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Environmental reforms in sugar industries of India: An appraisal

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ABSTRACT

Sugar industry in India has imparted significant contribution in the growth of agriculture and socio-economic status of the country. However, continuation of conventional practices owing to lack of awareness for environmentally sustainable technologies has led to the pollution in water resources resulting in degradation of environmental quality. Considering this, Central Pollution Control Board of India took initiative for minimizing the pollution load in rivers by formulating a charter and invoking environmental compensation for sugar industries. Present assessment of environment related reforms through national policy like charter implementation and environmental compensation is one of the primary baseline studies done so far. These reforms were implemented in 85 sugar industries situated along the main stem of River Ganga for validation. The analysis depicted that the implementation of charter and environmental compensation resulted in significant reduction in freshwater consumption (56.4%), effluent generation (13.8%), and biochemical oxygen demand load (34.6%). Thus, similar reforms may be adopted in other sugar industries as well in order to improve the environmental quality and sustained growth of the economy.

1. Introduction

Sugar industry is an agro-based industry which relies upon the production of sugarcane and sugar beet. These industries impart significant contribution in the socio-economic development of the nations as these fulfil one of the basic necessities of human survival. However, sugar industries are often targeted for being the polluter of environment *esp.* the freshwater resources (Sahu 2018). Almost all the major divisions in sugar manufacturing plant, such as mill house, processing plant, boilers, cooling towers *etc*. are responsible for waste generation (Wood 1995). These wastes include suspended solids, waste water having depleted oxygen content, molasses, press-mud, chemicals *etc*. (Solomon 2005). Various governments, regulatory authorities, and researchers across the globe are involved in finding the solution of these environmental issues through research and effective management (Bhatnagar et al., 2016; Dotaniya et al., 2016; Akhtar et al., 2020; Akhtar et al., 2021). Moreover, sustainable solution lies in the holistic approach involving adoption of environment friendly technologies, technical guidance to industries, optimum utilization of waste, and stringent managerial decisions.

1.1. Indian sugar industry: key features

In India, sugarcane is the basic raw material for the sugar production. The total sugarcane cultivation area in India has increased from 1.7 million hectares in 1950–51 to 5.2 million hectares in 2020 (GoI 2020). Further, the yield of sugarcane has doubled in six decades, from 33 tonnes/ha in 1950–51 to 71 tonnes/ha in 2015–16 (NATMO 2020). This unprecedented growth has led India to become the second largest sugar producer globally, besides being the largest consumer of sugar in the world (GoI 2018; Sheetal and Kumar 2019). Thus, sugar industries are one of the major components of Indian economy and contribute significantly to the socio-economic development of the nation as well (Sawhney 2002; Solomon 2016). In India, sugar production is largely concentrated in the state of Uttar Pradesh, Maharashtra, Karnataka, Tamilnadu, and some other pockets (Solomon 2016). Uttar Pradesh and Maharashtra are the leading states contributing 34% of the total sugar production in the country (Randhawa and Gupta 2014).

Sugar industry is a seasonal industry operating for a maximum period of 5 – 6 months in a year. There are two methods through which

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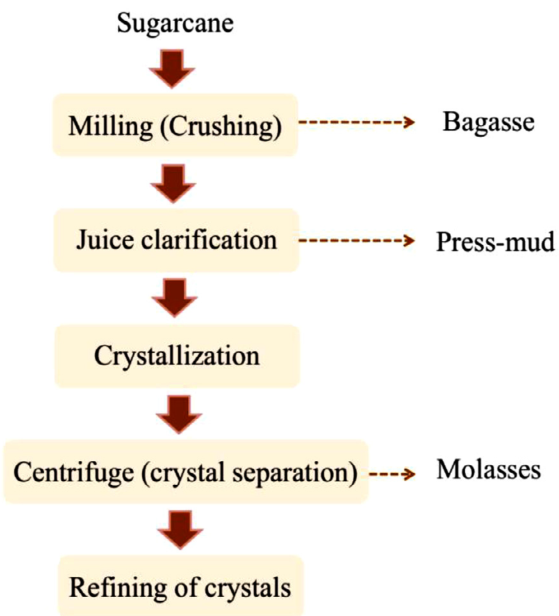

Fig. 1. Schematic diagram of sugar industry processes and generation of co-products
This figure was drawn by the authors to use in this manuscript.

sugar is produced in Indian sugar industries *viz.* **1)** Conventional double sulphitation process which produces direct consumption plantation white sugar, and **2)** two-stage process in order to produce refined sugar. There are six major stages of manufacturing in sugarcane based industries (Fig. 1), *viz.*: 1) Milling – sugarcane is cleaned, crushed, and juice is extracted; 2) Clarification of juice – through sulphitation (milk of lime + SO_2) and carbonation (milk of lime + CO_2); 3) Concentration and crystallization; 4) Separation of crystals; 5) Refining; and 6) Recovery of sugar molasses (Kushwaha 2015; Solomon 2016).

During the sugar production process, a number of co-products are formed as well, such as bagasse, press-mud, and molasses, as shown in Fig. 1. In India, the amount of bagasse produced is approximately 25–30% of the cane crushed, press-mud produced after the clarification is 3–5% (of the cane), and molasses are produced after the process of centrifuge which is approximately 3.5–5% of the cane (Sahu 2018). Amount of these co-products varies in the sugar industries of different countries depending upon the local climatological conditions, technological processes involved, and various other factors (Sahu 2018). These co-products have the potential to be used in variety of applications such as in distilleries, non-conventional energy production, medicinal products, and organic manure (Casas et al., 2015; Dotaniya et al., 2016; Sahu 2018).

1.2. Environmental issues associated with sugar industries

Though sugar industries are essential and economically important, these are responsible for being one of the biggest users and polluters of the fresh water. On an average, a typical sugar industry may produce approximately 1000 litres of wastewater for every tonne of sugarcane crushed (Sahu and Chaudhari 2015; Kushwaha 2015; Asaithambi and Matheswaran 2016) (Table 1). Further, effluent of sugar industries has complex characteristics having potential to contaminate the freshwater resources, if discharged inappropriately. Effluent from sugar industry is known to have high amount of biochemical oxygen demand (BOD) load. BOD values ranging from 500 mg/L to 1000 mg/L are observed in the effluent of a typical plantation white sugar industry (Sahu 2018). Apart from BOD, chemical oxygen demand (COD), total suspended solids (TSS), sulphate, and many other pollutants (Sahu 2018; Fito et al., 2019) are also the cause of concern if discharged without treatment onto the surface / ground water sources. Besides, the co-products formed during the process may also result in significant pollution if not utilized properly (Varshney et al., 2019; Mustafa et al., 2020; Singh 2020; Alokika et al., 2021).

1.3. Gaps in the existing system and need of an overhaul

In India, regulatory compliance of the industrial units (emission and effluent discharge) is monitored by the respective State Pollution Control Boards (SPCBs) of the state, and by the highest statutory authority for control of pollution, *viz.* Central Pollution Control Board (CPCB) from the centre. Ministry of Environment, Forest & Climate Change (MoEF&CC) of India has set the standards for effluent discharge from sugar industries in 2016 (The Gazette of India, 2016), as detailed in Table 2. It is important to note that as per the notified standards, the limit of the wastewater generation is significantly stringent in India compared to other countries (Table 1), allowing only 200 litre of wastewater per tonne of cane crushed (Table 2). This is so because; many of the industries in India are located in the water scarce belts where excessive dilution of the effluents cannot be permitted. Nevertheless, minimally diluted sugar industry effluent may be effectively utilized for various agricultural practices which help to maintain soil productivity (Kaushik et al., 1996; Kumar and Chopra 2012; Kumar 2014). Further, the regulatory authorities observed in some of the industries that the target of 200 litre effluent generation per tonne of cane crushed was possible to achieve with adoption of appropriate technologies. Hence, the limit of effluent generation was set as 200 litre/tonne of cane crushed, though it was ensured that sufficient technical guidance and supervision will be provided to industries in order to achieve this target.

However, it was repeatedly observed that the industries bypassed the untreated effluent illegitimately to the nearby freshwater resources instead of following the set norms. The reasons for adopting this practice could be assigned to the unawareness, least consideration for maintaining the environmental quality, and maximizing the economic gains. In the long run, this practice has resulted in serious degradation in the water quality of the recipient body. For example, River Ganga – the national river of India, a significant portion of which passes through the sugar belt of Uttarakhand and Uttar Pradesh, is an ultimate receiver of all the effluent discharged from the sugar industries located in these as well as other adjoining states (Dwivedi et al., 2018). Therefore, it was felt that besides making stringent norms, the implementation of the same also needs to be ensured in order to keep a check on the unscrupulous activities.

In this paper, important reforms made by the CPCB in the sugar industrial sector for better implementation of the set norms are discussed. The overall aim was to minimize the pollution load from sugar sector by supporting the industries, rather than only penalizing them for non-compliance. These reforms were also validated by implementing in the sugar industries situated along the main stem of River Ganga. This approach has not only helped in improving the quality of environmental resources, but also pushed the industries for better revenue generation. The success of these reforms can set an example and may be extended to sugar industries in other parts of the country as well to minimize the pollution load and boosting the growth of the sector.

2. Approach towards the sustainable environmental reforms in sugar industries

The existing system in the Indian sugar industries is the conventional one which operates on inefficient technologies, uneconomic processes of production, and obsolete machinery (Rao 2014). Most of the industries in India are small scale and unorganized having inefficient supply chain coordination, which makes large scale production uneconomical. Moreover, being a seasonal industry, financial issues also burden the system (Rao 2014). Therefore, management of pollution in industries by the

Table 1
Amount of wastewater produced in sugar industries.

Country	Amount of sugarcane crushed	Amount of wastewater generated	References
India	1 tonne	1000 L	Asaithambi and Matheswaran 2016
India	1 tonne	1000 L	Sahu and Chaudhari 2015
India	1 tonne	1000 L	Kushwaha 2015
Brazil*	1 tonne	1209 – 2055 L	Martinelli et al., 2013
India	1 tonne	1000 L	Hampannavar and Shivayogimath 2010
Mexico	–	713.83×10^9 L in 6 months' season	Mexican NWC 2006
Pakistan	1 tonne	700 L	Memon et al., 2006
India	1 tonne	1000 L	Solomon 2005

*Effluents from sugar industry with annexed distillery.

Table 2
Stipulated norms for treated effluent discharge for sugar sector as per MoEF&CC Notification, 14th January 2016 G.S.R. 35(E).

S. No.	Chemical parameters of the effluent	Standard values
1.	pH	5.5 – 8.5
2.	Total suspended solids (mg/L)	100 (for disposal on land) 30 (for disposal in surface water)
3.	Biochemical oxygen demand (3 days, 20 °C) (mg/L)	100 (for disposal on land) 30 (for disposal in surface water)
4.	Oil and grease (mg/L)	10
5.	Total dissolved solids (mg/L)	2100
6.	Final wastewater discharge limit (litre/tonne of cane crushed)	200

owners becomes an unapproachable issue and is often neglected owing to lack of awareness, limitation of options, and financial constraints.

In order to improve the existing situation, regulatory authorities realized that a lot of ground work is required in terms of resource generation, capacity building, and technology improvement. Merely penalizing the industries for violating the set environmental norms is not the solution for pollution minimization as it may further suppress the growth as well as demotivate the people. A major issue which has been observed in Indian scenario is that the industries often lack the environmental professionals at the managerial positions thus rendering management to take misinformed decisions. Moreover, the management can be easily misguided by the various commercial technology providers in the name of pollution control. It results in loss of money, time, and efforts without any substantial gain. Therefore, besides regulating the norms, it is also essential to provide proper guidance so that industries can adopt appropriate technologies and processes which can minimize the pollution load along with reducing burden on the environment.

To address these concerns, root-cause analysis of the issues relevant to the sugar industries, *esp*. those operating in the main stem of River Ganga, was done through field inspection of each industry. The inspection reports revealed that the non-compliance with the set standards was frequent amongst the industries both in terms of the quantity as well as quality of the effluent generated. Considering this, the idea of online continuous effluent/emission monitoring system (OCEMS) was introduced in 2014 and was made mandatory for the sugar industries (CPCB 2017, 2018). The purpose of this initiative was to develop a self-regulatory approach amongst the industries for complying with the set standards, besides tracking the release of pollutants on a continuous basis for monitoring purpose.

In order to further improve the quality of the discharged effluent and to minimize the freshwater consumption, CPCB decided to facilitate sugar industries through implementation of a scheme in the form of a charter. In order to formulate such a document, a number of consultation meets were realized with industries, authorities, technical institutions, and various stakeholders to understand their issues and dilemmas. The need for overhauling the existing system was discussed and importance of maintaining the environmental quality was made to realize to the stakeholders and industries personnel. Such a participatory approach helped the industries to change their mindset and believing in the support and solutions provided. However, putting the agenda of maintaining environmental quality at the top, it was also made sure that deviations from the set standards should be minimized. Henceforth, the provision of imposing a fine was also introduced based on certain specific grounds. This plan was also backed by the Hon'ble National Green Tribunal (NGT) of India, *viz*. the highest tribunal for expediting the issues related to environment (NGT order 2018; NGT order 2019).

3. Sugar charter and environmental compensation plan – approach and methodology

Series of consultations and discussions amongst the CPCB, technical institutions, industry personnel, and other stakeholders have resulted in the development of a charter which could be implemented in sugar industries for better environmental compliance and sustained growth. An environmental compensation plan in monetary terms was also formulated in case of any violation of the standards by the industries beyond certain limits.

3.1. Sugar charter

The charter for water recycling and pollution prevention was formulated with the intention to facilitate the sugar industries to adopt appropriate technologies and policy regulations for effluent treatment. The major points considered under the charter are summarized in Table 3. The charter mainly focused on the re-utilization of wastewater generated in various processes and keeping up the record of water utilized and consumed for each process so as to target the process(es) which utilize(s) the highest amount of water. Such a targeted approach eases the decision making for selecting the process which needs to be reformed for minimizing the pollution. The charter also emphasized over the establishment of a functional effluent treatment plant of suitable capacity and an in-house laboratory for analysing various water quality parameters. These initiatives were intended to take up immediate action upon finding that effluent water quality is being compromised for any reason. Installation of condensate polishing unit (CPU) was also made mandatory as it helps to reduce the wastewater load onto the effluent treatment plant, thus enhancing its efficiency.

3.2. Environmental compensation plan

The implementation of charter made a number of regulations mandatory, however, it was presumed that violations might take place at various ends and therefore, the concept of "polluter pays principle" by paying environmental compensation was introduced for the non-complying

Table 3
CPCB's charter for regulating the pollution from sugar industries.

S. No.	CPCB's sugar charter: Key points
1.	Installation of sealed flow metre in a borewells to ascertain usage of fresh water b at major areas of cold and hot water consumption c for measuring the effluent from prominent areas
2.	Maintenance of log book for recording the daily water consumption and effluent generation
3.	Recirculation of water employed in SO_2 gas coolers, massecuite cooling, and elsewhere with proper cooling through cooling towers
4.	Dry cleaning of factory floors using bagasse
5.	Construction of tank to collect hazardous wash water generated
6.	Installation of condensate polishing unit (CPU) where high pressure boiler is used
7.	Use of membrane-based technology to attain brine recovery
8.	Use of surplus cooled condensate as make-up water
9.	Maintenance of retention time in various units of effluent treatment plant (ETP)
10.	Colour coding of pipelines carrying recycled process water and fresh process water
11.	Development of proper infrastructure for operation and maintenance of ETP
12.	Development of analytical facility for analysis of various streams of water
13.	Commissioning of mechanical sludge handling system of adequate capacity
14.	Ensuring the analysis of effluent discharge parameters notified under Environment (Protection) Rules, 1986 and maintaining the logbook on daily basis.

Table 4
CPCB's environmental compensation plan: Instances leading to the compensation.

S. No.	Instances leading to the environmental compensation: Key points
1.	Discharges in violation of consent conditions, mainly prescribed standards/consent limits.
2.	Not complying with the directions issued, such as direction for closure due to non-installation of Online Continuous Emission/Effluent Monitoring System (OCEMS), non-adherence to the action plans submitted *etc*.
3.	Intentional avoidance of data submission or data manipulation by tampering the OCEMS.
4.	Accidental discharges lasting for short durations resulting into damage to the environment.
5.	Intentional discharges to the environment – land, water, and air resulting into acute injury or damage to the environment.
6.	Injection of treated/partially treated/untreated effluent to ground water.

sugar industries. The environmental compensation was intended to be levied on concerned industry, authority, and/or individual for the protection of environment with the objective of developing self-sense of responsibility towards the environment and to make defaulters realize their mistake. This monetary compensation was planned to be utilized for the protection/restoration of the environment. The instances which could be considered fit for violation and imposition of compensation are summarized in Table 4. The methodology adopted to calculate the amount of environmental compensation considers a number of factors, *viz*. pollution index of industrial sector, time period during which violation took place, location factor *etc*. It is important to mention that pollution index is calculated based on the guidelines proposed by CPCB and accepted by the Hon'ble NGT. A simplified formula for computing the environmental compensation can be expressed as shown in Eq. (1):

$$\mathrm{EC} = \mathrm{PI} \times \mathrm{N} \times \mathrm{R} \times \mathrm{S} \times \mathrm{LF} \quad (1)$$

where,

EC=Environmental compensation in ₹

PI=Pollution index, categorized based on Red, Orange, and Green zone industries (having the range of 60 to 100, 41 to 59, and 21 to 40, respectively)

N=Number of days when violation took place

R = *A* factor in rupees (minimum of 100 and maximum of 500)

S=Factor for scale of operation (0.5 for small / 1.0 for medium / 1.5 for large units)

LF=Location factor (population of the city/town and location of industrial unit)

4. Validation of the developed approach in sugar industries situated along the main stem of River Ganga

The formulation of the charter and environmental compensation plan for pollution regulation in sugar industries was a remarkable step. However, it was also necessary to validate the efficacy of these approaches. Therefore, as a pilot study, the charter was implemented in sugar industries situated along the main stem of River Ganga. A total of 85 sugar industries were selected situated in 4 Indian states *viz*. Uttarakhand (06), Uttar Pradesh (66), Bihar (11), and West Bengal (02) as shown in Fig. 2. The installed capacity of these industries ranged from 1000 tonnes of cane crushed per day (TCD) to 12,800 TCD while freshwater usage was limited between 0.25 million litres per day (MLD) to 10 MLD. Notably, the state of Jharkhand, which also lies along the River Ganga, does not have any sugar industry operating along the main stem of this river. The premise of the selection of industries lies in the fact that these industries share a significant portion in the total sugar production of India. Besides, the effluent from these industries is discharged into the River Ganga either directly or through various tributaries (Jain and Singh 2020; Roy and Shamim 2020; Singh et al., 2020). The unrestricted discharge of effluent from the industries situated in these states has led to serious deterioration of the river water quality (Jain and Singh 2020; Roy and Shamim 2020; Singh et al., 2020). Hence, there are concerns to reduce the pollution level of industries situated along the main stem of River Ganga, as this river is the major water source for irrigation and drinking water for inhabitants settled along it (Jain and Singh 2020). Moreover, ecosystem services provided by River Ganga are also compromised to a significant extent due to the deterioration in water quality (Sannigrahi et al., 2020). Thus, charter was implemented in these sugar industries in the year 2017 and continuous monitoring was done thereafter for 3 years. The impact was assessed in terms of fresh water consumption, effluent generation, and BOD load in the effluent of sugar industries.

5. Results

The efficacy of the sugar charter and environmental compensation plan introduced in the 85 sugar industries was assessed. Various parameters such as, freshwater consumption, effluent generation, and BOD load

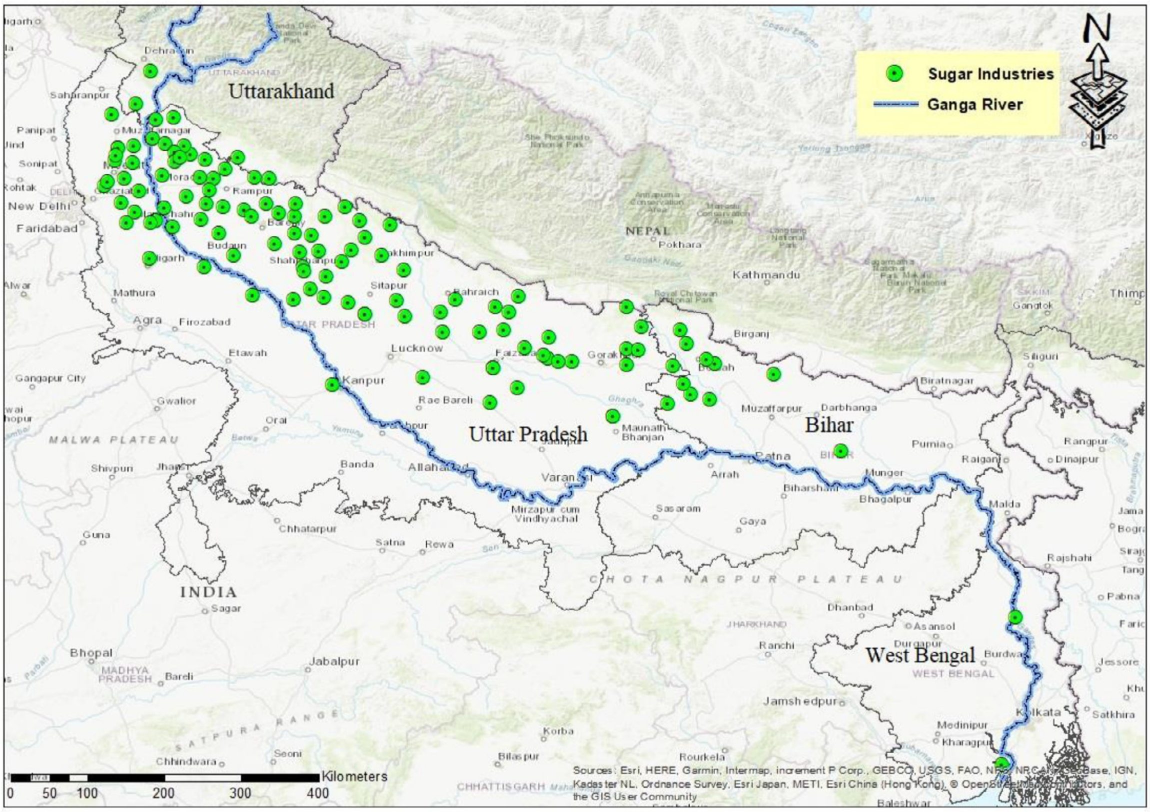

Fig. 2. Sugar industries along the main stem of River Ganga This map was drawn by the authors to use in this manuscript.

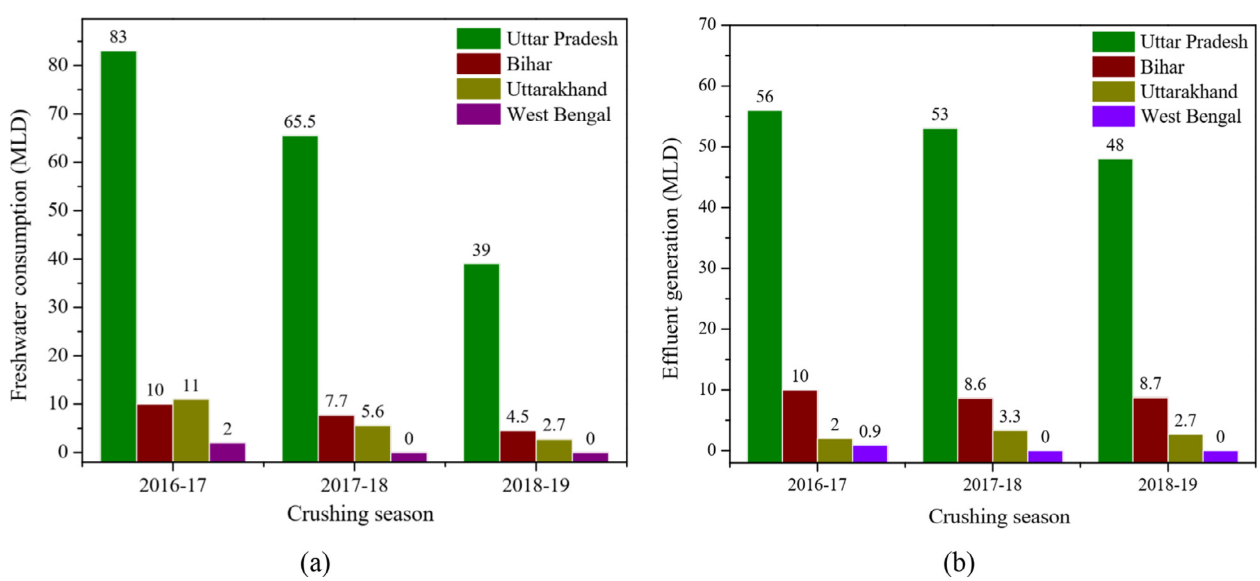

Fig. 3. Comparative evaluation of freshwater consumption and effluent generation before and after the CPCB's charter implementation.

were analysed during the pre-charter and post-charter period in order to understand the impacts facilitated by the charter and environmental compensation plan.

5.1. Freshwater consumption and effluent generation

The freshwater consumption was analysed during 2017 – 2019 in the sugar industries of study area (Fig. 3). The analysis showed that fresh water consumption was significantly reduced owing to the implementation of recirculation of water employed in SO_2 gas coolers, massecuite cooling, and installation of flow meters. The highest reduction in freshwater consumption was achieved by the state of Uttarakhand, which was approximately 75% as shown in Fig. 3a. In Uttar Pradesh and Bihar, freshwater consumption was reduced by approximately 53% and 55%, respectively (Fig. 3a). Comparative analysis could not be achieved in case of West Bengal due to the non-operational status of sugar industries in the given period. Similar to the freshwater consumption, effluent generation was also significantly reduced. Overall effluent generation

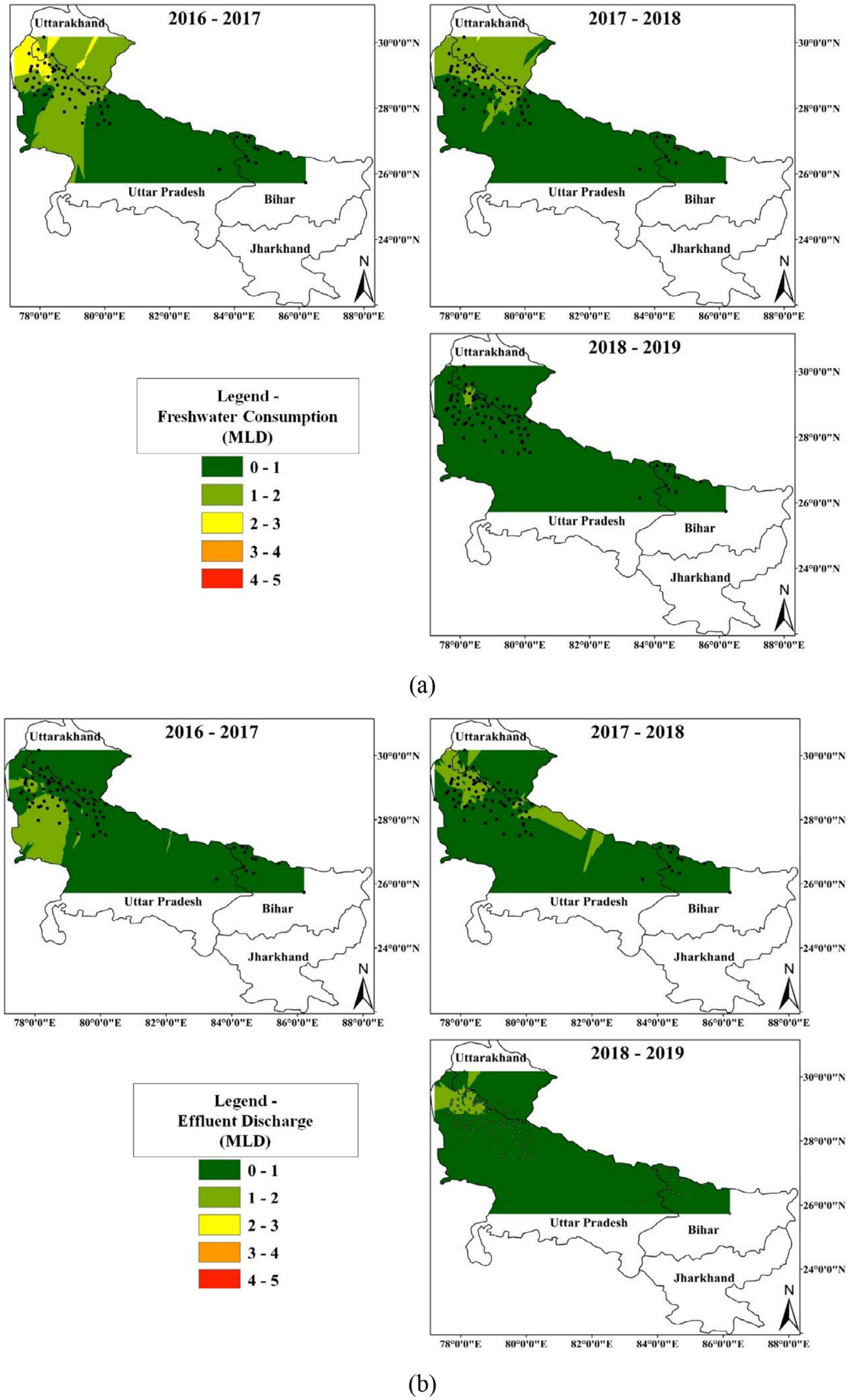

Fig. 4. Spatial and temporal variation in (a) freshwater consumption and (b) effluent generation by sugar industries.

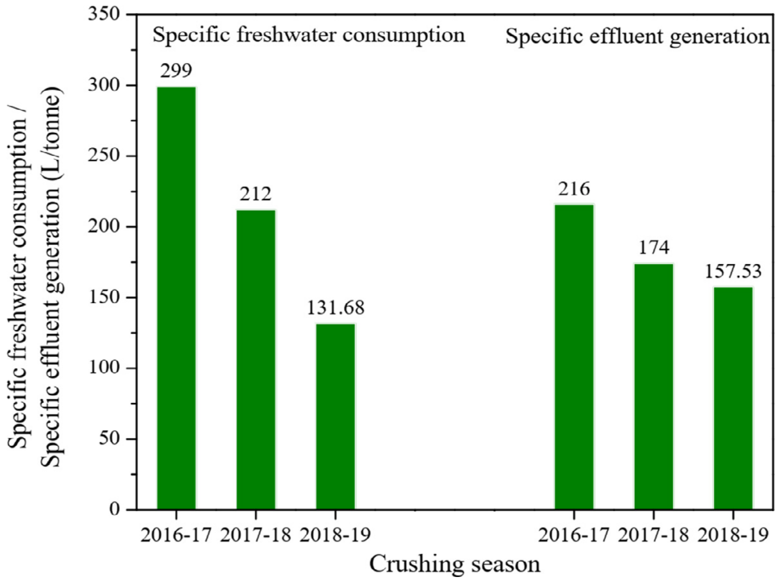

Fig. 5. Specific freshwater consumption and specific effluent generation in sugar industries before and after the CPCB's charter implementation.

Table 5
Major operational achievements of the CPCB's charter implementation.

S. No.	Major operational achievements of the CPCB's charter implementation	
1.	Reduction in fresh water consumption in 2019 with respect to 2017	56.42%
2.	Reduction in effluent generation in 2019 with respect to 2017	13.79%
3.	Reduction in BOD load in 2019 with respect to 2017	34.63%
4.	Reduction in effluent generation (litres/tonne of cane)	16.02%
5.	Reduction in process cooling tower/spray pond overflow (litres/tonne of cane)	57.48%

was reduced periodically as 69 MLD in the crushing season 2016–17 to 59 MLD in crushing season 2018–19, which is approximately 14.3% reduction after charter implementation (Fig. 3b). The spatial representation of the variation in freshwater consumption and effluent generation is shown in Fig. 4. An interesting fact which could be observed in case of effluent generation is that during the year 2018–19, the effluent generated exceeds the freshwater consumed (Fig. 3). This may be explained considering that sugarcane has approximately 60 – 70% of the moisture content which adds into the effluent; though, in previous years this factor did not impact substantially owing to its negligible amount as compared to the total amount of effluent generated in those years.

5.2. Specific freshwater consumption and effluent generation

Evaluation of specific water usage in the sugar mills is another important parameter. It helps to assess the efficacy of the system with respect to freshwater consumption and effluent generation upon changes in the amount of processed sugar cane (*viz.* fluctuating sugar plant capacity). Specific freshwater consumption refers to the specific values of freshwater consumption (in litres) per unit production of sugar (tonnes) in a particular year. Similarly, specific effluent generation refers to the effluent generation (in litres) per unit production of sugar (tonnes) in a particular year. Comparative analysis shows that the specific freshwater consumption has been reduced in 2018–19 as compared to 2016–17 and 2017–18. The reduction in specific freshwater consumption observed in 2018–19 was approximately 57.5% with respect to 2016–17 and 38.67% with respect to 2017–18 (Fig. 5). Similarly, reduction was observed in the specific effluent generation as well. The reduction in 2018–19 was 16.02% with respect to 2016–17 and 9% with respect to 2017–18 (Fig. 5). This shows that after implementation of charter there has been a significant reduction in specific freshwater consumption as well as specific effluent generation. The spatial representation of the same is shown in Fig. 6.

5.3. BOD load

Reduction in the BOD load of the discharged effluent was one of the concerns of introducing charter as high BOD is dangerous to the aquatic life. The comparative assessment of BOD load before and after the charter implementation shows that overall BOD load is reduced from 8.46 tonnes per day (TPD) in crushing season 2016–17 (before charter implementation) to 5.53 TPD in crushing season 2018–19 (after charter implementation). This amount to approximately 35% reduction in BOD load as demonstrated in Fig. 7 and 8. Most of the sugar industries along the main stem of River Ganga are located in Uttar Pradesh, where significant reduction was observed in BOD load *viz.* 7.63 TPD in crushing season 2016–17 to 3.5 TPD in crushing season 2018–19. This amounts to 54% reduction and hence explains the efficacy of charter implementation.

6. Discussion

The implementation of charter and environmental compensation plan has positively motivated sugar industries to focus on process technology up-gradation, effluent treatment plant up-gradation, and adoption of best management practices. These changes have resulted in the significant reduction in freshwater consumption and effluent generation which further reduced the BOD load of sugar industries.

6.1. Benefits to the environment

The optimization of processes, operations, and increased recycling and reuse of treated effluent has started showing good results in sugar

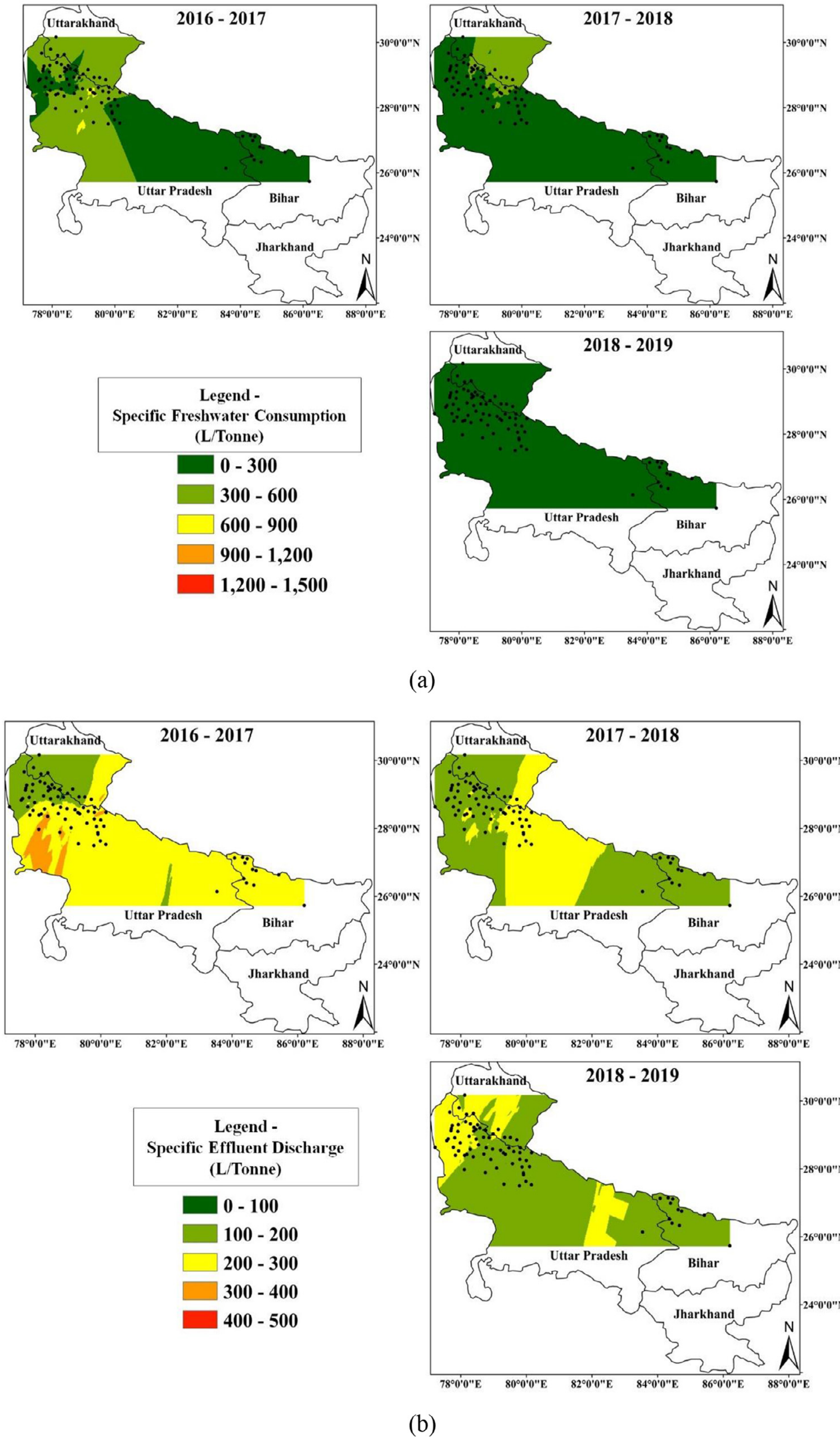

Fig. 6. Spatial and temporal variation in (a) specific freshwater consumption and (b) specific effluent generation by sugar industries.

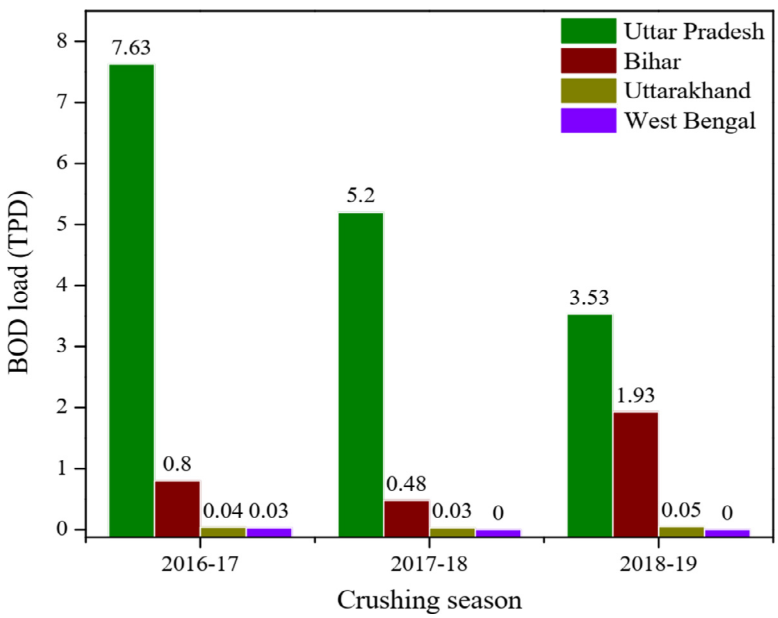

Fig. 7. BOD load in sugar industries before and after the CPCB's charter implementation.

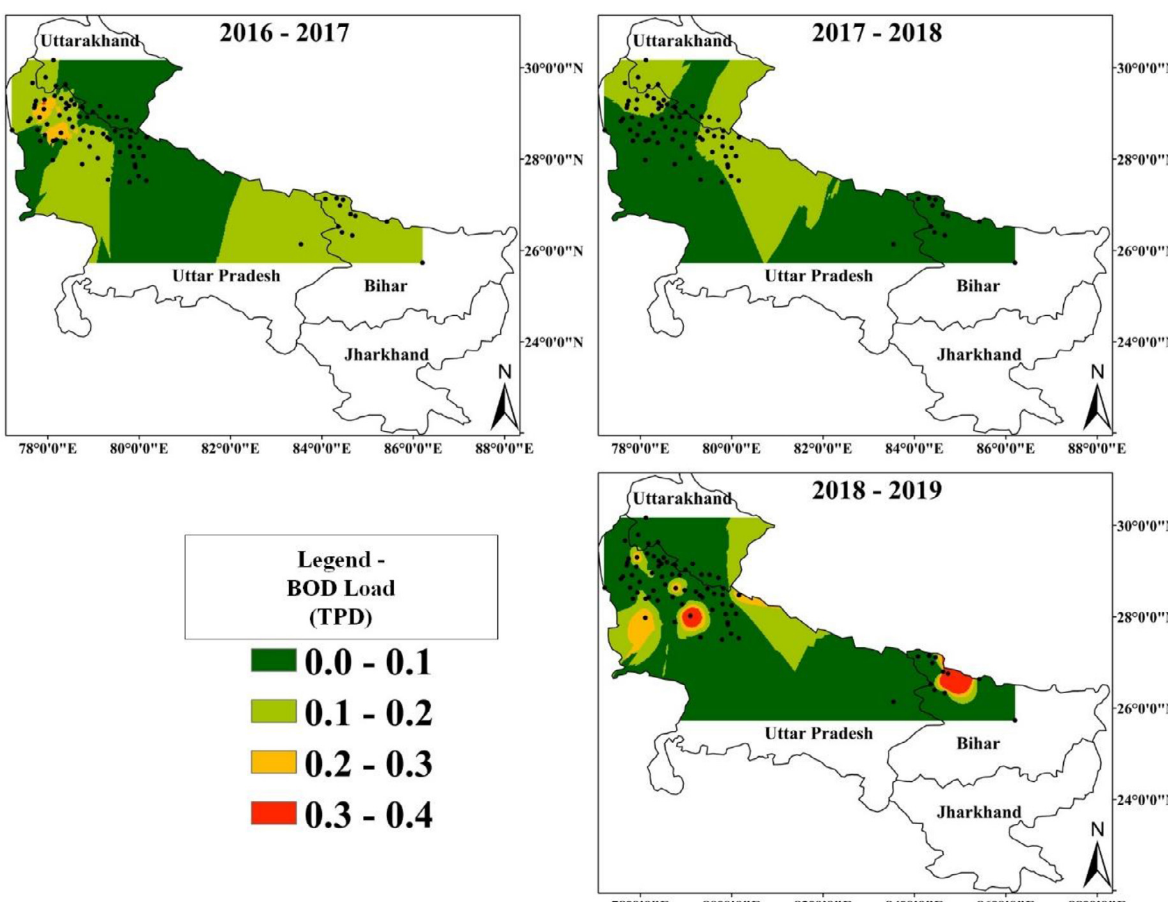

Fig. 8. Spatial and temporal variation in BOD load by sugar industries.

industries in terms of reduction in fresh water consumption and effluent generation. This is due to the fact that prior to charter implementation, all the water consuming processes utilized the freshwater, while after the charter implementation; the treated effluent was re-circulated and reused thus reducing the amount of freshwater consumption as well as effluent generation. Further, less requirement of freshwater has also lowered down the need of groundwater extraction; thus, conserving the groundwater resources. Adoption of rainwater harvesting practices, use of sludge for the purpose of filling low lying areas, and consumption of used oil with bagasse in boiler are other significant moves in the line of environmental sustainability and economical operation of sugar industries after the charter implementation.

As far as the environmental compensation plan is concerned, the amount of compensation was calculated either on the basis of pollution index or on the basis of actual damage caused to the environment. The levied amount was utilized for the protection of environment. In this case, protecting measures require immediate and short-term actions; compensation towards loss of ecology, *etc*. and this amount was utilized exclusively for the defined purpose at specific site. This approach has further benefitted the environment.

6.2. Benefits to the industries

Implementation of charter has resulted in a number of operational benefits to the industries. For example, reduction in consumption of freshwater / groundwater has benefitted the sugar industries economically by saving the power cost to run the motor for water extraction. The major outcomes of the charter implementation in sugar industries are summarized in Table 5.

In continuation of charter implementation, CPCB's approach of levying environmental compensation on non-complying sugar industries in case of damage to the environment has not only benefitted the environment but also to the industries. This has further encouraged sugar industries to improve the system for the conservation and protection of environment. Moreover, sugar industries have considered the charter positively because, following the charter was far cheaper than breaking the norms of pollution control and paying a huge amount towards environmental compensation. Thus, overall charter implementation and environmental compensation mechanism have proved to be a significant attempt in the direction of attaining environmental sustainability.

6.3. Benefits to the local population

After the implementation of charter, sugar industries have become capable to supply their treated water to small and marginal farmers, who could not afford the cost of ground water extraction through tube well. This has not only helped the farmers but also resulted in the reduced requirement of freshwater for irrigation purposes, thus, further conserving the fresh/groundwater resources. Conversion of non-hazardous sludge into bio-fertilizers and its free of cost distribution to the farmers is another notable attempt.

7. Conclusion

Indian sugar industries have overcome various challenges in order to achieve the mark of being the second largest producer globally. However, in process of doing so, significant negative impacts were inflicted onto the environment, *esp*. on to the water resources. To overcome these impacts and to promote sustainable practices, Central Pollution Control Board of India introduced a charter and environmental compensation plan for the sugar industries. Charter mainly focused on the reutilization of wastewater generated in various processes and technical upgrading of effluent treatment plants. To assess the efficacy, the charter was implemented in sugar industries situated along the River Ganga and carefully monitored in terms of impact on freshwater consumption, effluent generation, and BOD load. The environmental compensation was further levied on the defaulting industries. The outcome of these initiatives was proved to be very effective in minimizing the pollution load from sugar industries and in conserving the groundwater resources. Therefore, similar policy implementations may be introduced in other industries as well to promote environmental sustainability.

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Author contributions

Prabhat Ranjan: Data curation, Investigation, Formal analysis
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Ajit Kumar Vidyarthi: Supervision, Funding acquisition, Project administration

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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References

Akhtar, A., Singh, M., Subbiah, S., Mohanty, K., 2021. Sugarcane juice concentration using a novel aquaporin hollow fiber forward osmosis membrane. Food Bioprod. Process. 126, 195–206. doi:10.1016/j.fbp.2021.01.007.
Akhtar, A., Subbiah, S., Mohanty, K., Sundar, R., Unnikrishnan, R., Hareesh, U.S., 2020. Sugarcane juice clarification by lanthanum phosphate nanofibril coated ceramic ultrafiltration membrane: PPO removal in absence of lime pre-treatment, fouling and cleaning studies. Sep. Purif. Technol. 249, 117157. doi:10.1016/j.seppur.2020.117157.
Alokika, Anu, Kumar, A., Kumar, V., Singh, B., 2021. Cellulosic and hemicellulosic fractions of sugarcane bagasse: potential, challenges, and future perspective. Int. J. Biol.Macromol. 16, 564–582. doi:10.1016/j.ijbiomac.2020.12.175.
Asaithambi, P., Matheswaran, M., 2016. Electrochemical treatment of simulated sugar industrial effluent: optimization and modeling using a response surface methodology. Arab. J. Chem. 9, S981–S987. doi:10.1016/j.arabjc.2011.10.004.
Bhatnagar, A., Kesari, K.K., Shurpali, N., 2016. Multidisciplinary approaches to handling wastes in sugar industries. Water Air Soil Pollut 227, 11. doi:10.1007/s11270-015-2705-y.
Casas, L., Hernandez, Y., Mantell, C., Casdelo, N., Ossa, E.M., 2015. Filter cake oil-wax as raw material for the production of biodiesel: analysis of the extraction process and the transesterification reaction. J. Chem. 2, 946462. doi:10.1155/2015/946462.
CPCB, 2017. Guidelines for Continuous Emission Monitoring Systems. Central Pollution Control Board, Delhi Available online at http://environment.rajasthan.gov.in/content/dam/environment/RPCB/Online Monitoring/Guidelines_on_CEMS_02.08.2017.pdf .
CPCB, 2018. 1st Revised Guidelines for Continuous Emission Monitoring Systems. Central Pollution Control Board, Delhi Available online at https://www.jspcb.nic.in/upload/uploadfiles/files/revised-ocems-guidelines%20(2)_compressed.pdf .
Dotaniya, M.L., Datta, S.C., Biswas, D.R., Dotaniya, C.K., Meena, B.L., Rajendiran, S., Regar, K.L., Lata, M., 2016. Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. Int. J. Recycl. Org. Waste Agric. 5, 185–194. doi:10.1007/s40093-016-0132-8.
Dwivedi, S., Mishra, S., Tripathi, R.D., 2018. Ganga water pollution: a potential health threat to inhabitants of Ganga basin. Environ. Int. 117, 327–338. doi:10.1016/j.envint.2018.05.015.
Fito, J., Tefera, N., Kloos, H., Van Hulle, S.W.H, 2019. Physicochemical properties of the sugar industry and ethanol distillery wastewater and their impact on the environment. Sugar Tech 21, 265–277. doi:10.1007/s12355-018-0633-z.
Government of India 2018. Department of Food and Public Distribution. Available online at https://dfpd.gov.in/sugar.htm, accessed on Aug. 9th, 2020.
Government of India 2020. Department of Agriculture, Cooperation and Farmers Welfare. Available online at https://www.chinimandi.com/area-coverage-under-sugarcane-increases/accessed on Aug. 9th, 2020.
Hampannavar, U.S., Shivayogimath, C.B., 2010. Anaerobic treatment of sugar industry wastewater by upflow anaerobic sludge blanket reactor at ambient temperature. Int. J. Environ. Sci. 1, 631–639.
Jain, C.K., Singh, S., 2020. Impact of climate change on the hydrological dynamics of River Ganga. India. J. Water Clim. Chang. 11, 274–290. doi:10.2166/wcc.2018.029.
Kaushik, A., Kadyan, B.R., Kaushik, C.P., 1996. Sugarmill effluent effects on growth, photosynthetic pigments and nutrient uptake in wheat seedlings in aqueous vs. soil medium. Water Air Soil Pollut. 87, 39–46. doi:10.1007/BF00696827.

Kumar, V., Chopra, A.K., 2012. Fertigation effect of distillery effluent on agronomical practices of *Trigonella foenum-graceum* L. (Fenugreek). Environ. Monit. Assess. 184, 1207–1219. doi:10.1007/s10661-011-2033-7.

Kumar, V., 2014. Sugar mill effluent utilization in the cultivation of Maize (*Zea mays* L.) in two seasons. J. Waste Manag. 408509. doi:10.1155/2014/408509.

Kushwaha, J.P., 2015. A review on sugar industry wastewater: sources, treatment technologies, and reuse. Desalin. Water Treat. 53, 309–318. doi:10.1080/19443994.2013.838526.

Martinelli, L.A., Filoso, S., Aranha, C.B., Ferraz, S.F.B., Andrade, T.M.B., Ravagnani, E.C., Coletta, L.D., Camargo, P.B, 2013. Water use in sugar and ethanol industry in the state of Sao Paulo (Southeast Brazil). J. Sustain. Bioenergy Syst. 3, 135–142. doi:10.4236/jsbs.2013.32019.

Memon, A.R., Soomro, S.A., Ansari, A.K., 2006. Sugar industry effluent – characteristics and chemical analysis. J. Appl. Emerg. Sci. 1, 152–157. doi:10.36785/jaes.v1i2.64.

Mexican National Water Commission (NWC), 2006. National Wastewater Discharge Inventory. Sanitation and Water Quality Department, Mexico.

Mustafa, G., Arshad, M., Bano, I., Abbas, M., 2020. Biotechnological applications of sugarcane bagasse and sugar beet molasses. Biomass Convers. Bior. Just Accepted Manuscript. doi:10.1007/s13399-020-01141-x.

NATMO, 2020. National Atlas and Thematic Mapping Organization. Sugarcane. Available online at http://geoportal.natmo.gov.in/sites/default/files/SUGARCANE.pdf . accessed on Jan. 3rd, 2021.

NGT Order 2018. In its order dated 03.08.2018 in original application no. 593/2017.Available online at https://greentribunal.gov.in/gen_pdf_test.php?filepath=L25ndF9kb2N1bWVudHMvbmd0L2Nhc2Vkb2Mvb3JkZXJzL0RFTEhJLzIwMTgtMDgtMzEvY291cnRzLzEvZGFpbHkvMTU5Mzc1MzAzNzIwMzg5OTA5MjY1ZWZlYmRjZDhhMzFkLnBkZg==, accessed on Apr. 7th, 2021.

NGT Order 2019. In its order dated 19.02.2019 in original application no. 593/2017. Available online at https://greentribunal.gov.in/gen_pdf_test.php?filepath=L25ndF9kb2N1bWVudHMvbmd0L2Nhc2Vkb2Mvb3JkZXJzL0RFTEhJLzIwMTktMDItMTkvY291cnRzLzEvZGFpbHkvMTU4OTk3NDA4NTE3MzAwOTAwNDg1ZWM1MTQ0NTUyNzhkLnBkZg==, accessed on Apr. 7th, 2021.

Randhawa, G., Gupta, A., 2014. Present status and challenges of sugar industry in Punjab. Prajnan 42, 375–391.

Rao, M.V., 2014. Problems of Indian sugar industry. Paripex – Ind. J. Res. 3, 126–128.

Roy, M., Shamim, F., 2020. Research on the impact of industrial pollution on River Ganga: a review. Int. J. Preven. Control Ind. Pollut. 6, 43–51.

Sahu, O.P., Chaudhari, P.K., 2015. Electrochemical treatment of sugar industry wastewater: COD and color removal. J. Electroanal. Chem. 739, 122–129. doi:10.1016/j.jelechem.2014.11.037.

Sahu, O.P., 2018. Assessment of sugarcane industry: suitability for production, consumption, and utilization. Ann. Agrar. Sci. 16, 389–395. doi:10.1016/j.aasci.2018.08.001.

Sannigrahi, S., Zhang, Q., Pilla, F., Joshi, P.K., Basu, B., Keesstra, S., Roy, P.S., Wang, Y., Sutton, P.C., Chakraborti, S., Paul, S.K., Sen, S., 2020. Responses of ecosystem services to natural and anthropogenic forcings: a spatial regression based assessment in the world's largest mangrove ecosystem. Sci. Tot. Environ. 715, 137004. doi:10.1016/j.scitotenv.2020.137004.

Sawhney, D.M., 2002. The Indian sugar industry. Zuckerindustrie 127, 186–194.

Sheetal, Kumar, R., 2019. Rethinking on growth mechanism of Indian sugar industry. J. Asia Bus. Stud. 13, 412–432. doi:10.1108/JABS-12-2016-0182.

Singh, P., 2020. Sugar industry: a hub of useful bio-based chemicals. In: Sugar and Sugar derivatives: Changing consumer Preferences. Springer, Singapore, pp. 171–194. doi:10.1007/978-981-15-6663-9_11.

Singh, V., Nagpoore, N.K., Jaichand, Lehri, A., 2020. Monitoring and assessment of pollution load in surface water of River Ganga around Kanpur, India: a study for suitability of this water for different uses. Environ. Technol. Innov. 18, 100676. doi:10.1016/j.eti.2020.100676.

Solomon, S.K. 2005. Environmental pollution and its management in sugar industry in India: an appraisal. Sugar Tech. 7, 77–81. DOI: 10.1007/BF02942422

Solomon, S., 2016. Sugarcane production and development of sugar industry in India. Sugar Tech 18, 588–602. doi:10.1007/s12355-016-0494-2.

The Gazette of India (2016), MoEF&CC Notification on stipulated norms for treated effluent discharge for sugar sector, G.S.R. 35(E). Available online at https://parivesh.nic.in/writereaddata/ENV/envstandard/envstandard3.pdf, accessed on Apr. 7th, 2021.

Varshney, D., Mandade, P., Shastri, Y., 2019. Multi-objective optimization of sugarcane bagasse utilization in an Indian sugar mill. Sustain. Prod. Consum. 18, 96–114. doi:10.1016/j.spc.2018.11.009.

Wood, C., 1995. Environment Impact assessment: A comparative Review. Longman, Harlow, UK, p. 337 ISBN 0582236967.