Available online at www.worldscientificnews.com

World Scientific News

WSN 64 (2017) 84-98 EISSN 2392-2192

Assessment of Water Footprint in Paper & Pulp Industry & its Impact on Sustainability

Abhishek Nandan[1,a], Bikarama Prasad Yadav[1,b], Soumyadeep Baksi[1,c], Debajyoti Bose[2,d]

[1]Department of Health, Safety & Environmental Engineering,
University of Petroleum and Energy Studies, Dehradun, India

[2]Department of Electrical, Power & Energy,
University of Petroleum and Energy Studies, Dehradun, India

[a-d]E-mail address: abhisheknandanhseddn@gmail.com ; bpyadav@ddn.upes.ac.in ; sbaksi@ddn.upes.ac.in ; dbose@ddn.upes.ac.in

ABSTRACT

Unsustainable utilization of water assets conveys challenges these days identified with the generation periods of water devouring products, for example, pulp & paper. This industry is portrayed by noteworthy water utilization at every procedure venture of creation. This study concentrates on the water footprint appraisal of paper and pulp generation at a medium measured paper and pulp industry in Uttar Pradesh, India. Here, the evaluation depended on the creation chain outline. A framework limit was proposed to evaluate the water footprint at different procedure stages from the source to the last item and additionally the natural contacts with extraordinary spotlight on maintainability. Through this study water footprint accounting has been done and the outcomes were utilized to break down the supportability as far as, Blue water footprint, Grey water footprint and Green water impression for Kraft & White paper. Also, recommendations for reasonable practices have been touched upon.

***Keywords*:** Water footprint; paper and pulp Industry; Blue water footprint; Grey water footprint; Green water impression

1. INTRODUCTION

People expanded apportionment of freshwater assets alongside environmental change will put expanded strain on worldwide water assets, and the significance of freshwater assets and administration of freshwater cycles will get more noteworthy consideration later on. Human exercises expand and contaminate a ton of water. At a worldwide scale, the majority of the water use happens in rural creation, yet there are additionally significant water volumes devoured and contaminated in the mechanical and residential segments.

The pulp and paper industry is one of India's most seasoned and center mechanical division. The financial significance of paper has its own particular quality to the nation's improvement as it is specifically identified with the mechanical and monetary development of the nation. Paper assembling is an exceedingly capital, vitality and water serious industry. The substantial water necessities and utilization by the Indian pulp and paper commercial ventures has prompted, water quick turning into a rare ware and bringing down of the groundwater table and along these lines expanded pumping expenses and all the more imperatively water lack in numerous areas. Understanding the significance of water and exorbitant uses of water by pulp and paper part, 'water footprint' has been utilized.

The concept of sustainable water use laterally resource restraints has increased relevance later the evolution of the idea of ‘Water Footprint or Impression' by Hoekstra. Water impression is one of the markers of water usage that expresses not just at water that is utilized of a purchaser or maker, nonetheless similarly at roundabout water use. It can be considered as freshwater assets allocation’s exhaustive marker.

2. BACKGROUND

Water, being an inadequate product adds to a disturbing weight of a global economy and gets appreciation via economic pioneers, legislators etc. (McKinsey and Company, 2009). A lot of freshwater are required all through the inventory network of an item until the snippet of utilization. Weight on freshwater assets is expanding quickly with environmental change, populace development and proceeding with financial advancement. For these reasons, numerous commercial enterprises are trying to show great corporate citizenship by measuring and tending to negative effects of unsustainable water usage in processes (Chapagain and Orr; 2009).

For measuring this sum, a pointer is fundamental for which the water footprint idea is utilized (Chapagain and Hoekstra 2007; 2008). The water impression of an item is characterized as aggregate sum of fresh water that is expected for creating it. The water impression can contain grey, green and blue parts. Green element is amount of water vanished through water put away in/on the vegetation or put away in dirt as dampness of soil, segment (blue) alludes to dissipated earth water and surface water and the grey segment is the amount of contaminated surface and ground water (Chapagain and Orr, 2009) (Ridoutt et. al. 2009a). Water footprint has straightforward the unfavorable effects of unsustainable utilization and generation on freshwater accessibility (Ridoutt and Pfister 2010).

Water footprint estimations have as of now been done for a few items like ethanol from molasses (Chooyok *et. al*., 2013), carbonated drink containing sugar (Ercin *et. al.*, 2011), cotton (Chapagain *et. al.*, 2005), sweeteners (Leenes *et. al.*, 2009). Some prior studies have

likewise centered around the general water footprint of businesses including wine production industry (Simona *et. al.*, 2013), iron and steel industry (Gu *et. al.*, 2015) to give some examples.

From the investigation of prior studies it is understood that paper plants ought to consider water footprint bookkeeping as a vital stride for maintainability appraisal of an industry and an appropriate model ought to be taken after for figurings (Quian *et. al.*, 2012). The approach utilized as a part of this paper incorporates the general framework examination and determination of exploration reach in the generation chain of paper (Gu *et. al.*, 2015). Also, a water parity study has been performed before the genuine water footprint estimation to comprehend the water stream in the business betterly. Water footprint assessment figurings and maintainability appraisal has been done by formulas given in Water Footprint Assessment Manual, 2011.

3. REVIEW OF LITERATURE

The appraisal of virtual water streams between countries as an aftereffect of exchange farming and mechanical items is vital. Where the stream bowl is for the most part seen as the proper unit for examining freshwater accessibility and utilize, this paper demonstrated that it turns out to be progressively imperative to put freshwater issues in a worldwide connection. Worldwide exchange things infer streams of 'virtual water' over extensive separations, where virtual water ought to be comprehended as the content of water used to create merchandise. Virtual streams of water between countries have been assessed from measurements on global item exchange and the virtual water content per item in the sending out country.(Champaign *et. al.*, 2008)

The issue of water and its administration is integral to worldwide level headed discussion. Water is a rare asset, albeit renewable; atmosphere changes, rural, modern and regular folks use have restricted the accessibility of this asset for future eras. Lately, organizations had demonstrated a developing enthusiasm for results of water use and utilization, particularly the agri-nourishment segment organizations. In this study, through an outline of methodological and operational methodologies utilized as a part of exploratory writing to evaluate water use and utilization, they have condensed their principle applications in agri-nourishment segment. (Mazzi *et. al.*, 2014)

This study gave an outline of an expansive scope of techniques created to empower bookkeeping and effect appraisal of water use. The basic survey uncovered that methodological extensions vary with respect to sorts of water use represented, consideration of neighborhood water shortage, and also separation in the middle of watercourses and quality viewpoints. As the utilization of the most exceptional strategies requires high determination stock information, the exchange off in the middle of exactness and pertinence should be tended to in future studies and in the new universal standard. (Berger *et. al.*, 2010)

The issue actualizing stricter natural regulation to improve eco-proficiency and maintainability by directing a contextual investigation of Shandong Province, China’s paper and pulp industry has been appeared. In this investigation, foundation is usage in year 2003 of Shandong Province's Paper and Pulp Industry SPPI in the Stricter Discharge Standard (SDS) , contrasted with the China’s national principles. The sterner rules were expected to advance business change from aloof administration leading to dynamic regulator and from end of the

channel action to domestic creation. The study examined the green productivity patterns of SPPI from 2001 to 2008 in the following fields: water effectiveness, vitality proficiency and atmosphere productivity. A "deconnecting" and "reconnecting" instrument was used to complete a further study. The study demonstrated that with the use of firmer regulation the vast majority of the productivity markers (aside from CO_2 emanation and vitality utilization) had accomplished noteworthy upgrades, and the general ecological execution patterns of SPPI indicated it to be more sustainable (Wang *et. al.*, 2011).

Auditing the procedures included in paper making and analyzing the impacts which they could have on the earth is a matter of significant concern. The concentrate additionally assessed the treatment forms which are utilized to minimize these impacts. In accordance with the dominant part of UK practice, it concentrated essentially on oxygen consuming organic treatment and, specifically, on the initiated oozes process. The paper likewise talked about the route in which anaerobic absorption can be connected to the treatment of fluid squanders from the assembling of paper. (Thompson *et. al.*, 2001)

The examination on fusing the Water Impression and Practical Water into Strategy taking likenesses of the Occidental Area of Mancha, Spain has been concentrated on. The virtual water idea (the volume of water utilized as a part of the generation of a merchandise, decent or administration) along with the footprint of water (water pointer utilization that takes a gander for immediate and backhanded water utilization of a purchaser and maker), interfaces an extensive scope of divisions and issues, in this manner giving a possibly proper structure to bolster more ideal water administration rehearses by advising creation and exchange choices. The paper gave an examination of the two ideas inside the setting of the Occidental area, Spain, investigating the hydrographic and financial parts of agrarian generation. (Aldaya *et. al.*, 2010)

There are two contextual investigations of applying the Water Footprint or impression (WF) and Life Cycle Assessment (LCA) and ways to deal with margarine and tea. The stock results in the Life Cycle Assessment plan (blue water) were 114 L and 13L for margarine and for tea. Coonoor of South India showed up as a possible spot for tea generation, despite the fact that the water devoured in vitality to heat up the pot and by the purchaser was likewise huge. The main spot for margarine was watered sunflower in Ukraine. The effect appraisal penalties of LCA for tea alludes to water in customer use stage to be downcast biased and apprehensions the commitment of Coonoor because of the advanced liquid shortage of this locale. (Jefferies *et. al.*, 2012)

Contrasting the comparison of Water Footprint Assessment and water Intensive Life Cycle Assessment and makes it clear that both systems have the aberrant objective to help their experts safeguard water assets, in any case, the way they accomplish this varies. The LCA philosophy goes for measuring potential natural effects created by a human action on an extensive variety of ecological issues (human respiratory effects, environmental change, soil use, and so on.). The LCA procedure incorporates four stages: objective and degree, stock bookkeeping, sway appraisal and understanding. The Water Footprint Assessment strategy discourses freshwater assets assignment in a 4-stage method counting setting objectives and degree, water impression bookkeeping, supportability evaluation, and reaction definition. Both LCA and WFA use measurable markers, however at various periods of appraisal. (Boulay *et. al.*, 2013)

Assessment of two techniques for water footprint appraisal i.e. volumetric and sway evaluation is considered. The study assessed these procedures utilizing a New Zealand-based

tissue paper inventory network. It was found that for the reference stream of one kilogram of tissue paper the volumetric water footprint was 1284 kg and the effect appraisal footprint was 0.4 kg (as biological community water-reciprocals). The outcomes demonstrated that whilst the water connected with tissue paper creation in New Zealand is extensive, the effect of this water use was insignificant. Both strategies are constrained by an absence of information. The volumetric strategy requires clearer delimitations and the effect evaluation technique utilized can't claim to completely measure the effects of the water use utilizing the flow pointers and criteria. In this way it was suggested that a solitary, more comprehensive water footprint strategy that uses more modern pointers of water anxiety ought to be produced. (Mcdevitt *et. al.*, 2012).

An involved study on the proposition of water-shortage weighted water footprint in LCA demonstrated the primary focuses which were: (1) including liters of water utilize distinctively in view of the level of neighborhood water shortage darkens the real verbal confrontation of water shortage, which considers assigning water assets to contending exhaustion and uses at a worldwide scale; (2) the disregard of water which is green utilization overlooks the way that green water is occasional too; (3) meanwhile water shortage in a catchment increments with developing general water utilization in a space, increase of the immoderate water utilization of particular procedure or action with water shortage suggests that the subsequent biased WF of a procedure or action will be influenced by the WFs of different procedures or exercises, which can't be the motivation behind a natural execution pointer; (4) the LCA action of the WF is conflicting with in what way other ecological footprints are characterized; and (5) the Water Stress Index, the most referred to water lack metric in the LCA group, needs significant physical understanding. It is proposed to join the subject of freshwater reduction in LCA as a 'characteristic asset consumption' group, considering exhaustion from a worldwide point of view. (Hoekstra 2016)

There was a study in which the appraisal of the footprint of water of Ethanol Production from Supanburi Province of Thailand and Molasses in Kanchanaburi was conveyed out. The water impression counts were performed in three sections: sugar stick, molasses, and ethanol generation. The study considers the components, for example, climate, soil and planting date. Evapotranspiration rate was computed utilizing CROPWAT model. The blue, green, and grey footprints of water of ethanol creation commencing of molasses in Kanchanaburi Province were 45.0, 209.6, and 849.7 (m^3/ton), separately, though of ethanol in Province of Suphanburi are 48.6, 102.9, and 708.3 (m^3/ton), individually. Both regions in the study region had their particular measure of the grey water impression of ethanol generation, and molasses generation is zero. The wastewater in ethanol and molasses generation have a high BOD and temperature, while the grey water impression in the study is nil in light of the fact that the wastewater might be put away in lake, or it might be reused in region of manufacturing plant and do not have an immediate release into water framework. (Chooyok *et. al.*, 2013).

Improvement of another water footprint estimation strategy incorporating immoderate and degrading water usage in a solitary separate weighted marker made the concentrate more subjective. Results for both wasteful and degradative water use were communicated in the reference unit H_2Oe, empowering summation and reporting as a solitary stand-alone esteem. Immoderate water use was evaluated thinking about the nearby water stress in respect to the worldwide normal water stress (0.602). Concerning degradative water utilize, every outflow was displayed independently utilizing the ReCiPe sway evaluation approach, with results in this manner standardized, weighted and changed over to the reference unit (H_2Oe) by

correlation with the worldwide normal quality for immoderate water utilize (1.86×10^{-3} ReCiPe focuses m^{-3}). (Ridoutt *et. al.,* 2013)

An overhauled way to deal with water footprinting to have straightforward the effects of utilization and generation on worldwide freshwater lack has been completed. In this paper, an overhauled water footprint computation technique, fusing water stress characterization elements, was displayed and showed for two contextual analysis items, Dolmio1 pasta sauce and Peanut M&M's1 utilizing essential generation information. The strategy offers a basic, yet important method for making quantitative examinations between items, creation frameworks and administrations as far as their capability to add to water scarcity. This reexamined technique speaks to a distinct option for current volumetric water impression count strategies which join green and blue water utilization from water rare and water plenteous locales so that they result in no unmistakable sign about where the genuine probable for mischief exists. (Ridoutt *et. al.*,2010)

The study took a shot at the estimation of water footprint wastewater treatment plants. The water footprint (WF) gave corresponding data to assess the effect of a WWTP with respect to the utilization of freshwater. The paper introduced the reception of the Water Footprint Assessment procedure to survey the utilization of water assets in WWTPs by seeing two of them, blue and grey WFs. The value of the planned strategy in evaluating the natural effect and advantages through WWTP release to the waterway was represented with a real WWTP, which gives 4,000 $m^3$$d1, utilizing three situations: nil treatment, phosphorous evacuation and optional treatment. A lessening of the water impression by 72.4% and 51.5% was accomplished utilizing optional action and compound phosphorus expulsion, individually, to satisfy as far as possible. These outcomes showed that during handling wastewater, there is a huge abatement footprint which is grey contrasted and the nil-treatment situation; notwithstanding, there is little blue water footprint. (Morera *et. al.*, 2015)

The specialist has chipped away at the appraisal of water footprint in a Romanian intermediate size wine generation plant, checked for a 4-year period with various rainfall administrations. The evaluation depended on the generation chain outline, showing the significant procedure stages starting from the foundation to the last item, and the present discharges and ecological effects. The wine exchange offs financial probable, and assessment of the water footprint nationwise plan identified with Romanian wine creation and utilization were evaluated. The discoveries of this study demonstrated that very nearly 99% of the aggregate water impression is identified with the inventory network water usage, out of which 15% grey, 82% green, 3% blue. (Simona *et. al.*, 2013)

The count of footprint of water of cotton utilization was finished. The paper surveyed the 'water impression' of overall cotton utilization, distinguishing the two areas and the atmosphere of the effects. This work recognized the following sorts of effect: vanishing of penetrated water for cotton development (green water use), withdrawal of surface-or ground water for watering system or handling (blue water utilize) and water contamination amid development or preparing. The last effect is measured as far as the weakening volume important to acclimatize the contamination. For period of 1997–2001 the study demonstrated that the overall utilization of cotton items needs 256 Gm3 of water for each year, out of which around 19% is grey water, 39% green water and 42% blue water. Around 84% of the water impression of cotton utilization in the EU25 district was situated outdoor Europe, with significant effects especially in Uzbekistan & India. (Chapagain *et. al.*, 2006)

The study took a shot at the estimation of blue footprint of water of power via hydropower. The study surveyed the blue water impression of hydropower; water disappeared from artificial stores for creating electricity vitality in 35 chosen destinations. Amassed blue water impression of the chose hydroelectric power plants was 90 Gm^3 yr^{-1}, which is equal to 0.1 of blue water impression of worldwide harvest generation in 2000. In this study it is understood that water footprint ought to be included as a critical element of assessment for recently settled hydropower plants. (Hoekstra, *et. al.*, 2012)

The study connected Multiple Criteria Analysis to six water administration choice issues. The MCA techniques test included weighted summation, scope of quality, PROMTHEE II, Evamix and bargain programming. They demonstrated that distinctive MCA techniques were in solid concurrence with high relationships amongst rankings. The outcomes recommended that whilst determination of the MCA strategy is imperative more accentuation is required on the underlying organizing of the choice issue, which includes picking criteria and choice alternatives. (Hajkowicz *et. al.*, 2008)

Idea of minimizing the green, blue and dark water footprint utilizing soil material science was utilized to make manageable utilization of water. The study tells that biophysical information of use of green water through plants, when supplemented with soil material science demonstrating of both green and blue water stream in soil, licenses advancement of watering system conventions and approaches so as to ensure regular capital loads of blue-water assets that are utilized for watering system. Display of filtering procedures prompts rehearses for constraining dim water. These instruments and systems will prompt eco-proficient methods to lessen the indirect water substance for sustenance, fiber & fuel items we develop, while keeping up other biological community benefits that are water subordinate. (Clothier *et. al.*, 2010)

The study built up a multi-target enhancement model to recognize the supply blend that minimizes the water footprint bookkeeping results and expenses of compound pulp, in this manner encouraging the appraisal of the water footprint by representing distinctive synthetic pulps obtained from different suppliers, with an emphasis on the proficiency of the generation process. A multi-target model for supply blend improvement was likewise created utilizing multi-criteria choice investigation (MCDA). The MCDA that they created was utilized to decide the ideal blend of concoction pulps from various nations, which exhibited how the ideal blend changed while considering one and only of the two variables. (Manzardo *et. al.*, 2014)

3. METHODOLOGY

Development of system boundary

The circle of life of pulp and paper sector incorporates crude material derivation, pulp arrangement, dying and paper making. Be that as it may, the water footprint of a few inputs (e.g. crude materials and inventory network) is hard to acquire for ventures. What's more, the logistics of crude resources could be altogether dissimilarities relying upon the bases and are regularly not very much recorded. At long last, the water utilized as a part of establishment and decommissioning of the paper factory is not regularly followed, so there is no information accessible for this angle. Fig. 1 outlines the exploration limit (the object of the study in strong lines) for this situation.

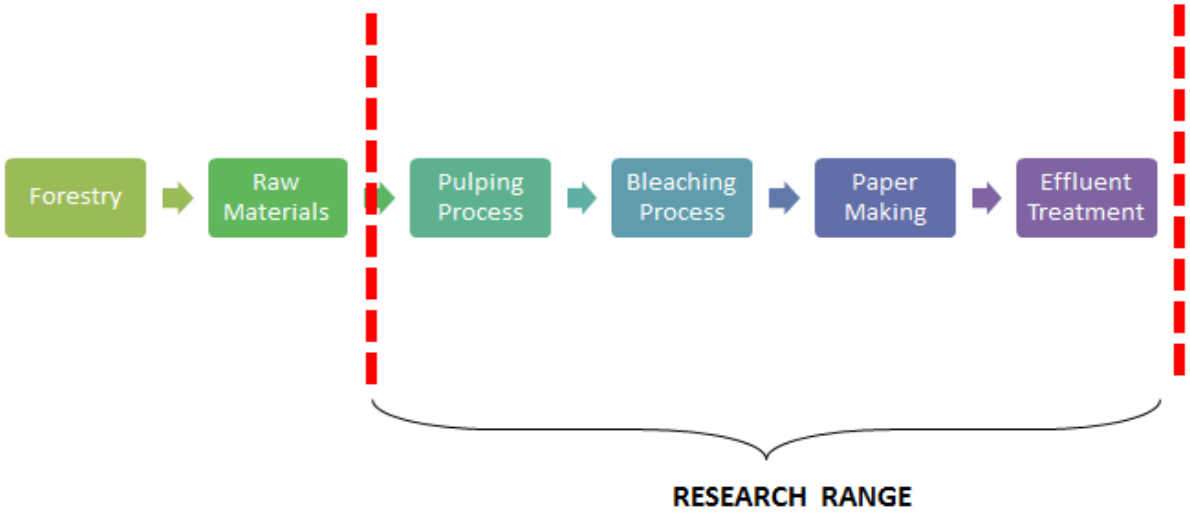

Fig. 1. System limit and Research Range

Setting of goals and objectives

In reference to water footprint appraisal manual, particular objectives and destinations must be characterized considering a definitive focus of the study, the term of the study and extent of hobby.

Extreme focus of the study is mindfulness raising and arrangement development. All progressions in the generation of paper have been considered. The extent of interest lies in water footprint bookkeeping including immediate and aberrant footprint giving particular spotlight on blue, green and dark water footprint.

Water footprint accounting

Water footprint bookkeeping is the principle venture in the evaluation of water footprint of anything or business. It incorporates the figuring of the careful utilization of water at every procedure step, or because of human exercises. It comprises of two stages, to be specific water equalization study and water footprint figuring.

Water parity study is the adjusting of the amounts of water devoured at every procedure venture in the generation stage. The study gives an understanding into water stream system and the aggregate sum of water expended, used, treated and returned for reuse.

Water footprint can be arranged into immediate and backhanded water footprint. Direct water footprint again fans out into green impression, grey footprint and blue water impression. Blue water footprint is the pointer of new surface or ground water. Green water impression is the pointer of precipitation.

Grey water impression is the pointer of level of freshwater impurity which can be connected with the procedure step. It can be communicated regarding the amount of water that is needed to weaken poisons so that they get to be innocuous.

In this study, water footprint bookkeeping is ascertained by considering every day normal water utilization from 30 days test information. Aberrant water footprint is computed by considering the normal utilization of water per individual, as per IS 1172: 1993.

Sustainability assessment

Supportability appraisal is about contrasting water footprint and what the Earth can reasonably bolster. It is the appraisal where water impression of a procedure, item or corporate is contrasted and the maintainability of its range. Ecological, Social and financial manageability can be considered while doing supportability evaluation. In this paper, the water footprint bookkeeping results have been contrasted with the Central Pollution Control Board Standards indicated as for paper and pulp industry considering natural perspective.

Response formulation

Taking into account the water footprint estimation and the manageability evaluation, proposals and reaction measures have been recommended to discover whether the business is utilizing water as a part of a reasonable way.

4. RESULTS AND DISCUSSION

Water footprint accounting

Direct water footprint

Blue Water Footprint:

Table 1. Blue water footprint observation for different processes during 30 days sampling period

	Blue Water Footprint for different processes in m^3/day										
Day	Pulp Mill & Bleach Plant	ClO_2 plant	Soda Recovery Plant	DM Plant including power generation	Paper m/c 1	Paper m/c 2	Paper m/c 3	Paper m/c 4	Paper m/c 5	Paper m/c 6	Mill Colony and Miscellaneous
1	689.2	33.6	127	303	126.9	149	241.1	215.5	20.7	141.8	570.8
2	688.2	35.2	125.5	299.9	126.2	146.2	239.3	215.1	19.3	140.8	570.4
3	688.3	35.1	126.4	302.5	127.4	148.5	240.7	215.8	19	139.6	571.2
4	688.1	33.7	224.1	303.5	125.9	152.8	238.2	214.7	22.1	139	569.9
5	688.1	34.4	120.4	307.9	126.4	150.5	239.1	215.8	19.1	140.9	570.8
6	686.5	35	132.3	297.8	126.2	148.6	238.7	215.4	21.1	141	570.8
7	688.5	34.5	126.7	302.9	125.9	146.3	238.2	214.6	19	139.2	572
8	686.4	35.3	115.4	303	125.2	149.4	240.6	216.4	20	143.8	568.8

9	688.3	35.4	134.4	272	123.7	152.2	239.8	216.5	19.3	138.2	571.6
10	691.1	34.5	126.5	339	124.3	145.1	239.3	214.7	20.2	145.7	570.1
11	687.5	34.2	125.3	334	123.1	142.6	240.8	214.8	21	133.7	570.9
12	686.8	34.8	124.4	288	125	147.6	241.4	215.6	21.4	129.3	571.3
13	687.4	34.5	125.6	299	123.8	151.5	242.9	216	20.2	149.6	570.8
14	689	34.3	124.1	281.8	132.6	153.2	239.1	216.2	19.9	143.2	569.4
15	688.5	35	121.7	302.7	122.2	144.5	238.7	215.4	19	141.7	570.7
16	688.1	34.5	124.7	305.5	122.8	144.6	240.4	215.8	18	143.1	569.9
17	688	34.8	127.2	299.4	124.5	145.3	238.2	215.6	17.5	141	569.1
18	688.7	34.2	226	302.3	121.9	140.4	237.7	215	16.4	140.6	569.9
19	686.5	34.8	127.4	298.2	124.9	144.6	238.1	215	15.5	142.2	570.9
20	689.6	34.7	124.7	302.9	126.1	146.3	239	215.5	23.4	138.8	570.4
21	688.8	34.8	127.2	301.3	126.5	66.5	240.5	215.5	24.4	143.8	459.7
22	687.3	34.6	150.9	297.4	127.3	169.1	238.5	215.3	19.9	140.2	570.2
23	688.1	34.1	125.9	296.8	122.8	185.1	244.1	215.7	19.1	145.3	572.2
24	686.4	34.6	125.1	301.7	124.4	143.7	238.5	215.6	17.9	117.7	569.2
25	688.7	34.7	123.7	303.6	123.6	149.1	240.4	215.4	23.2	144.9	571.3
26	688.1	34.5	127.1	305.4	125.3	146.6	240.4	215.6	20.5	144.8	570
27	685.1	34.9	122.7	302.2	126.5	150.8	238.2	215.7	18.6	142.6	686.3
28	790	34.5	124.1	301.8	127.2	149.5	238.8	215.4	16.4	141.6	571.2
29	689.1	34.6	125.5	298.1	125.9	145.9	237.4	214.3	19	132.8	572.1
30	640	34.2	143.9	300.4	143.5	157.5	239.64	211.1	19.9	118	572.1

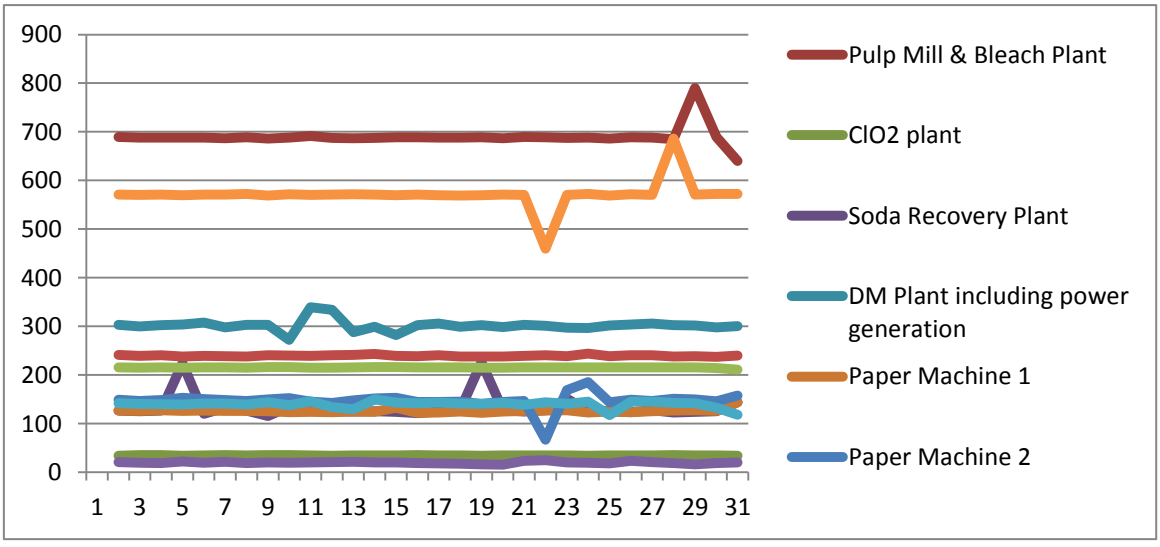

Fig. 2. Distribution of blue water footprint observations over 30 days sampling period

Table 2. Total Blue water footprint calculation.

	Blue Water Footprint in m^3/day					
Process	Total Water Supplied m^3/day	Water sent to ETP m^3/day	Total Water Evaporated m^3/day	Lost Return Flow m^3/day	Total Water Incorporated m^3/day	Blue Water Footprint m^3/day
Pulp Mill & Bleach Plant	8592	7903.9	257.8	341	89.3	688.1
ClO_2 Plant	432	397.4	4.32	14.3	15.98	34.6
Soda Recovery Plant	1560	1435.1	31.2	42.7	51.1	130
DM Plant Including Power Generation	3768	3466.2	75.36	113.4	113.04	301.8
Blade Coating Plant	744	684.4	7.44	25.3	26.9	59.6
Paper Machine 1	1992	1866.1	59.76	37	29.14	125.9
Paper Machine 2	2328	2180.9	69.84	39.1	38.6	147.1
Paper Machine 3	3792	3552.4	113.76	57.4	68.44	239.6
Paper Machine 4	3408	3192.7	102.24	46.3	66.76	215.3
Paper Machine 5	312	292.3	9.36	4.34	6	19.7
Paper Machine 6	2208	2068.5	66.24	37.8	35.5	139.52
Mill Colony & Miscellaneous	4128	3557.2	123.84	243	203.96	570.8

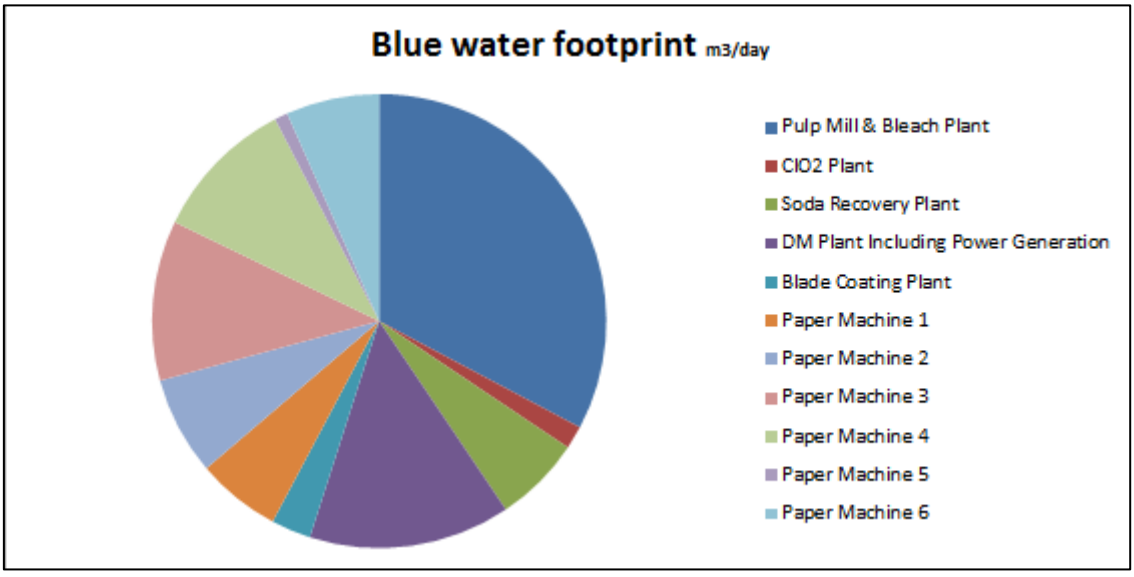

Fig. 3. Distribution of blue water footprint among various processes.

Total Blue Water Footprint = 2,672.02 m^3/day

Grey Water Footprint:

EFFLUENT CHARACTERISTICS OF SAMPLES COLLECTED FROM ETP

S. No.	Parameters	Effluent Final Discharge mg/l	C_{max}
1	T.D.S	860	2000
2	T.S.S	1410	100
3	C.O.D	1752	250
4	Ca	222	200
5	Mg	46	100

L = 4290 mg/l
C_{max} = 2650
Total Grey Water Footprint = 4290 / (2650-0) = 1.62 m^3/day

Indirect water footprint

Number of employees = 672
Average use of water per day = 45 l/ head/ day (*According to IS 1172:1993)*
Total Water Footprint due to Human Activities = 672 x 45 = 30.24 m^3/day
Total Water Footprint for Pulp and Paper industry
= Direct Water Footprint + Indirect Water Footprint
= [Blue Water Footprint + Grey Water Footprint + 0] + Indirect Water Footprint
= [2672.02 + 1.62 + 0] + 30.24 m^3/day
= **2703.88 m^3/day**

Sustainability Assessment

The aggregate normal information of water footprint representing 30 days results to 2703.88 m^3/day which incorporates both immediate and roundabout water footprint. Central Pollution Control Board standard for paper and pulp industry demonstrates that the benchmark standard for utilization of water for a medium estimated coordinated paper and pulp industry ought to be 38m3/ton of paper. In Pulp and Paper industry, the normal generation every day is 220 tons. Along these lines, all out water footprint ought to be 8360 m3/day, which demonstrates that there has been reasonable utilization of water in the business.

Response formulation

Despite the fact that the water use in the business is practical, some answerable measures ought to be executed since decreasing water footprint ought to be a ceaseless procedure, in order to spare the national water accessibility for various exercises.

In light of studies directed, the accompanying are the suggestions as for water protection:

- The real zones of crisp water utilization are showers on paper machines and chestnut stock washers. The Mills must utilize fitting systems to clear up Paper Machines back water suitable for further reuse to the conceivable degree in showers.
- Use of high consistency pumps to dodge superfluous pulp weakening.
- Optimum utilization of types of gear, machines to keep away from over stacking which may influence the execution effectiveness of the framework.
- Mills may likewise consider going mechanical seal pump or earthenware based pumps where water necessity is less, or even mechanical face and lip seal where water prerequisite is just about nil.
- Use of new era pulp washer to minimize the water prerequisite which eventually enhance the financial matters of different impact evaporators.
- In perspective of shortage of water, the utilization of film filtration for chose emanating stream will be valuable in accomplishing framework conclusion. The factories or affiliation ought to elevate R&D studies to-evaluate techno-financial suitability of these advancements.

5. CONCLUSION

Pulp and paper making procedure is profoundly water serious and requires colossal measure of water in each and every phase of procedure. The abnormal state of water utilization in Indian plants contrasted with factories worked abroad, is principally because of use of different number of paper machine, utilization of blended stringy crude materials without great quality timberland based crude materials, utilization of ordinary innovation and types of gear and in addition low level of operation.

Factories are taking every single conceivable measure to lessen water utilization through proficient utilization of water, water evaluating and also setting focus in individual area of paper making. Through this paper, it is clear that utilizing water economically spares our standout amongst the most vital resource as water. Leading a water footprint of an industry makes the utilization of water more noticeable and makes important strides. Pulp and Paper industry has been utilizing water as a part of a practical way however its constantly great to lessen water footprint however much as could reasonably be expected for which recommendations have as of now been talked about..

References

[1] Aldaya, M. M., Martínez-Santos, P. & Llamas, M. R. 2010. Incorporating the water footprint and virtual water into policy: Reflections from the Mancha Occidental Region, Spain. *Water Resources Management*, 24, 941-958.

[2] Berger, M. & Finkbeiner, M. 2010. Water footprinting: How to address water use in life cycle assessment? *Sustainability*, 2, 919-944.

[3] Chapagain, A. K., Hoekstra, A., Savenije, H. & Gautam, R. 2006. The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. *Ecological economics,* 60, 186-203.

[4] Chapagain, A. K. & Hoekstra, A. Y. 2008. The global component of freshwater demand and supply: an assessment of virtual water flows between nations as a result of trade in agricultural and industrial products. *Water international,* 33, 19-32.

[5] Chooyok, P., Pumijumnog, N. & UssawarujikulchaI, A. 2013. The water footprint assessment of ethanol production from molasses in Kanchanaburi and Supanburi province of Thailand. *APCBEE Procedia,* 5, 283-287.

[6] Clothier, B. Green, blue and grey waters: Minimising the footprint using soil physics. 19th World Congress of Soil Science, Soil Solutions for a Changing World, 2010. 1-6.

[7] Ene, S. A., Teodosiu, C., Robu, B. & Volf, I. 2013. Water footprint assessment in the winemaking industry: a case study for a Romanian medium size production plant. *Journal of Cleaner Production,* 43, 122-135.

[8] Ercin, A. E., Aldaya, M. M. & Hoekstra, A. Y. 2011. Corporate water footprint accounting and impact assessment: the case of the water footprint of a sugar-containing carbonated beverage. *Water Resources Management,* 25, 721-741.

[9] Gu, Y., Xu, J., Keller, A. A., Yuan, D., LI, Y., Zhang, B., Weng, Q., Zhang, X., Deng, P. & Wang, H. 2015. Calculation of water footprint of the iron and steel industry: a case study in Eastern China. *Journal of Cleaner Production,* 92, 274-281.

[10] Hajkowicz, S. & Higgins, A. 2008. A comparison of multiple criteria analysis techniques for water resource management. *European journal of operational research,* 184, 255-265.

[11] Jefferies, D., Muñoz, I., Hodges, J., King, V. J., Aldaya, M., Ercin, A. E., I Canals, L. M. & Hoekstra, A. Y. 2012. Water footprint and life cycle assessment as approaches to assess potential impacts of products on water consumption. Key learning points from pilot studies on tea and margarine. *Journal of Cleaner Production,* 33, 155-166.

[12] Manzardo, A., Ren, J., Piantella, A., Mazzi, A., Fedele, A. & Scipioni, A. 2014. Integration of water footprint accounting and costs for optimal chemical pulp supply mix in paper industry. *Journal of Cleaner Production,* 72, 167-173.

[13] Mcdevitt, J. E., Love, S. R., Seadon, J. K. & Allison, R. W. 2012. An evaluation of alternative water footprint methodologies using an indicative tissue paper supply chain. *Appita Journal,* 65, 159.

[14] Mekonnen, M. & Hoekstra, A. 2012. The blue water footprint of electricity from hydropower. *Hydrology and Earth System Sciences,* 16, 179-187.

[15] Morera, S., Corominas, L., Poch, M., Aldaya, M. & Comas, J. 2016. Water footprint assessment in wastewater treatment plants. *Journal of Cleaner Production,* 112, 4741-4748.

[16] Ridoutt, B. G. & Pfister, S. 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. *Global Environmental Change,* 20, 113-120.

[17] Ridoutt, B. G. & Pfister, S. 2013. A new water footprint calculation method integrating consumptive and degradative water use into a single stand-alone weighted indicator. *The International Journal of Life Cycle Assessment,* 18, 204-207.

[18] Spiess, W. 2014. Virtual Water and Water Footprint of Food Production and Processing. *Encyclopedia of Agriculture and Food Systems*, 333-355.

[19] Thompson, G., Swain, J., Kay, M. & Forster, C. 2001. The treatment of pulp and paper mill effluent: a review. *Bioresource technology,* 77, 275-286.

[20] Wang, Y., Liu, J., Hansson, L., Zhang, K. & Wang, R. 2011. Implementing stricter environmental regulation to enhance eco-efficiency and sustainability: a case study of Shandong Province's pulp and paper industry, China. *Journal of Cleaner Production,* 19, 303-310.

[21] Zhang, G., Hoekstra, A. & Mathews, R. 2013. Water Footprint Assessment (WFA) for better water governance and sustainable development, editorial. *Water resources and industry,* 1, 1-6.

(Received 22 December 2016; accepted 10 January 2017)