = \chi \end{cases}$$

$$\chi = \frac{390.7 \times 5.9}{1} = 2305\ cubic\ meters$$

For 390.7 tons of production in the mentioned period, 2,305 cubic meters of water are removed from the system.

Calculating the Amount of Fibers Before and After Dissolved Air Flotation (DAF)

The DAF machine of this factory had two 500-liter tanks made of chemicals, in one of these tanks 5 kg alum was dissolved in 500 liters of water and in another tank, 700 g of polyelectrolyte was dissolved in 500 liters of water, and by dosing pump and air injection It was injected into the tank of the device and the fibers in the returned water came to the surface of the tank and these fibers were collected by the device and returned to the factory system.

The TSS obtained before DAF was 3662 mg, based on which the amount of fiber entering DAF from the system along with water can be calculated,

$$\chi = \frac{0.003662\ kg \times 2305000\ lit}{1\ lit} = 8441\ kg$$

where there are 8441 kg of fibers in the effluent entering DAF, during the production of 390.7 tons.

The TSS obtained after DAF was 545 mg, based on which the amount of fiber that leaves the DAF system along with water is as follows: lit (2305000, the amount of water that leaves the system during the mentioned period)

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$$\chi = \frac{0.000545\ kg \times 2305000\ lit}{1\ lit} = 1256\ kg$$

The amount of fiber that is removed per 390.7 tons of production in one month, x = 1256 kg

Now, based on the amount of TSS before and after DAF and the calculated amount of fiber, the quantity of the fiber returned to the system can be determined as:

8441 - 1256 = 7185 kg

Based on the price of water in the period when this research was conducted, each cubic meter of water was 0.0673 (United States dollars), which can be said that in the mentioned period, based on the production of 390,700 tons and the calculated water output of 2305 cubic meters. If it is to be completely removed from the system, it would cost the company 208.5 USD in terms of water costs alone. In addition, the lack of this amount of water, in addition to the fiber in the outgoing water, must be compensated with raw water, and if it is not returned to the system, it is a significant number.

The Amount of Fiber Price If it is Not to be Used from DAF and Not Returned to the System

Based on the price of 0.128 USD per kilo of OCC and the amount of fiber obtained from the input of DAF based on the amount of TSS, it was 8,441 per 390.700 tons of production, and it can be calculated as follows:

The output cost of fibers when DAF is not used is as follows:

$$8441 \times 0.128 \text{ USD} = 1082 \text{ USD}$$

The Amount of Fiber Price if DAF is Used and Water Exits from the System

Based on the price of 0.128 USD per kilo of OCC and the number of fibers obtained from the output of DAF based on the amount of TSS, which was 1256 kg per 390.7 tons of production, it can be calculated as follows:

$$1256 \times 0.128 \text{ USD} = 160.7 \text{ USD}$$

Therefore, it can be said that the use of DAF makes a considerable amount of fiber, worth 918.5 USD, return to the system. Therefore, the treatment of water leaving the recycling plant is important from two points of view:

1. Preventing wastage of materials in wastewater
2. Reducing the load of sewage pollution to not harm the environment

Table 1. Amount of Water Consumption and the Cost of Wastewater Output Based on the Price of the Water Tariff

Items	Before DAF	After DAF
The output volume of consumed water	2305 cubic meter	2305 cubic meter
Output volume of fibers based on TSS	8441 kg	1256.2 kg
Cost of fiber output	1082 USD	160.7 USD
Water consumption cost	208.466 USD	208.466 USD

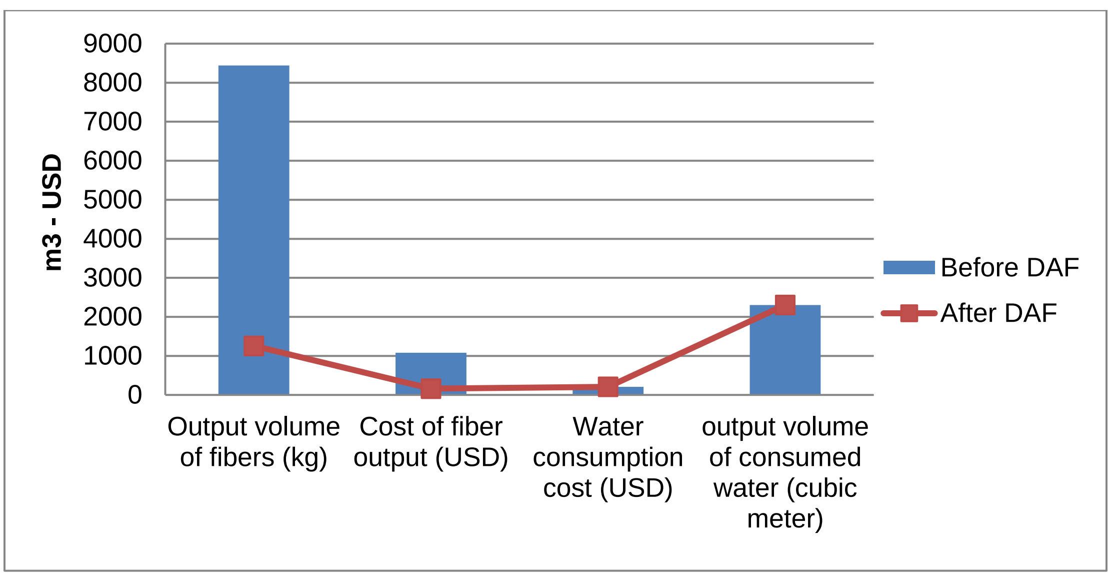

Fig. 1. Graph of water consumption and cost of fiber output from wastewater

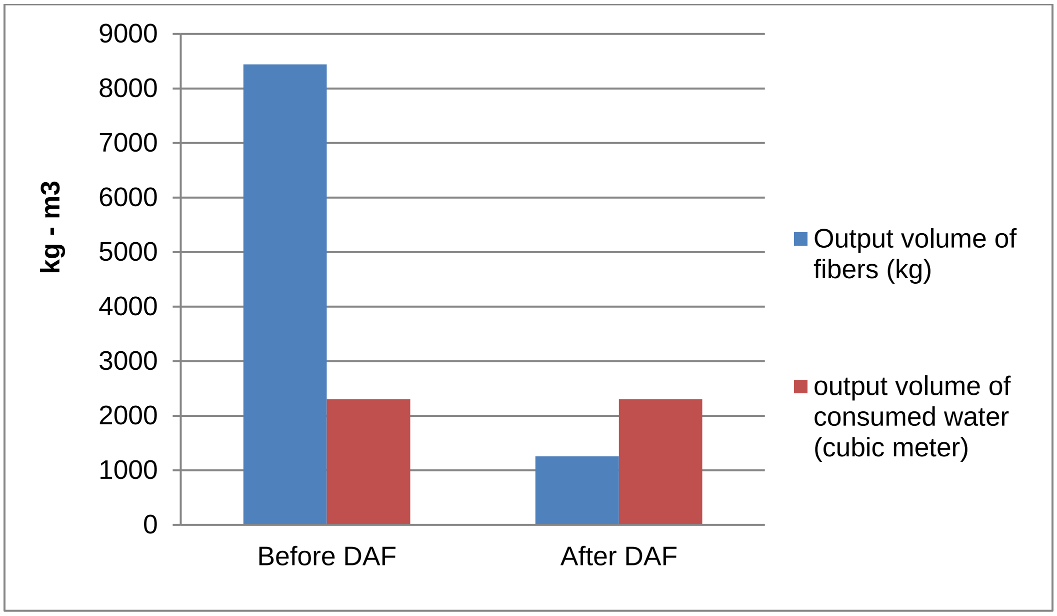

Fig. 2. Graph of fiber and water output from wastewater before and after DAF

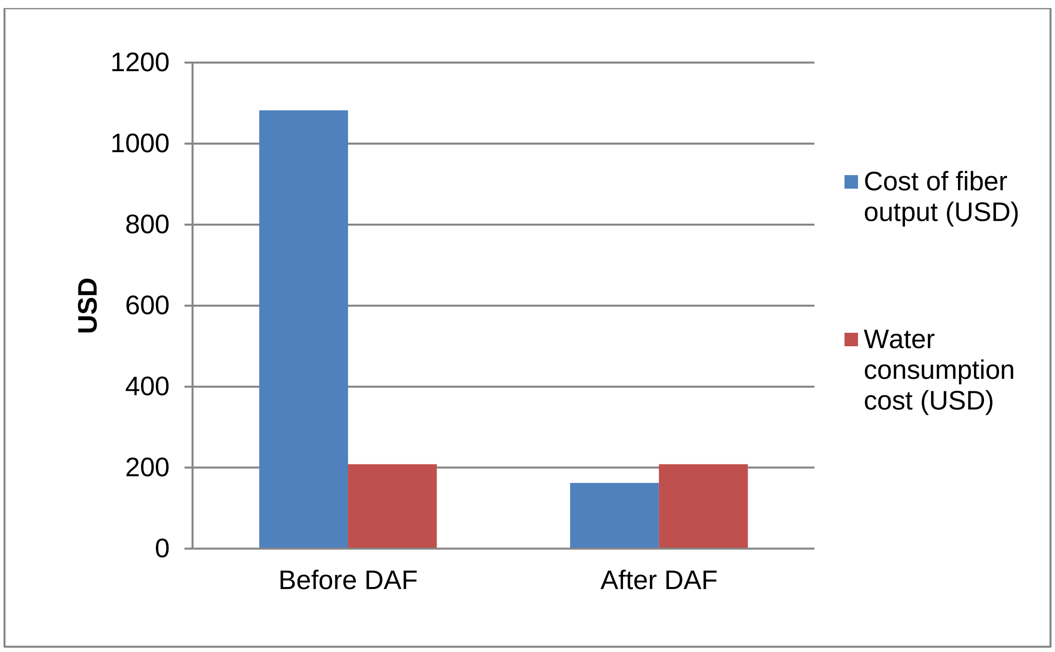

Fig. 3. The graph of the output cost of fibers and water before and after DAF

Relationship between Wastewater and Paper Quality

Paper and cardboard recycling factories usually use somewhat closed water recirculation systems because they do not have ink removal and pulp dyeing. That is, there is no need for the optical performance of this type of paper to be high, and more attention is paid to its quality from the point of view of mechanical strength. In contrast, it should be noted that paper fiber is a type of organic material that has organic compounds, and these compounds sometimes affect the quality of paper. If the circulation system is used and the wastewater treatment is not done properly, it will increase the wastewater load and affect the pH, which in this case can cause the formation of specks on the surface of the paper (tar formation). In addition, acidification causes corrosion of equipment and propellers, which also brings huge costs for the factory in the long run. If the water is to be removed from the system, then there are substantial costs that cannot be ignored. In this case, the factory must be equipped with a comprehensive wastewater system to be able to take all the materials in the wastewater and transfer environmentally acceptable water to the surface waters of the region, which is also costly.

CONCLUSIONS

1. In this factory, to produce one ton of paper, 7.9 cubic meters of water is consumed, $\frac{1}{4}$ of which is through steam, and there is 5.9 cubic meters of excess water that must be removed from the system. According to the TSS obtained from the effluent output of this factory, if the DAF device is used, for one ton of paper production, 3.2 kg of fibers are also removed from the system along with the effluent, and if the DAF device is used Also, for one ton of paper production, 21.6 kg of fibers are removed from the system along with wastewater. Therefore, according to the costs of water consumption and wastewater output and the environmental consequences that can have for the company in question, it must have adequate management in water consumption.
2. Due to the materials present in the wastewater of the paper mill, releasing the return water without treatment into the environment due to its high pollution load will endanger living organisms and cause irreparable damage to the environment. Therefore, the environmental organization follows the effluent output of paper mills and if it is observed that the effluent output is not treated, it will strictly act against the offending company according to the law, in some cases leading to the closure of the paper mill. Therefore, according to the mentioned cases, the paper company in question is now using a closed water flow system to avoid its output costs and environmental problems.
3. Because the degumming and dyeing system of paper pulp is not used during production and the light resistance of paper is less important than mechanical resistance, there is no need to continuously use raw water. The proper wastewater prevented the wastage of water and fibers in it and kept the pH in the neutral range to prevent the corrosion of equipment and chemical interactions in the fibers. It is also possible to increase the level of fiber bonding by using pulp refining to increase the mechanical strength to meet the quality objectives of the paper in question.

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