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Volume 18, Number 4 • December 2019

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Evaluation of Human Health Risks by Potentially Toxic Elements in Roadside Deposited Sediment and Road Surface Run-off Water: A Case Study

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TERI Information Digest on Energy and Environment 18(4): 373–396

ABSTRACT

To comprehend the influence of potentially toxic elements (PTEs) in the road surface run-off water (RSRW) and roadside deposited sediment (RDS) on National Highway 2 (NH-2), Delhi–Kolkata, India, 18 samples were collected transversely from 9 sampling sites. The study determined the probable cancer risk by using Monte Carlo simulation with a value (90%) of 3.2×10^{-5} for adults and 2.7×10^{-5} for children in RDS at the extremely polluted site. In RSRW, the study implies (90%) risk value of 1.5×10^{-6} and 1.8×10^{-6} for children and adults, respectively. The hazard index (HI) in RDS and RSRW was found to be 1.42 and 0.599, respectively, for children and adults at highly contaminated sites. These values were within the permissible limits (10^{-6} to 10^{-4}). The pollution load index (P_LI) due to PTEs (Cr, Cd, Ni, Cu, Zn, and Pb) was maximum at the site S8 (3.591).

This study reveals pollution load at each site along with the carcinogenic and non-carcinogenic risks in RDS and RSRW, thus perceptibly exposing the effects of contamination caused by inorganic pollutants that results in adverse health effects on residents staying in adjacent areas of the sampling sites. A similar type of study would be more useful and beneficial for identical concerns observed elsewhere in the world.

Keywords: Potentially toxic elements, Sediment, Run-off water, Health risk assessment, National Highway 2

INTRODUCTION

Potentially toxic elements (PTEs) in roadside soil, dust, and run-off water have led to serious concerns during the last two decades (Ghosh and Maiti, 2018). The high traffic volume aggravates the problem of toxic metal contamination due to wear and tear of motor vehicles. The origin of toxic elements may be associated with the degradation of road edges and road pavements. This leads to frequent and continuous pollution of roadside soil by toxic materials resulting from auto parts, wearing of the tyres, vehicular exhausts, surface run-off (a variety of contaminants, road surface run-off water (RSRW)– mostly a non-point emitting pollutant), anthropogenic activities (obliteration/building, industrial actions, residential heating, etc.), and natural causes. The effects of toxic elements and organic contaminants call for global attention (Ghosh and Maiti, 2018; Adeniyi and Owoade, 2010). All these pollutants produced are swept out of the road surface run-off water and eventually dumped adjacent to the road edges in roadside deposited sediment (RDS) (Ghosh and Maiti, 2018). The toxic elements present in the sediments affect the storm water quality (Zhang and Hao, 2009). The high concentrations of all these toxic elements and other contaminants are owing to the extensive human activities together with vehicular pollutants present in the RDS (Duong and Lee, 2009; Eriksson, Baun, Scholes, *et al.*, 2007; Duzgoren-Aydin, 2007). RDS is a splendid absorber and displaces toxic metals, including copper (Cu), cadmium (Cd), nickel (Ni), chromium (Cr), zinc (Zn), and lead (Pb), to the aquatic ecosystem (Praveena, Ahmed, Radojevic, *et al.*, 2008; Alkarkhi, Ismail, Ahmed, *et al.*, 2009; Tian, Li, and Yang, *et al.*, 2009; Sutherland, Tack, and Ziegler, 2012). The excessive deposition of potentially toxic and hazardous elements in the form of sediments through transportation is splendid evidence of human influence (Yu, Xie, and Ma, 2014; Guevara, Rizzo, Sanchez, *et al.*, 2005). The presence of these PTE in the sediments beyond the acceptable limits can be a serious threat to human beings – from entering through the aquatic animals and eventually into the food chain (Iqbal and Shah, 2014). Presently, the roadside run-off water and sediments have become serious problems in many countries of the world, and so it is vital to know the level of contamination in RDS in a roadside ecosystem (Zhao, Li, Wang, *et al.*, 2010; Zhu, Bian, and Li, 2008). In the arid areas of Western Cape, South Africa, the run-off water was considered the most significant factor for contamination of surface water (Everts, 1997). The total suspended solids (TSS) and pesticides in run-off water may originate due to water-dissolved or particle-associated chemicals, leading to an increment of organic and inorganic pollutants in the surface water (Wauchope, 1978). The research indicated that the road surface water can be effectively treated depending on the local information (Thomson and Siddique, 1997). The traffic intensity has risen significantly in National Highway 2 and activities, such as industrial, transportation, and domestic have increased the contamination load of RDS and RSRW on the transverse side of the roadside ecosystem from Jangalpura to Ranisayer that links National Highway 2 in India. The principal objectives of the current study are to assess the pollution load index at each site with the human health hazard index (HI) and hazard quotient (HQ) between two groups of children and adults. Human health index and cancer risk index are the measures of possible cancer development resulting from exposure to toxic elements (USEPA, 1989; USEPA, 2005) in RDS and RSRW. Contaminants in RDS and RSRW have been the most studied topics throughout the world and in India, but the information is incomplete about the total cancer risk (TCR) assessment. This study also aims to evaluate the incremental lifetime cancer risk (ILCR) and TCR in RDS and RSRW between the two groups of children and adults for the entire locations along the study area, and it compares the carcinogenic risk with the studies from 20 cities

conducted worldwide by assessing their PTE concentration using Monte Carlo simulation. This type of study will be helpful to evaluate the magnitude of carcinogenic risk caused by potentially toxic elements relocated in the sediment that is displaced from the road surface by run-off water.

MATERIALS AND METHOD

Study Area

Nine sampling locations were selected across the road edge in a transverse position surrounded by villages plus urban colonies in 2014 (north side A and south side B) from Govindpur to Raniganj, 87 km along the east-west alignment of National Highway 2 (NH-2) (Delhi–Kolkata) (Table 1), with heavy traffic volume (Figure 1). This area has a population of approximately 824,912 (Census of India, 2011–19a,b). All the sampling sites have more or less high contamination due to the influence of traffic, coal mines, hard coke, and other industries. The annual average rainfall was 1306–1442 mm and the temperature recorded in winter was 21°C and in summer was 44.7°C



Figure 1 Jharkhand state map portraying NH-2 (top) and location map of area showing sampling sites of sediment and road surface run-off water along the NH-2 (bottom)

(Ghosh and Maiti, 2019). The direction of wind flow was south-west (SW), with a speed of 12.33 m/s in Ranisayer, Raniganj. The annual average daily traffic (AADT) as per the data of National Highway Authority of India (NHAI) from 2010 to 2015 was 209,777 (Ghosh and Maiti, 2019; Sarkar, 2016). To know the actual pollution level, control samples (soil) were collected from rural and suburban sites within 300–500 m from the roadside at the sampling site having a low traffic volume, with no animal burrowing, landfills, or any influence of anthropogenic activities.

Table 1 Description of sampling locations for sediment and road surface run-off water samples

Site	Position	Longitude	Latitude
Jangalpura Gobindpur (JG) S1, W1, $n = 4$	NORTH	86°35'38.61"E	23°48'26.63"N
	SOUTH	86°35'38.46"E	23°48'25.91"N
Mugma More (MM1) S2, W2, $n = 4$	NORTH	86°44'38.44"E	23°46'12.96"N
	SOUTH	86°44'01.72"E	23°48'12.29"N
Gopalpura Mugma (GM) S3, W3, $n = 4$	NORTH	86°45'37.72"E	23°45'52.16"N
	SOUTH	86°45'37.72"E	23°45'51.49"N
Mithon More (MM2) S4, W4, $n = 4$	NORTH	86°48'17.39"E	23°45'56.26"N
	SOUTH	86°48'17.57"E	23°45'55.22"N
Sanjay Check Post (SCP) S5, W5, $n = 4$	NORTH	86°45'51.64"E	23°45'49.50"N
	SOUTH	86°47'52.33"E	23°45'48.09"N
Devipur Barakar (DB) S6, W6, $n = 4$	NORTH	86°50'19.55"E	23°46'09.59"N
	SOUTH	86°50'19.73"E	23°46'08.74"N
Chanda Asansol (CA) S7, W7, $n = 4$	NORTH	86°57'10.21"E	23°43'00.94"N
	SOUTH	86°57'10.04"E	23°43'00.10"N
ADDA More Asansol (AM) S8, W8, $n = 4$	NORTH	86°59'17.27"E	23°41'57.73"N
	SOUTH	86°59'16.95"E	23°41'57.00"N
Ranisayer Raniganj (RR) S9, W9, $n = 4$	NORTH	87°07'00.25"E	23°38'13.85"N
	SOUTH	87°06'59.73"E	23°38'13.18"N

Note: The parameter " n " denotes the number of sediment and water samples.

Sample Collection, Preparation, and Digestion

Transversely, 18 samples were collected for RDS (0–10 cm deep) and RSRW (sampled at nine sites of roadside NH-2). The RDS samples were air-dried and thoroughly mixed using agate pestles and mortars. The process was followed by the separation of large pebbles or stones with the help of a 2 mm nylon sieve (0.45 mm pore size). The samples were kept in polypropylene (PP) plastic bottles. Fine sediment samples of 0.2 g (approx.) after drying in hot air oven were ultimately digested (USEPA, 1996). The RSRW samples were kept in PP plastic bottles after the addition of HNO_3 to reduce the pH value to 2 so as to prevent the oxidation of metals (Ghosh and Maiti, 2018). Analytical Reagent (AR) grade chemicals were used. The standards and reagents were prepared by Milli-Q (Millipore water, model Elix and Milli-Q, 18.2 m Ω , France). The correctness and investigative outcomes of the measurements were acquired for the reference material (LGC 6137) that differed by <12% from the PTEs of sediment. Flame atomic absorption spectrometry (FAAS) (GBC, Model Avanta, Australia) was used to determine the potentially toxic element concentrations of digested RDS and RSRW.

Human Health Risk Evaluation in India and the World

The steps included in the human health risk evaluation were collection and analysis of data and determination of the exposure and risk simulation (Wu, Zhang, Zhang, *et al.*, 2011). The published mean value of the PTE concentration of sediment and roadside dust from across the world was taken for cancer risk assessment individually and evaluated using the Monte Carlo simulation with the help of probability distribution for children and adults and was compared with the present study. The concentrations were converted to mg/kg to maintain consistency. The present study is assumed to be the first attempt to research in this particular area and review the PTE concentration exposure in roadside dust and sediments and thus evaluate their corresponding cancer risk.

Pollution Load Index

The magnitude of metal contamination in the roadside sediments at each location was determined by applying the method of pollution load index (P_LI). This method was developed by Tomlinson (1980). The equation used is as follows:

$$P_LI = (C_f1 \times C_f2 \times C_f3 \dots C_fn)^{1/n} \quad (1)$$

Here, C_f is the contamination factor for each studied metal and n is the number of metals studied. The categories of pollution are thus defined: for $P_LI < 0$, unpolluted; $0 < P_LI \leq 1$, pollutant present at baseline levels; $1 < P_LI \leq 10$, contaminated; $10 < P_LI \leq 100$, highly contaminated; $P_LI > 100$, environment deteriorating progressively.

Risk Assessment of Human Health Through Ingestion and Dermal Pathways

The contamination of RDS and RSRW by the inorganic and other pollutant sources can increase the human health risk. Cancer risk assessment signifies the possibility of cancer developed by carcinogens or mutagens (Li, Ma, Van Der Kuijp, *et al.*, 2014). The present study has been the first to attempt the review of carcinogenic and non-carcinogenic risks in RDS and RSRW for the particular study area. To determine the total cancer risk (TCR), Monte Carlo simulation was used. The contact of PTEs with humans results from two pathways via sediment and run-off water: (i) oral ingestion and (ii) dermal absorption of PTEs. The average PTE concentration and non-carcinogenic risk estimations were used for the calculation of an upper limit of 95 percent confidence interval (95% UCL (upper confidence level)). The hazard exposure risk for non-carcinogens was estimated by following USEPA guidelines (USEPA, 2011; USDoE, 2011) and using Eqs (2)–(6) (Shi, Xiao, Wang, *et al.*, 2014). The human non-cancer and cancer risk assessment constraints are given in Table 2. The calculation interprets as follows: if the value of HI is <1 , there is no non-cancer risk and if HI is >1 , there is a possibility of non-cancer risk that grows with the rise of HI value (USEPA, 2001). The estimation of chronic daily intake (CDI) (mg/kg/day) of RDS and RSRW was made by following Eqs (2)–(10) and the guidelines (USEPA, 1989; USEPA, 2004; USEPA, 2009; Tarafdar and Sinha, 2017). The sum of HQs of two exposure pathways for all PTEs was evaluated by Eq. (5), and to determine the HI in each site for non-cancer of all the PTEs, the sum of the HQs of two exposure pathways was calculated from Eq. (6) (Guerra, Konz, Lisi, *et al.*, 2010).

Non-carcinogenic Risk Assessment

$$CDI_{ing-nc} = \frac{(C \times IngR \times EF \times ED)}{BW \times AT(nc)} \times 10^{-6} \quad (2)$$

$$CDI_{dermal-nc} = \frac{C \times SA \times AF \times ABS \times EF \times ED}{BW \times AT(nc)} \times 10^{-6} \quad (3)$$

$$HQ = \frac{CDI(nc)}{RfD} \quad (4)$$

$$HI = \sum HQ = HQ_{ing} + HQ_{dermal} \quad (5)$$

$$HI = \sum HQ = HQ_{Cd} + HQ_{Cr} + HQ_{Cu} + HQ_{Ni} + HQ_{Pb} + HQ_{Zn} \quad (6)$$

Table 2 Human non-cancer and cancer risk assessment constraints

Exposure Parameters	Units	Description	Distributions		Metal	Rfd _{ing} (µg/kg/day) Chabukdhara and Nema (2013)	Rfd _{der} (µg/kg/day) Chabukdhara and Nema (2013)	References
			Child	Adult				
EF	Days/year	Exposure frequency	Non-cancer 350 Cancer- 365		Cd	1.0×10^{-3}	1.0×10^{-5}	USDoE (2011) Kumar, Verma, Kumar, <i>et al.</i> (2013)
ED	Year	Exposure duration	6	24	Cr	3.0×10^{-3}	7.5×10^{-5}	USEPA (2001)
AF	mg/cm ²	Skin adherence factor	0.2	0.07	Cu	4.0×10^{-2}	4.0×10^{-2}	USEPA (2011)
AT	Days	Averaging time _{nc} Averaging time _{ca}	ED × 365 Cancer - 25550		Ni	2.0×10^{-2}	5.4×10^{-3}	USDoE (2011) Ferreira-Baptista and De Miguel (2005)
IngR	Ingestion rate	mg/day	200	100	Pb	3.5×10^{-3}	5.3×10^{-4}	USEPA (2011)
HR	m ³ /day	Inhalation ratio _{ca}	10.1	16	Zn	3.0×10^{-1}	3.0×10^{-1}	USEPA (2011)
BW	kg	Body weight _{nc} Body weight _{ca}	15 20	60 60				USEPA (1989) Khadilkar, Khadilkar, Choudhury, <i>et al.</i> (2007)
PEF	m ³ /kg	Particulate emission factor _{nc} and _{ca}	1.36×10^9	1.36×10^9				Xu, Lu, Han, <i>et al.</i> (2015); USEPA (2011)
ABS	-	Dermal absorbance factor _{nc} Dermal absorbance factor _{ca}	0.001 (for all metals) 0.13 (for all metals)					De Miguel, Iribarren, Chacon, <i>et al.</i> (2007); Zhang, Yao, Zhu (2010); Shi, Chen, Bi, <i>et al.</i> (2011); USEPA (2011)

Exposure Parameters	Units	Description	Distributions		Metal	Rfd _{ing} (µg/kg/day) Chabukdhara and Nema (2013)	Rfd _{der} (µg/kg/day) Chabukdhara and Nema (2013)	References
			Child	Adult				
SA	cm ²	Skin surface area for daily contact _{nc}	2800	5700				USEPA (2001) Harinarayan, Holick, Prasad, <i>et al.</i> (2013)
		Exposed skin area _{ca}	3500	10,500				
ET	h/day	Exposure time _{nc}	24	24				USDoE (2011)

CARCINOGENIC RISK ASSESSMENT

Risk analysis by Monte Carlo simulation

The inaccuracy in the estimation of cancer risk arises from human topographies and comportment. The unison of this inconsistency in the assessment of cancer risk by Monte Carlo simulation was used for two age groups – children and adults – performed by the software from Oracle, Crystal Ball (11.1.02.4.600). The probabilistic exposure risk estimation and the parameters with their random value ranges used in software simulation are given in Table 3. For risk assessment, simulation selected random values of each variable for their distribution and 10,000 iterations were run (Praveena, Ahmed, Radojevic, *et al.*, 2008). For calculating the carcinogenic risk for nearby residents, carcinogenic elements such as Cr, Cd, Ni, Cu, Zn, and Pb were selected and the estimation was carried out by the summation of two different exposure pathways by using Eqs (7)–(10) (Chiang, Chio, Chiang, *et al.*, 2009).

$$CDI_{(Ingestion)ca} = \frac{CS_{soil} \times IR \times CF \times ED \times EF}{(BW \times AT)} \quad (7)$$

$$CDI_{(Dermal contact)ca} = \frac{CS_{soil} \times CF \times ED \times EF \times AF \times ABS \times SA}{AT \times BW} \quad (8)$$

$$ILCR = CDI_{ca} \times CSF \quad (9)$$

$$\text{Total risk} = ILCR_{ing} + ILCR_{dermal} \quad (10)$$

Here, CDI_{ing} and CDI_{dermal} are the chronic daily intake through ingestion (mg/kg/day) and skin contact (mg/kg/day) of the soil particulates (mg/m³) for non-cancer and cancer, respectively. The cancer slope factor (CSF) was used to assess cancer risk (CR). The CSF values of dermal absorption and ingestion were 37.47 and 7.3 mg/kg/day, respectively (Knafla, Philipps, Brecher, *et al.*, 2006; Liu, Cheng, Ou, *et al.*, 2007). The aforementioned analysis was carried out to assess the presence of toxicity in RDS and RSRW for both carcinogenic and non-carcinogenic categories. The standards of the variables collected from the different literature via reference dose value (RfD) for the calculation of different receptor parameters through different pathways are given in Table 2. The quantitative interpretation of total cancer risk (TCR) predicted by the Department of Health, New York is: very low $\leq 10^{-6}$; low $10^{-6} < \text{to} < 10^{-4}$; moderate $10^{-4} \leq \text{to} < 10^{-3}$; high $10^{-3} \leq \text{to} < 10^{-1}$; and very high $\geq 10^{-1}$ (DoH, 2012).

Table 3 Parameters in the probabilistic exposure risk assessment and their random value ranges (geomean, geostdev) used in software simulation

Definition	Units	Distributions	Children	Adults	References
IR _{ds}	mg/day		100	50	USEPA (1997); USEPA (2011)
SA	cm ²	Log-normal	LN(4619.11, 1.77)	LN(12633.93, 1.13)	USEPA (2011)
AF	mg/cm ²	Log-normal	LN(0.04, 3.40)	LN(0.02, 2.67)	Chen, Wang, Hsieh, <i>et al.</i> (2012)
BW	kg	Log-normal	LN(27.14, 1.37)	LN(57.45, 1.06)	ICMR-NIN (2011)
ED	year		Uniform U(0, 11)	U(0, 52)	Yang, Lang, and Li (2014)
EF	days/year	Log-normal	LN(252, 1.01)		USEPA (2002a); Chen and Liao (2006)
ABS	unitless	Log-normal	LN(0.13, 1.26)		Chen and Liao (2006)
CSF _{ingestion}	mg/kg/day	Log-normal	LN(7.3, 1.56)		Chen, Wang, Hsieh, <i>et al.</i> (2012)
HR	m ³ /day	Log-normal	LN(7.19, 1.62)	LN(13.9, 1.07)	USEPA (2011)
PEF _{soil}	mg ³ /kg		1.36 × 10 ⁹	1.36 × 10 ⁹	Yang, Lang, and Li (2014)
CSF _{inhalation}	mg/kg/day	Log-normal	LN(3.14, 1.8)		Chen and Liao (2006)
CSF _{dermal}	mg/kg/day		37.47		Hussain, Rae, Gilman, <i>et al.</i> (1998)

DATA ANALYSIS AND EVALUATION METHODS

In order to study the human health risk assessments in RDS and RSRW, a spatial variation distribution was done with the help of surfer-13 (V13.5.583). MS Excel (one-way analysis of variance (ANOVA)) was used for the statistical calculation.

RESULTS AND DISCUSSIONS

Pollution Load Index

To determine and identify the magnitude and extent of metal contamination in the sediments, P_LI was assessed for all the sites for sediments using Eq. (1). Figure 2 shows the P_LI for all the nine sampling sites. It can be observed that the P_LI values for all the sampling sites were higher than the baseline levels (P_LI = 1). The values indicate that the sites are contaminated (Tomlinson, 1980). The P_LI at S8 was highest, which shows a higher environmental deterioration at the site S8 due to anthropogenic causes (vehicular emission, road construction, etc.). The study complies with the results of Ghosh and Maiti (2018), where a higher concentration of metals in roadside sediments was found at the site S8. According to Salah, Zaidan, and Al-Rawi (2012), in Turkey, only one site projects P_LI higher than the baseline. In the present study, sites having a higher P_LI other than S8 are S5, S6, S9, and S1. These areas tend to show a higher deterioration owing to the presence of industrial clusters around the roadside environment, particularly coal and hard coke industries. Traffic density is one of the biggest factors for the assimilation of metal contaminants around roadsides. This is because the contaminants like road dust and vehicular pollutants, such

as tyre wear, spillage of oil, corrosion of metal parts, and so on, from the roads get washed off by the rainwater. These pollutants were thus deposited in the roadside as sediments. The presence of a higher concentration of PTEs in the sediment is because of the sediment that receives road dust and polluted roadside run-off water during monsoons (Karak and Bhattacharyya, 2010). The $P_L I$ in urban areas near the Ganga Plain in India was evaluated. The areas with their $P_L I$ values were as follows: Kanpur (1.71), Allahabad (1.13), Varanasi (1.20), Lucknow (1.64), Delhi (3.61), and Agra (4.4). Delhi and Agra had a higher $P_L I$ due to the industrial influences dominating the sampling sites (Singh, Müller, and Singh, 2002). The results similar to the present study were obtained by Nazzal, Rosen, and Al-Rawabdeh (2013) in Canada on the highway road dust where the $P_L I$ was higher than the baseline levels. The $P_L I$ levels in the roadside areas of Botswana were found to be higher than the baseline levels for two sites (Mmolawa, Likuku, and Gaboutloeloe, 2011). The author suggests that a higher pollution load could be attributed to the escalation of human activities, primarily through vehicular contamination (Mmolawa, Likuku, and Gaboutloeloe, 2011).

Non-carcinogenic Risk Assessment

The transverse concentrations of PTEs in RDS and RSRW are given in Tables 4 and 5. The mean concentration of PTEs shown in these tables was used for non-carcinogenic and carcinogenic risk analysis (Ghosh and Maiti, 2018). The HQ and HI were calculated from their CDI values using Eqs (2)–(6). The HI of children and adults was calculated using Eq. (6), taking the sum of HQ of all the metals, and the summation of HI for all the metals at each location was evaluated. These cumulative HI calculations at each location for the two groups of children and adults were used for the generation of contour plots (x-axis represents latitude and y-axis represents longitude) for both sediment and run-off water. The higher values of HI can be seen in cases where the heat colour is dark as per the scale in the plot. The contour of run-off water for children is shown in Figure 3a. It can be seen from the figure that the non-carcinogenic risk for children was found to be maximum at S9 (latitude – 23.6372°; longitude – 87.1167°). The HI risk for children was unpredictably higher than adults, similar to the results of Luo, Ding, Xu, *et al.* (2012). This is because children unknowingly ingest or have dermal contact with contaminants in their day-to-day lives (Shi, Xiao, Wang, *et al.*,

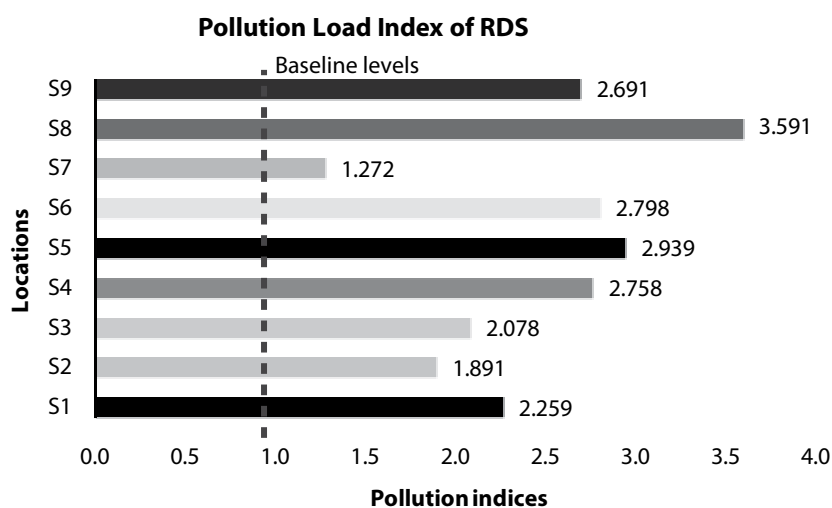


Figure 2 Pollution load index at each location along NH-2

2014). This was verified by the results obtained by the calculations that showed the higher HI at S9. Similarly, for adults, the non-carcinogenic risk was found more at S5 (latitude – 23.7639°; longitude – 86.7644°), as shown in the contour plot in Figure 3b. A study in the region of Raniganj found higher values of risk for both children and adults (Tarafdar and Sinha, 2017). Figure 3c shows the contour plot of sediment for children. The maximum risk could be seen at S5 followed by S6 (latitude – 23.7694°; longitude – 86.8389°). Figure 3d shows the contour of sediment for adults and the highest risk can be seen at S5 followed by S4 (latitude – 23.7656°; longitude – 86.8047°). The particular increase in the non-carcinogenic risk in these regions can be attributed to the fact that these regions are surrounded by coal mines, coke industries, and brick kilns. Also, regions such as S5 have a heavy traffic density due to the presence of toll booths (Ghosh and Maiti, 2019). Some researchers found Cr to have higher risk values for both exposure pathways (ingestion and dermal) (Bello, Muhammad, and Bature, 2017). A study showed that the non-carcinogenic effect in children was found to be higher compared to adults (Chabukdhara and Nema, 2013). In this study, the exposure was primarily caused by the ingestion and less by dermal. The exposure risk values were less than those given under USEPA guidelines (USEPA, 1989; USEPA, 2004; USEPA, 2009), but children's exposure risk was found to be higher than in adults. A similar result was found by Chabukdhara and Nema (2013). The author also stated that 95% UCL of Cr for non-cancer risk in Ghaziabad urban soil was 0.23 in adults and 1.8 for children (Chabukdhara and Nema, 2013). In accordance with this, the present study found the HI of Cr for sediment to be 0.42 in children at S4 and 0.05 in adults at S5. A higher risk in children could be due to their engagement with more outdoor activities, thus resulting in more exposure to toxic metals (Karim and Qureshi, 2014).

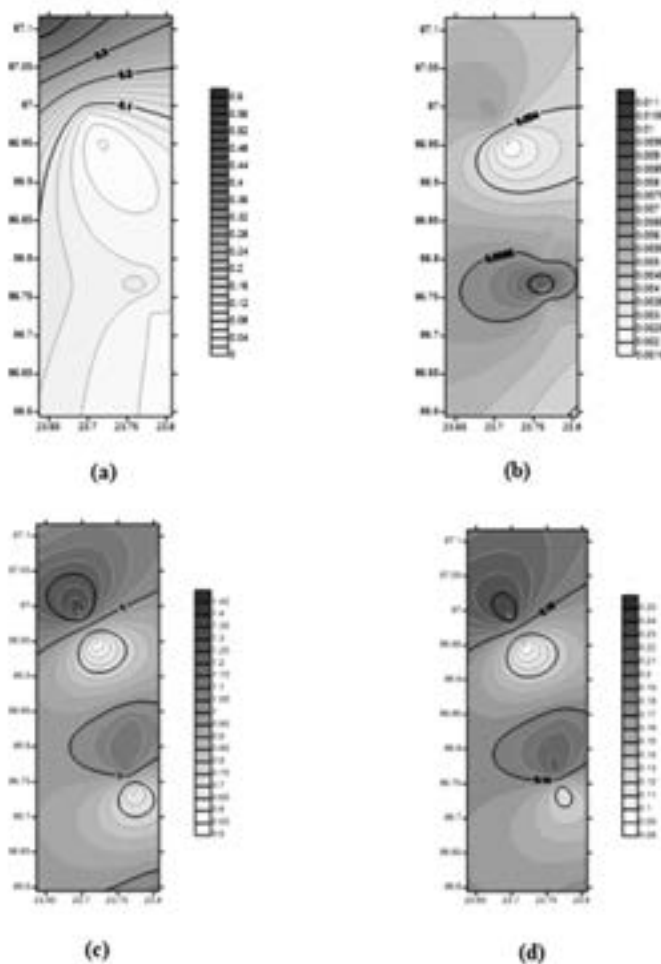


Figure 3 Spatial variation of cumulative HI at each location of the total toxic element in run-off for (a) children and (b) adults and in sediment for (c) children and (d) adults

Table 4 PET concentration transversely in sediment along NH-2

Sediment samples	Cd	Cr	Cu	Ni	Pb	Zn
S1	11.60	54.70	47	74.9	220.5	125
SD	0.055	0.1	0.3	0.115	0.5	0.24
S2	9.696	22.985	37.493	51.44	121	96.5
SD	0.015	0.007	0.012	0.006	0.058	0.01
S3	7.46	84.74	52.68	55.59	48.99	111
SD	0.01	0.01	0.026	0.006	0.012	0.01
S4	5.85	51.603	57.773	60.99	34.02	126
SD	0.01	0.005	0.005	0.115	0.04	0.1
S5	9.16	91.116	57.796	61.15	53.37	134
SD	0.01	0.005	0.015	0.006	0.105	0.05
S6	8.426	49.256	48.773	59.01	44	129
SD	0.005	0.011	0.225	0.04	0.02	0.02
S7	10.123	109	58.7	64.48	152.36	188
SD	0.035	1	0.3	0.005	0.050	0.3
S8	8.163	88.693	49.613	49.01	124	172
SD	0.005	0.011	0.165	0.06	0.06	0.195
S9	11.356	113.753	62.5	66.25	161.75	193.5
SD	0.005	0.005	0.52	0.08	0.01	0.5
S10	9.356	59.25	58.756	56	131	222.5
SD	0.005	0.01	0.09	0.025	0.025	0.5
S11	17.886	51.786	76.21	71.01	201.4	174.6
SD	0.005	0.005	0.005	0.76	0.385	0.4
S12	11.883	44.233	63.866	41	123.6	155.8
SD	0.005	0.005	0.015	0.08	0.1	0.01
S13	8.436	22.753	21.256	42	68.01	72.25
SD	0.015	0.005	0.170	0.02	0.79	0.01
S14	9.756	35	47	10.01	47	27
SD	0.005	0.025	0.005	0.006	0.006	0.01
S15	21.803	75.753	71.5	75.26	172.5	192.75
SD	0.005	0.015	0.2	0.04	0.105	0.01
S16	19.693	72.5	104.016	73.5	202	165.5
SD	0.005	0.5	0.155	0.7	0.025	0.07
S17	15.11	71.5	67	68	191.25	234.25
SD	0.01	0.04	0.49	0.1	0.045	0.01
S18	11.74	57.5	24.246	51.01	60	169
SD	0.005	0.02	0.005	0.031	0.935	0.99
*BG	0.08	1.135	0.43	3.26	0.016	20.51
*SD	0.014	0.23	0.12	1.42	0	2.46
F*	4.21	5.08	8.42	17.11	112.29	24.66

SD, standard deviation; $p < 0.05$; No. of samples (n) = 18

*Ghosh and Maiti (2018)

Table 5 PET concentration transversely in run-off water along NH-2

Run-off water samples	Cd	Cr	Cu	Ni	Pb	Zn
W1	1.1	3.34	3.2	0.91	1.11	9.25
SD	0.076	0.100	0.067	0.090	0.110	0.115
W2	0.7	2.1	1.52	0.16	0.24	6.52
SD	0.025	0.110	0.050	0.045	0.030	0.515
W3	1.21	4.75	2.71	5.02	0.49	11.67
SD	0.100	0.130	0.050	0.115	0.030	0.710
W4	0.88	3.61	3.96	1.61	0.34	5.8
SD	0.085	0.345	0.310	0.125	0.070	0.351
W5	1.34	5.74	1.76	1.15	1.37	13.4
SD	0.115	0.095	0.130	0.040	0.121	1.290
W6	1.07	4.16	0.64	0.59	0.44	8.72
SD	0.105	0.305	0.203	0.202	0.153	0.695
W7	1.57	3.88	2.82	0.48	1.52	16.7
SD	0.190	0.325	0.435	0.108	0.135	0.760
W8	1.16	3.17	1.52	0.74	1.27	7.26
SD	0.060	0.185	0.085	0.213	0.132	0.180
W9	2.34	16.34	5.66	6.25	3.75	19.31
SD	0.185	1.115	1.210	0.110	0.205	0.195
W10	1.17	5.25	2.94	2.63	2.33	2.25
SD	0.080	0.115	0.150	0.105	0.120	0.140
W11	1.87	4.71	4.18	0.71	1.28	17.46
SD	0.125	0.160	0.210	0.270	0.160	0.115
W12	1.1	1.65	3.17	0.48	0.47	5.58
SD	0.120	0.130	0.155	0.370	0.130	0.340
W13	0.08	0.98	0.44	1.25	0.68	2.25
SD	0.040	0.625	0.200	0.135	0.195	0.085
W14	1.09	0.35	1.61	0.87	1.07	2.77
SD	0.215	0.205	0.141	0.180	0.120	0.180
W15	1.05	5.75	2.52	2.25	1.72	1.94
SD	0.155	0.205	0.150	0.135	0.125	0.195
W16	1.91	2.5	3.01	3.87	2.02	3.65
SD	0.215	1.050	0.930	0.225	0.105	0.875
W17	1.37	3.15	3.17	2.68	3.91	23.48
SD	0.185	0.175	0.220	0.110	0.105	1.500
W18	0.96	2.78	2.25	1.51	2.06	16.91
SD	0.385	0.210	0.115	0.645	0.120	1.105
F*	9.04	45.78	15.42	4.72	19.89	42.64

SD, standard deviation; $p < 0.05$; No. of samples (n) = 18; * (asterisk) denotes the ANOVA test significant with probability < 0.0001

EXPOSURE AND CARCINOGENIC RISK EVALUATION

The evaluation of the total cancer risk (TCR) and the exposure was carried out with the geometric mean and the standard deviation of PTE concentration as previously mentioned. For the risk analysis of the sediments and run-off water of the entire area, Monte Carlo simulation of each division (division, according to Polish standard) was conducted aiming at children and adults at 90% confidence level involving exposure duration (ED), inhalation ratio (HR), skin surface area (SA), skin adherence factor (AF), exposure frequency (EF), body weight (BW), and so on using Eqs (3) and (4). Figure 4a shows the simulation of children in sediments, while Figure 4c shows the simulation of adults in the sediment. The 90% risk value found in sediment for children was 2.7×10^{-5} and that for adults was 3.2×10^{-5} . A similar study done in 2017 revealed that the 90% risk value for PAHs (polycyclic aromatic hydrocarbons) in sediment was 7.86×10^{-5} for children and 3.99×10^{-4} for adults, which indicated a higher cancer risk compared to the present study (Tarafdar and Sinha, 2017). In the same study area, the PAH concentration was studied with the aid of Monte Carlo and it was found that 90% risk values were slightly higher in children than adults, whereas the present study revealed the risk value to be much higher than the PAH study (Ghosh and Maiti, 2019). The cancer risk assessment via ingestion was 4.33×10^{-4} for adults and 6.5×10^{-4} for children and via dermal, it was 1.48×10^{-3} for children and 2.12×10^{-3} for adults, which was higher by about 10^{-1} times than that through ingestion. The studied result was found consistent with Tarafdar and Sinha (2017), Yang, Lang, and Li (2014), and Passuello, Mari, Nadal, *et al.* (2010). The sediment has a significant impact on causing cancers in children and adults. The simulation of surface run-off water is shown in Figure 5a for children and in Figure 5c for adults. The 90% risk value was 1.5×10^{-6} in children and 1.8×10^{-6} in adults. The consistent higher risk value for adults than children could be attributed to lower body weight of the children and a higher exposure duration (ED) value of the adults (Wu, Zhang, Zhang, *et al.*, 2011; Yang, Lang, and Li, 2014). The sensitivity plots were analysed using tornado plots that illustrate the input parameters that are ranked based on their effects on the output risk. The sensitivity plots for children and adults in sediment are shown in Figure 4b and Figure 4d, respectively. The main carcinogenic risk factors were ED (50.3–50.1%) and concentration of elements in sediment (49.3–49.0%). Some studies suggest ED to be an important contributor to the carcinogenic risk (Tarafdar and Sinha, 2017). ED and AF are considered to be some of the main components that contribute to the carcinogenic risk (Chen and Liao, 2006; Chiang Chio, Chiang, *et al.*, 2009; Wu, Zhang, Zhang, *et al.*, 2011). In case of run-off water, as shown in Figure 5b and Figure 5d for children and adults, respectively, the concentration of metals in run-off water (72.6–71.8%) contributed the most, followed by ED (27.8–26.5%). A similar result was found in sediments where the concentration of metals in soil contributed the most, followed by ED (Tarafdar and Sinha, 2017). Tables 6 and 7 show the mean ILCR, TCR, SD, and 95% UCL (upper confidence limit) for sediment and run-off water for both children and adults. The TCR for both children and adults is high enough, showing higher carcinogenic risk. For both sediments and run-off water, the adult has a higher carcinogenic risk exposure than the children as evident from the values of TCR, standard deviation (SD), and 95% UCL. In Beijing, TCR values for adults and children were found to be 2.48×10^{-5} and 6.72×10^{-6} , respectively (Peng, Chen, Wang, *et al.*, 2011). In China, the cancer risk for adults via ingestion and dermal pathway was 3.36×10^{-5} and 5.97×10^{-5} , respectively (Yu, Xie, and Ma, 2014). In the current study, the risk through ingestion and dermal pathways was 4.33×10^{-4} and 2.12×10^{-3} , respectively. Thus, it illustrated a result that was 100 times higher than the results of Yu, Xie, and

Ma (2014). The study showed that the increase in TCR was due to the contribution of Pb and Cr (Bello, Muhammad, and Bature, 2017). The cancer risk through ingestion was higher for Pb in Nigeria, which was 7.6×10^{-6} (Bello, Muhammad, and Bature, 2017). The preceding researchers showed Pb to be one of the first five largest contributors to cancer risk, while Cu and Ni were found among the least five contributors (Zhang, Yao, and Zhu, 2010). In high amounts, Cr causes kidney damage, respiratory problems, and alteration of genetic materials. Higher concentrations of Pb in the human body may lead to convulsions, nervous system failures, and declined fertility in males through sperm damage (Ghosh, Maiti, and Singh, 2009).

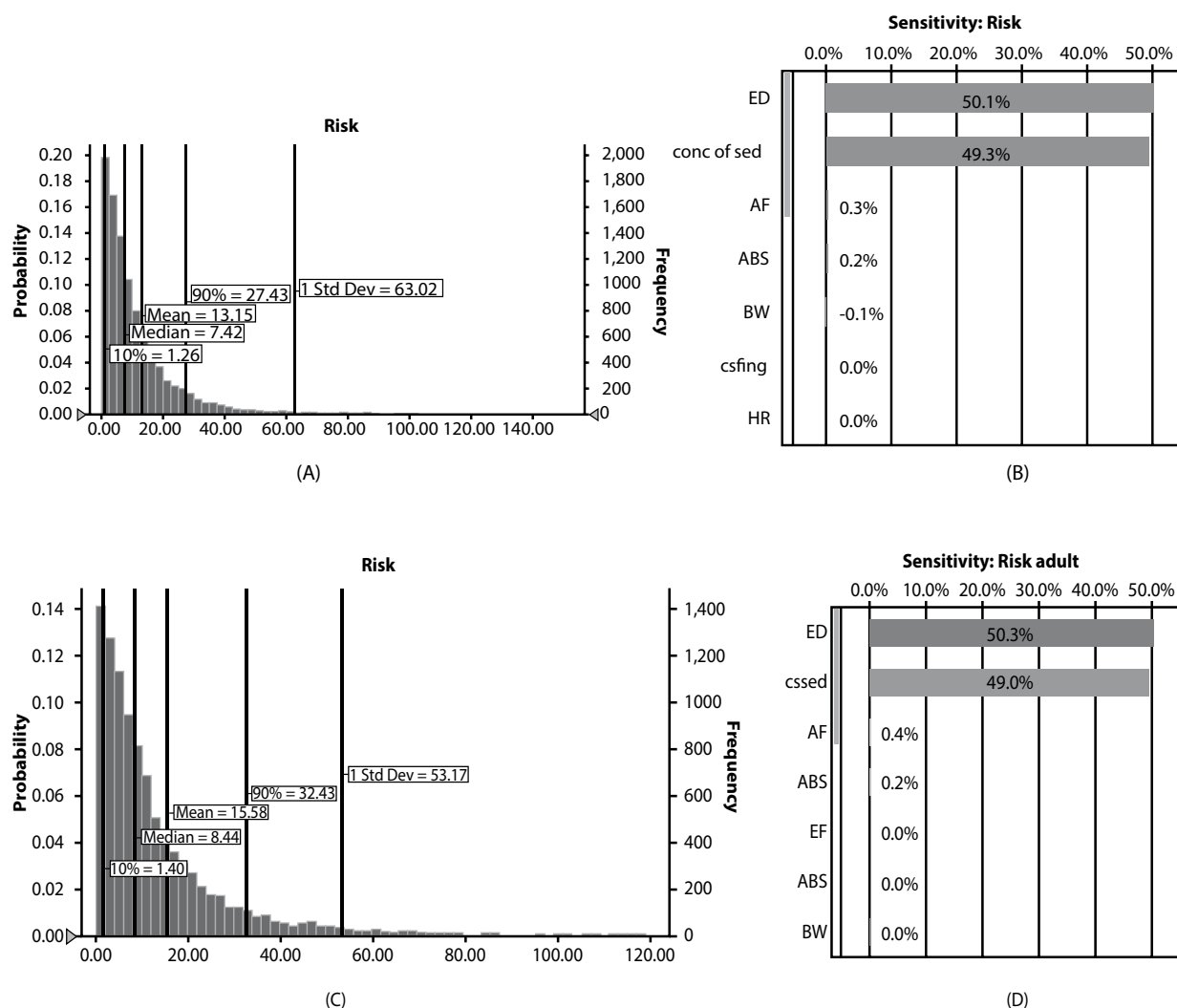


Figure 4 Cancer risk assessment by probability density function in RDS for (a) children and (c) adults and sensitivity analysis of risk in RDS for (b) children and (d) adults

COMPARISON WITH OTHER STUDIES

Table 8 shows the 90% risk factors assessed from the PTE concentration of sediments and roadside dust from other studies around the world. The mean value and standard deviation along with the 90% risk value were also evaluated using Monte Carlo as previously mentioned. It is evident

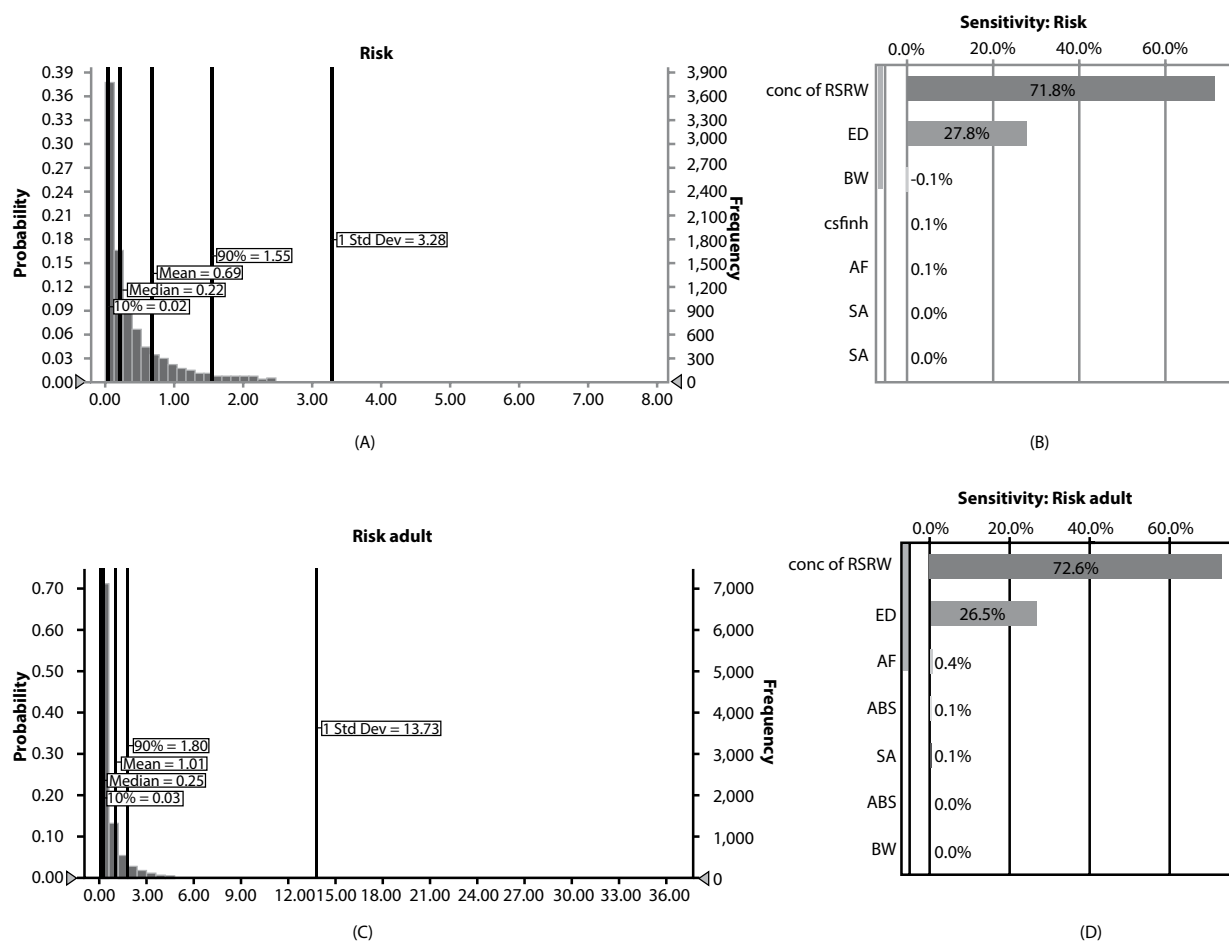


Figure 5 Cancer risk assessment by probability density function in run-off for (a) children and (c) adults and sensitivity analysis of risk in run-off for (b) children and (d) adults

from the results that the risk value for children in the present study was much higher than any of the results found in some studies around the world. Only in Zhenjiang, China, 90% risk value for children was higher than the present study (Zhu, Bian, and Li, 2008). The carcinogenic risk in sediments and the roadside dust across the world exposed the risk value of adults to be 1.43×10^{-4} in Zhenjiang, China. The author suggests that these high values of PTE concentration resulting in higher exposure rates could be due to high traffic densities (Zhu, Bian, and Li, 2008). The mean for children was found to be higher in the present study, but was comparatively lower than the results of Iran and Zhenjiang (Moore, Attar, and Rastmanesh, 2011; Zhu, Bian, and Li, 2008). The sensitivity analysis in the present study showed that the concentration of toxic elements in sediments contributed the most towards exposure risk followed by exposure duration. The result was in compliance with the other studies presented in Table 8. In the case of adults, the 90% risk was found to be highest in the present study when compared with the rest of the world. Places in China such as Zhenjiang (Zhu, Bian, and Li, 2008) and Shanghai (Shi, Chen, Xu, *et al.*, 2008) had a higher 90% risk value. The author claimed that the reason behind the presence of PTEs in higher concentration was due to anthropogenic activities such as industries and traffic, including atmospheric deposition (Shi, Chen, Xu, *et al.*, 2008). The retention of PTEs such as Cu by the

Table 6 Mean value of incremental lifetime cancer risk and total cancer risk for sediment

Child					Adult			
<i>Sampling site</i>	<i>95% UCL</i>	<i>Mean of ILCR</i>	<i>SD</i>	<i>TCR</i>	<i>95% UCL</i>	<i>Mean of ILCR</i>	<i>SD</i>	<i>TCR</i>
S1	1.02×10^{-3}	8.01×10^{-4}	1.16×10^{-3}	9.62×10^{-3}	1.61×10^{-3}	9.28×10^{-4}	3.73×10^{-3}	1.11×10^{-2}
S2	5.7×10^{-4}	6.21×10^{-4}	7.62×10^{-4}	7.45×10^{-3}	9.02×10^{-4}	7.14×10^{-4}	2.82×10^{-3}	8.57×10^{-3}
S3	6.49×10^{-4}	6.68×10^{-4}	8.29×10^{-4}	8.02×10^{-3}	1.03×10^{-3}	7.64×10^{-4}	3.02×10^{-3}	9.17×10^{-3}
S4	9.7×10^{-4}	9.88×10^{-4}	1.25×10^{-3}	1.1×10^{-2}	1.65×10^{-3}	1.1×10^{-3}	4.39×10^{-3}	1.32×10^{-2}
S5	1.21×10^{-3}	1.02×10^{-3}	1.44×10^{-3}	1.23×10^{-2}	1.95×10^{-3}	1.17×10^{-3}	4.72×10^{-3}	1.41×10^{-2}
S6	1.20×10^{-3}	8.71×10^{-4}	1.33×10^{-3}	1.04×10^{-2}	1.78×10^{-3}	1.06×10^{-3}	4.25×10^{-3}	1.27×10^{-2}
S7	2.79×10^{-4}	3.5×10^{-4}	3.63×10^{-4}	4.2×10^{-3}	4.18×10^{-4}	4.21×10^{-4}	1.63×10^{-3}	5.05×10^{-3}
S8	1.16×10^{-3}	1.06×10^{-3}	1.38×10^{-3}	1.28×10^{-2}	1.75×10^{-3}	1.27×10^{-3}	5.05×10^{-3}	1.53×10^{-2}
S9	1.24×10^{-3}	9.10×10^{-4}	1.38×10^{-3}	1.09×10^{-2}	1.98×10^{-3}	1.04×10^{-3}	4.24×10^{-3}	1.25×10^{-2}
BG	2.02×10^{-4}	4.5×10^{-5}	1.67×10^{-4}	5.4×10^{-4}	2.66×10^{-4}	5.21×10^{-5}	2.67×10^{-4}	6.26×10^{-4}

S1–S9, sampling location; BG, background; TCR, total cancer risk; ILCR, incremental lifetime cancer risk; SD, standard deviation

Table 7 Mean value of incremental lifetime cancer risk and total cancer risk for run-off water

Child					Adult			
<i>Sampling site</i>	<i>95% UCL</i>	<i>Mean of ILCR</i>	<i>SD</i>	<i>TCR</i>	<i>95% UCL</i>	<i>Mean of ILCR</i>	<i>SD</i>	<i>TCR</i>
S1	1.6×10^{-3}	2.62×10^{-5}	1.12×10^{-4}	3.14×10^{-4}	1.61×10^{-3}	3.09×10^{-5}	1.76×10^{-4}	5.18×10^{-4}
S2	9.02×10^{-4}	3.65×10^{-5}	1.49×10^{-4}	4.38×10^{-4}	9.02×10^{-4}	4.31×10^{-5}	2.5×10^{-4}	7.28×10^{-4}
S3	1.03×10^{-3}	3.51×10^{-5}	1.53×10^{-4}	4.21×10^{-4}	1.03×10^{-3}	4.14×10^{-5}	2.34×10^{-4}	6.78×10^{-4}
S4	1.65×10^{-3}	3.66×10^{-5}	1.6×10^{-4}	4.39×10^{-4}	1.65×10^{-3}	4.31×10^{-5}	2.38×10^{-4}	6.92×10^{-4}
S5	1.95×10^{-3}	6.1×10^{-5}	2.42×10^{-4}	7.32×10^{-4}	1.95×10^{-3}	7.20×10^{-5}	4.35×10^{-4}	1.27×10^{-3}
S6	1.78×10^{-3}	3.70×10^{-5}	1.6×10^{-4}	4.45×10^{-4}	1.78×10^{-3}	4.37×10^{-5}	2.49×10^{-4}	7.30×10^{-4}
S7	4.19×10^{-4}	1.16×10^{-5}	4.61×10^{-5}	1.4×10^{-4}	4.18×10^{-4}	1.37×10^{-5}	7.43×10^{-5}	2.21×10^{-4}
S8	1.76×10^{-3}	2.79×10^{-5}	1.07×10^{-4}	3.35×10^{-4}	1.75×10^{-3}	3.30×10^{-5}	2.07×10^{-4}	6.02×10^{-4}
S9	1.98×10^{-3}	5.58×10^{-5}	2.52×10^{-4}	6.70×10^{-4}	1.98×10^{-3}	6.59×10^{-5}	3.43×10^{-4}	9.59×10^{-4}

S1–S9, sampling location; TCR, total cancer risk; ILCR, incremental lifetime cancer risk; SD, standard deviation

sediment is possible through exchange or specific absorption, but the process of precipitation is also an important mechanism in the retention of metal in contaminated sediments (Sundaray, Nayak, Lin, *et al.*, 2011). The higher concentration of PTEs and exposure risk, thus, obtained were due to the gathering of lubricants, ongoing construction work on the highway, automobile exhaust, and coal mines. The higher carcinogenic risk for adults than children was found at S9 (Ghosh and Maiti, 2019).

Table 8 Cancer risk and sensitivity assessment of children and adults using probability distribution across India and the world

Sl No.	Location	Type	Child				Adult				References
			90%	Mean	SD	Sensitivity (%)	90%	Mean	SD	Sensitivity (%)	
1	Punta Mala Bay	Sediment	1.80×10^{-5}	9.68×10^{-6}	1.21×10^{-4}	Cssed – 50.3 ED – 49.2	2.09×10^{-5}	1.04×10^{-5}	4.72×10^{-5}	Cssed – 51.1 ED – 47.9	Guzmán and Jiménez (1992)
2	Toro point, Panama	Sediment	8.86×10^{-6}	4.06×10^{-6}	1.85×10^{-5}	Cssed – 66.1 ED – 33.6	9.85×10^{-6}	4.85×10^{-6}	2.95×10^{-5}	Cssed – 66.9 ED – 32.3	Guzmán and Jiménez (1992)
3	Galeta, Panama	Sediment	7.46×10^{-6}	3.46×10^{-6}	2.75×10^{-5}	Cssed – 69 ED – 30.6	7.5×10^{-6}	3.75×10^{-6}	3.98×10^{-5}	Cssed – 69.6 ED – 29.8	Guzmán and Jiménez (1992)
4	Payardi, Panama	Sediment	7.75×10^{-6}	3.45×10^{-6}	1.32×10^{-5}	Cssed – 71.5 ED – 28.1	9.19×10^{-6}	4.84×10^{-6}	3.58×10^{-5}	Cssed – 70.9 ED – 28.5	Guzmán and Jiménez (1992)
5	Puerto Portete, Costa Rica	Sediment	1.02×10^{-5}	4.75×10^{-6}	2.28×10^{-5}	Cssed – 67.7 ED – 31.7	1.18×10^{-5}	5.77×10^{-6}	5.45×10^{-5}	Cssed – 67.4 ED – 31.9	Guzmán and Jiménez (1992)
6	Punta Piuta, Costa Rica	Sediment	9.12×10^{-6}	3.91×10^{-6}	1.36×10^{-5}	Cssed – 68.9 ED – 30.6	1.07×10^{-5}	4.77×10^{-6}	2.04×10^{-5}	Cssed – 70.7 ED – 28.6	Guzmán and Jiménez (1992)
7	Cienaga Grande	Sediment	8.16×10^{-6}	3.64×10^{-6}	1.3×10^{-5}	Cssed – 71.3 ED – 28.4	9.19×10^{-6}	5.35×10^{-6}	5.92×10^{-5}	Cssed – 69.2 ED – 30.2	Perdomo, Ensminger, Espinosa, et al. (1999)
8	Clean Mangrove	Sediment	1.63×10^{-6}	8.6×10^{-7}	5.07×10^{-6}	Cssed – 82.4 ED – 17.1	1.95×10^{-6}	1.32×10^{-6}	2.21×10^{-5}	Cssed – 81.8 ED – 17.7	Shafie, Aris, Zakaria, et al. (2013)
9	Zhenjiang, China	Sediments	1.23×10^{-4}	6.88×10^{-5}	9.87×10^{-4}	Cssed – 55.1 ED – 44.4	1.43×10^{-4}	1.83×10^{-4}	1.05×10^{-2}	Cssed – 55 ED – 44.1	Zhu, Bian and Li (2008)
10	Shanghai, China	Roadside dust	4.38×10^{-5}	1.90×10^{-5}	7.34×10^{-5}	Csdust – 76 ED – 23.6	5.02×10^{-5}	2.46×10^{-5}	1.31×10^{-4}	Csdust – 76.5 ED – 23.1	Shi, Chen, Xu, et al. (2008)
11	Hangzhou, China	Sediments	2.41×10^{-5}	1.05×10^{-5}	4.19×10^{-5}	Cssed – 71.7 ED – 27.8	2.74×10^{-5}	1.65×10^{-5}	2.64×10^{-4}	Cssed – 72 ED – 27.4	Zhang and Hao (2009)
13	Bida, Nigeria	Sediment	4.95×10^{-6}	3.58×10^{-6}	1.21×10^{-4}	Cssed – 71.6 ED – 28.1	5.6×10^{-6}	5.37×10^{-6}	2.63×10^{-4}	Cssed – 71.3 ED – 28.1	Yisa (2010)
14	Beijing, China	Sediment	9.09×10^{-6}	4.02×10^{-6}	2.42×10^{-5}	Cssed – 67.4 ED – 32.3	9.90×10^{-6}	8.47×10^{-5}	7.37×10^{-3}	Cssed – 67.8 ED – 31.8	Chen, Xia, Zhao, et al. (2010)
15	Nigeria	Sediments	2.52×10^{-5}	1.22×10^{-5}	9.71×10^{-5}	Cssed – 59.1 ED – 40.3	2.86×10^{-5}	1.57×10^{-5}	1.39×10^{-4}	Cssed – 58.6 ED – 40.6	Yisa, Jacob, and Onoyima (2011)

Sl No.	Location	Type	Child				Adult				References
			90%	Mean	SD	Sensitivity (%)	90%	Mean	SD	Sensitivity (%)	
16	Iran	Sediments	1.3×10^{-5}	7.8×10^{-5}	7.28×10^{-3}	Cssed – 58.9 ED – 40.2	1.49×10^{-5}	7.15×10^{-6}	3.16×10^{-5}	Cssed – 60 ED – 39.3	Moore, Attar, and Rastmanesh (2011)
17	Australia	Sediments	1.14×10^{-5}	8.76×10^{-6}	7.84×10^{-5}	Cssed – 86.7 ED – 12.7	1.3×10^{-5}	1.17×10^{-5}	1.53×10^{-4}	Cssed – 86.8 ED – 12.9	Pratt and Lottermoser (2007)
18	Dhanbad, Bokaro	Sediment	1.82×10^{-5}	1.04×10^{-5}	9.36×10^{-5}	Cssed – 69.1 ED – 30	2.09×10^{-5}	1.45×10^{-5}	2.22×10^{-4}	ED – 69.3 Cssed – 29.3	Singh (2011)
19	Beijing, China	Roadside dust	1.9×10^{-5}	9.46×10^{-6}	7.44×10^{-5}	Csdust – 73 ED – 26.4	2.19×10^{-5}	1.09×10^{-5}	9.31×10^{-5}	Csdust – 73.5 ED – 25.7	Du, Gao, Zhou, <i>et al.</i> (2013)
20	Indian Suburban	Sediment	1.42×10^{-5}	6.83×10^{-6}	5.80×10^{-5}	Cssed – 72.3 ED – 27.4	1.71×10^{-5}	9.11×10^{-6}	5.67×10^{-5}	Cssed – 73 ED – 26.4	Chowdhury and Maiti (2016)
21	Present study	Sediment	2.74×10^{-5}	1.31×10^{-5}	6.3×10^{-5}	Cssed – 49.5 ED – 50.1	3.24×10^{-5}	1.55×10^{-5}	5.31×10^{-5}	Cssed – 49 ED – 50.3	

Cssed, concentration of metals in sediments; ED, exposure duration; SD, standard deviation

CONCLUSIONS

The pollution load index study highlights the high pollution load in the sites as follows: S8 > S9 > S5 > S6 > S4 > S1 > S3 > S2 > S7; these sites are surrounded by coal mines, hard coke and steel industries, and brick kilns, which aggravate the high traffic density. The hazard risk assessment via two pathways was represented by the contour map that reveals S4, S5, S6, and S9 to have a higher risk value. The hazard quotient via ingestion was found more compared to the HQ of dermal for children and adults in both sediment and run-off. In the run-off, the highest risk value for children was found at S9 while for adults, it was at S5. In the case of sediment, high values for children were obtained at S5 followed by S6 and for adults at S5 followed by S4. The high risk values in these areas could be due to dense population, heavy traffic, wear and tear of tyres, lubricating oil, brake oil leakage, and so on. The Monte Carlo simulation was performed on the carcinogenic risk value from PTE concentration and it was observed that the 90% risk value in run-off was higher than the sediment. This can be explained by anthropogenic activities, industrial pollutants present transversely along the NH-2, oil spills, and other vehicular contaminants. The ED contributed more to the carcinogenic risk values, which are evident from the sensitivity charts in case of both sediments and run-off. The mean value of lifetime cancer risk showed higher risk values for adults than children because adults have a higher exposure to contaminants compared to children. The particular study areas are highly contaminated by PTEs. The authorities must implement strict remedial measures to reduce the cancer risk pertaining to these areas. Areas such as Raniganj, Sanjay Check Post, and ADDA need special attention as these areas are more prone to cancer risks.

ACKNOWLEDGEMENT

The author is grateful to Professor S.K. Gupta, Head of Department, Indian Institute of Technology (Indian School of Mines) Dhanbad, Jharkhand, for his kind support and encouragement to carry out this study.

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Assessment of Environmental Sustainability of Maritime Sector

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TERI Information Digest on Energy and Environment 18(4): 397–414

ABSTRACT

The maritime sector has a vital role to play as an indispensable element in terms of socio-economic development and as a potential source of excellent employment opportunities, with several million people currently engaged in activities and companies directly and indirectly related to oceans and seas worldwide. The prime objectives of the study are to review the activities and the potential of the maritime sector both globally and nationally. The study further assesses environmental impacts from ships, including past, present, and future fuel consumption and emission status. It also proposes some strategies for emission control for sustainable growth of the sector.

The global CO₂ emissions from shipping estimated based on bunker sales were about 270 Tg (CO₂) in 1955 and 600 Tg in 2005. The corresponding SO₂ emissions were approximately 3.8 Tg in 1955 and 8.0 Tg in 2005. The study reveals that ship emissions might affect the levels of ozone, sulfate, nitrate, NO₂, NMVOCs, SO₂, and OH, which may potentially cause problems in coastal areas and harbours. Under these circumstances, this article reviews the status of pollution control measures in the shipping sector. Moreover, the need to understand the global ecosystems and environment, as well as their necessary conservation, to find the more efficient mechanisms to deal with phenomena such as climate change, and so on have made research and study of the maritime environment a high priority issue. In addition, the maritime transportation sector has its share of responsibility to reduce carbon emission and take corrective and innovative measures on a global scale to minimize energy usages.

Keywords: Maritime sector, Environmental impact, Sustainability, Emission control

INTRODUCTION

The maritime sector is of crucial importance to modern societies. It has a vital role to play as an indispensable element in terms of socio-economic development and as a potential source of excellent employment opportunities, with several million people currently engaged in activities and companies directly and indirectly related to oceans and seas worldwide. Historically, the shipping and fishing industries have experienced continuous growth in fleets, total trade volume, and fishing capacity.

Shipping in the maritime sector has long been the major form of transportation as well as an essential communication link connecting coastal cities, countries, and continents. Next to rail transportation, water transportation is economically and environmentally the most efficient way to travel or transport merchandise. Now around 90% of the world trade is carried by the international shipping industry.

Around 50,000 merchant ships, registered in over 150 nations and manned by over a million seafarers of nearly every nationality, transport every kind of cargo internationally.¹ Several thousand oil rigs and offshore support and supply vessels are engaged in the exploration and drilling of oil and gas in almost every corner of the globe. Nearly four million commercial fishing vessels ply the seas and oceans at any given moment. A myriad of recreational ships (with approximately 45,000 privately owned ships operating out of the United States in December 2010), including several hundred large and mega cruise ships, offer the most diversified leisure and tourism services to an expanding market.²

In parallel to the amazing increase in the traditional sea-related activities, the maritime sector has witnessed a significant qualitative and quantitative expansion with the appearance and development of organizations and activities such as maritime transportation, the naval industry (naval engineering and shipbuilding companies and the component supply sector), commercial fishing and aquaculture industry, the cruise and recreational sector, sport and commercial ports and marinas, marine energy sources, navies, marine and ocean research and sciences, maritime training academies and training centres, a wide range of professional services around the maritime activities, and professional associations, trade unions, and organizations supporting the rights and interests of seafarers and maritime professionals.

OBJECTIVES OF THE STUDY

The main objectives of the study are to review the activities and the potential of the maritime sector both globally and nationally. The study further assesses environmental impacts of ships, including past, present, and future fuel consumption and emission status. Moreover, the study elucidates the global impact of the maritime sector and proposes some emission control strategies for the sustainable growth of the sector. Finally, for the sustainability of the maritime sector, it highlights policy implications at global and national levels.

MARITIME SECTOR: GLOBAL AND NATIONAL SCENARIO

The global maritime sector, supported in the 20th century by the economies of the North America and Western Europe, has seen strong growth over the last four decades, despite the worldwide

¹ Details available at <http://www.ics-shipping.org>, last accessed on 27 January 2020

² Details available at <http://www.windrosenetwork.com>, last accessed on 27 January 2020

economic recession of the early 1980s and the financial crises of the late 1990s and 2007,³ from just over 8000 billion ton-miles in 1968 to over 40,000 billion ton-miles in 2010. It is expected to witness further growth in the coming decades owing to the increasing demand of the emerging economies of China and India, with the subsequent rise in the level of maritime activities and the economic value and impact they represent.

The Indian port and shipping industry plays a vital role in sustaining the growth of the country's trade and commerce. There are two geographical factors that put the Indian maritime sector at an advantageous position. They are the vast coastline of 7500 km and the strategic location along most major shipping highways.⁴ For years, the maritime routes have been used for trade and a show of strategic strength. Today, the country boasts of a modern shipbuilding and shipping sector, with all the variables necessary for overall industrial growth. These factors provide a strong basis to attract big investments in the Indian maritime sector. In fact, the sector has a huge potential to become, the engine of growth for India.

India is the 16th largest maritime country in the world, with a coastline of about 7517 km. It has 12 major ports and 187 non-major ports. According to the Ministry of Shipping, around 95% of India's trading is by volume and 70% by value is done by maritime transport.⁵ Cargo traffic, which was recorded at 1.052 MMT (million metric tons) in 2015, reached 1.758 MMT by 2017 and 2.464 MMT in 2019. The Indian government plays a pivotal role in supporting the port sector and it has allowed foreign direct investment up to 100% under the automatic route for port and harbour construction and maintenance projects.

The government has launched a number of major initiatives, such as the Sagarmala project, modernization of ports, and development of inland waterways and coastal shipping. The increasing public-private partnership in response to these initiatives adds to the vibrancy of the sector and is a clear sign of resurged interest in its potential. Increased investments together with the 'Make in India' momentum can increase the sector's contribution to GDP and trade volumes. While the positive signs of progress in the sector have opened up immense opportunities, they have also exposed bottlenecks to progress. It is crucial to unblock these bottlenecks and capitalize on the opportunities to give direction to the country's maritime sector.

ENVIRONMENTAL POLLUTION IN MARITIME SECTOR

Generally, ship emissions are calculated by quantifying the fuel consumption from power production and then multiplying the consumption by emission factors (Endresen, Eide, Dalsøren, *et al.*, 2008). Emission of volatile organic compounds (VOCs) from oil cargo handling is exempted from this general approach. There are mainly two different bottom-up approaches to calculate the fuel consumption. The worldwide bunker sales per country and transport mode may be summed to determine shipping consumption. The other approach models the fleet activity and estimates the consumption resulting from this activity (summing up per ship/segment).

According to Endresen, Sørsgard, Sundet, *et al.* (2003), calculated emissions can be distributed based on global traffic data. Alternatively, as per Whall, Cooper, Archer, *et al.* (2002), Endresen, Sørsgard, Sundet, *et al.* (2003), and Dalsøren, Endresen, Isaksen, *et al.* (2007), geographically resolved emission inventories can be developed directly by calculating emissions for individual

³ See Footnote 2

⁴ Details available at <http://www.forbesindia.com>, last accessed on 27 January 2020

⁵ Details available at <https://www.ibef.org>, last accessed on 27 January 2020

ship movements on defined trades. Based on Lawrence and Crutzen (1999), Capaldo, Corbett, Kasibhatla, *et al.* (1999), Endresen, Sørsgard, Sundet, *et al.* (2003), and Dalsøren, Endresen, Isaksen, *et al.* (2007), the geographically resolved emission inventories can then be used to assess regional and global impacts of ship emissions. For detailed methodology for constructing ship emission inventories, refer to EMEP/CORINAIR (2002).

The annual fuel consumption by fleet is significantly affected by demand for sea transport, technical and operational improvements, and changes in the fleet composition (Endresen, Sørsgard, Behrens, *et al.*, 2007). During the last century, as the fleet expanded by 72,000 motor ships to a total of 88,000 in the year 2000, the total fuel consumption and emissions from the ocean-going civil world fleet increased significantly. The corresponding increase in gross tonnage (GT) was from 130 million GT in 1960 to 558 million GT in 2000 (Endresen, Eide, Dalsøren, *et al.*, 2008) (Figure 1). This growth has been driven by increased demand for passenger and cargo transport, from 300 Mt (million tons) cargo transported in 1920 (Stopford, 1997) and 5400 Mt in 2000 (Fearnleys, 2002). The present world fleet is mostly diesel powered. In the year 2007, there were about 96,000 ships above 100 GT (LRF, 2007), of which cargo-carrying ships (including passenger ships) accounted for roughly 50%. The other half was employed in non-trading activities, such as offshore supply, fishing, and general services (e.g., towage, surveying).

The ocean-going civil world fleet gradually shifted from sail around 1870 to a full engine powered fleet around 1940 (LR, 1961, 1984; Stopford, 1997). Till around 1920, coal-fired steamships dominated (Fletcher, 1997). Owing to the shift to diesel engines and oil fired steam boilers, there was gradual replacement of coal by marine oils (Figure 2). The shift to modern marine diesel engines has taken over 100 years. In 1961, there were still over 10,000 steam engine powered ships and 3536 steam turbine powered ships in operation (36% by number) (LR, 1961). As modern diesel engines consume about half the daily fuel compared to that of the old inefficient steam engines with the same power out-take, the shift to diesel needs to be considered for historical estimates of fuel consumption (Endresen, Sørsgard, Behrens, *et al.*, 2007).

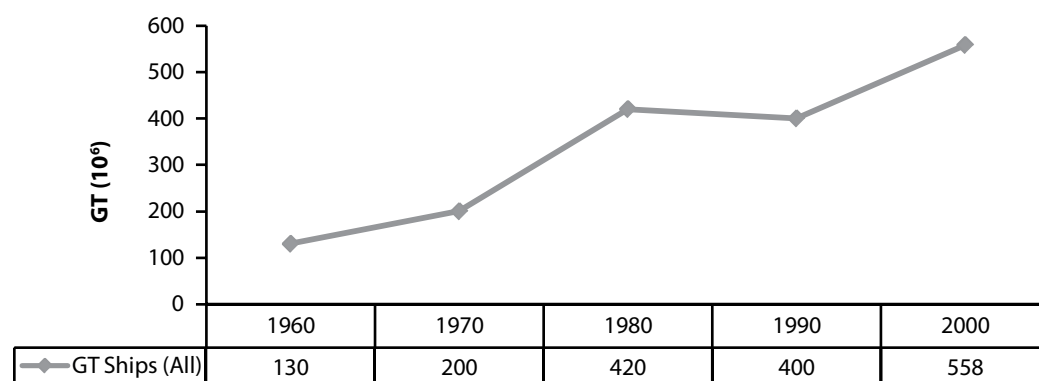


Figure 1 Status of world fleet of ocean-going civil vessels above or equal to 100 GT

Note: Military fleet is not included here

Source: Data from Lloyd's Register of Shipping (Endresen, Eide, Dalsøren, *et al.*, 2008)



Figure 2 Shift of coal to diesel in world's total merchant fleet (exclusive of sailing ships) using the specified form of motive power

Source: Fletcher (1997)

From 1870 to 1910, transport by steamers grew from 15% of the tonnage to 75% (Stopford, 1997), owing to the shift from sail to steam ships. At the turn of the century, more than 50% of the British coal exports were ultimately used for ship transportation (Fletcher, 1997). The amount of coal

burnt by ships exporting British coal was 21 Mt in 1913. About 270,000 tons of coal was consumed by transporting ships for every million tons of coal delivered abroad (Fletcher, 1997). This includes only the total amount of British coal consumed by vessels refilling at UK ports and not the total amount of British coal consumed by the world fleet. About 64% of the British coal export (94.4 Mt for 1913) was used as bunkers for ships (60 Mt) and Britain supplied 75% of the coal consumed as bunkers by all ships in the world fleet. The estimated coal sales and CO₂ emissions, assuming 2.58 CO₂ per ton fuel, are given in Table 1 (SNAME, 1983; Endresen, Sørsgard, Behrens, *et al.*, 2007). Endresen, Eide, Dalsøren, *et al.* (2008) found that the sales to shipping increase by a factor of about 7 from 1870 to 1913 (Table 1). As the tonnage with steamers increased by a factor of 6 from 1870 to 1910, the estimates may be reasonable. The estimated CO₂ emissions in 1913 were more than six times higher than those in 1870.

Table 1 Estimated global coal bunker sales based on quantity of coal (Mt) leaving ports of United Kingdom

Year	Exported as cargo	Shipped as bunker fuel ^a	Total export	Estimated		CO ₂ emissions (Mt)
				Bunker sale ^b in UK	Total bunker sale ^c	
1870	10.2	3.2	13.4	8.6	11.4	30
1880	17.9	4.9	22.8	14.6	19.5	50
1890	28.7	8.1	36.8	23.6	31.4	81
1900	44.1	11.8	55.9	35.8	47.7	123
1913	73.4	21.0	94.4	60.0	80.0 ^d	206

Source: Fletcher (1997)

^aEngaged in foreign trade

^b64% of the annual British coal export used by shipping

^cAssuming that Britain supplied 75% of the coal consumed as bunkers by all ships in the world fleet

^dReported by Annin (1920) based on estimates by the United States Shipping Board

Endresen, Sørsgard, Behrens, *et al.* (2007) made fuel-based estimates from 1970 to 2000 for each year (Figure 3). They suggested that fuel-based estimates based on sales for the past fuel consumption and emissions should consider variation in the demand for sea transport and operational and technical changes over the years in order to better quantify the real fuel consumption and corresponding emissions. As per the results, the yearly fuel consumption by ocean-going ships was of about 80 Mt of coal (corresponding to 56.5 Mt of heavy fuel oil) before the First World War. This increased to a sale of about 200 Mt of marine fuel oils in 2000, including the fishing fleet, which was about a 3.5-fold increase in fuel consumption. Of this, international shipping accounted for some 70–80%. On the basis of the estimated fuel sale, Endresen, Sørsgard, Behrens, *et al.* (2007) modelled the historical CO₂ and SO₂ emissions from shipping (Figures 4 and 5). It revealed that global ship CO₂ emission in 1870 was 30 Tg (CO₂), which increased to about 206 Tg (CO₂) in 1913. The major development during this period was the transition from sail to steam-powered ships. Based on the sales of bunkers, global ship CO₂ emissions were estimated to be 229 Tg in 1925, about 270 Tg in

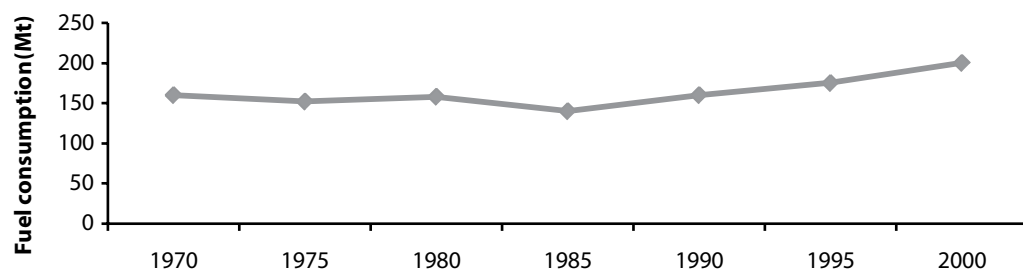


Figure 3 Reported estimate of fuel consumption

Source: Endresen, Sjørgard, Behrens, *et al.* (2007)

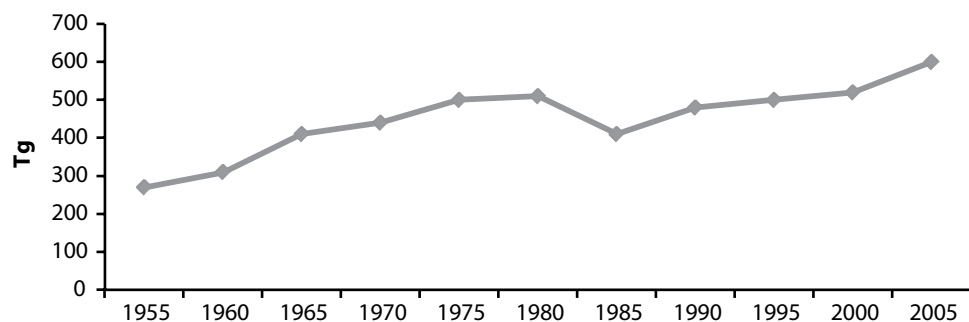


Figure 4 CO₂ ship emissions based on estimated sales of the marine fuel

Note: The fishing and military fleet is also included.

Source: Endresen, Sjørgard, Behrens, *et al.* (2007)

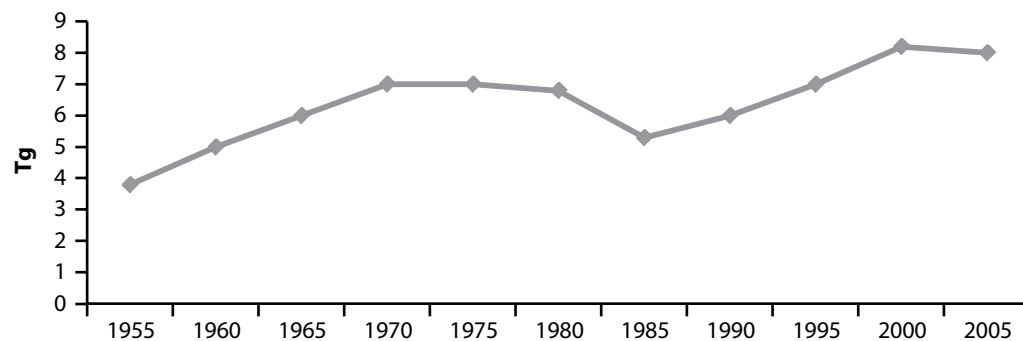


Figure 5 SO₂ ship emissions based on estimated sales of marine fuel

Note: The fishing and military fleet is also included.

Source: Endresen, Sjørgard, Behrens, *et al.* (2007)

1955, and 600 Tg in 2005. The corresponding SO₂ emissions were approximately 2.5 Tg in 1925, about 3.8 Tg in 1955, and 8.0 Tg in 2005. During this period, the major development was the transition to diesel-powered fleet.

IMO (2000) estimated CO₂, NO_x, and SO_x emissions, which were based on an estimate of marine bunker fuel consumption and a statistical model, and found that ocean-going vessels

accounted for about 1.8% of the total global CO₂ emissions in 1996 (Han, 2010). Corbett and Koehler (2003) and Eyring, Kohler, van Aardenne, *et al.* (2005) produced substantially higher estimates of emissions from international maritime vessels. They found that international marine vessels accounted for about 30% of global NO_x emissions from all sources and 9% of global SO_x emissions. The summarized previous studies on fuel consumption that estimated emissions from international ships are given in Table 2.

Table 2 Fuel consumption and emission from international shipping

Source	Fuel consumption	NO _x	SO _x	PM	(Over 100 GT, MMT)	
					CO ₂	Inventory year
Eyring, Kohler, van Aardenne, <i>et al.</i> (2005)	280	21.4 (29%)	12 (9%)	1.7	813 (3%)	2001
Corbett and Koehler (2003)	289	22.6 (31%)	13 (9%)	1.6	912 (3%)	2001
Endresen, Sørsgard, Sundet, <i>et al.</i> (2003)	158	12 (17%)	8 (5%)	0.9	501 (2%)	2000
IMO (2000)	120–147	10 (14%)	5 (4%)	–	419 (1.5%)	1996

Source: Han (2010)

Another approach, proposed by Fearnleys (2006), is to extrapolate the growth in transport work (ton-miles). For historic data (LRF, 2007), transport work is linearly correlated with installed fleet power (correlation coefficient higher than 0.95). Assuming this linear correlation is valid also for the future, estimates for future fleet power are obtained by the extrapolated values for transport work by the same linear function. If the extrapolation is based on the growth trend in transport work from 2002 to 2005, the growth in installed fleet power to 2020 will be 64%; if the extrapolation is based on the growth trend from 1995 to 2005, the growth to 2020 would be 33%. However, again, due to high growth in the transport activity in recent years, use of short regression periods leads to high estimates. In all, these methods suggest a best guess growth of approximately 30% in emissions towards 2020.

Fuel consumption and emissions were calculated for the years 2025 and 2050 based on estimates of IPCC A1 and A2 scenarios (Endresen, Eide, Dalsøren, *et al.*, 2008). The model estimates for 2050 reveal that for the fuel consumption between 453 and 810 Mt, emissions from the maritime fleet were 1308–2271 Tg for CO₂, 17–28 Tg for NO_x, and 2–12 Tg for SO₂. The results of CO₂ emissions are shown in Figures 6 and 7. Scenario A1B and Scenario A2 give the highest and lowest CO₂ estimates, respectively. This conforms to the results for fuel consumption, for which A1 gives the highest estimate and A2 gives the lowest. These results imply that by adopting the ranges of A1 and A2 scenarios, ships in 2050 will account for significantly higher share of world anthropogenic CO₂ emissions compared to the existing 2–3%. While CO₂ emission and fuel consumption reduction in the scenarios is mainly dependent on improved technical and operational conditions, alternative fuels, and propulsion systems, additional reduction in NO_x and SO₂ emissions (and other exhaust compounds) can be achieved via specific emission reduction measures (e.g., after-treatment of exhaust gases).

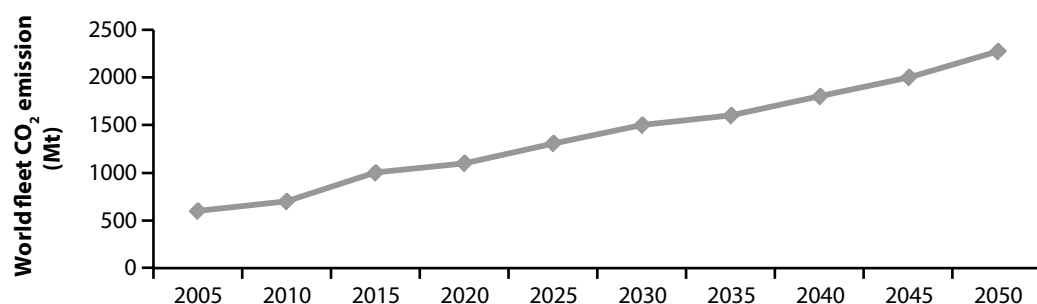


Figure 6 World fleet CO₂ emissions based on IPCC A1B Scenario and extrapolation of trends giving 30% growth by 2020

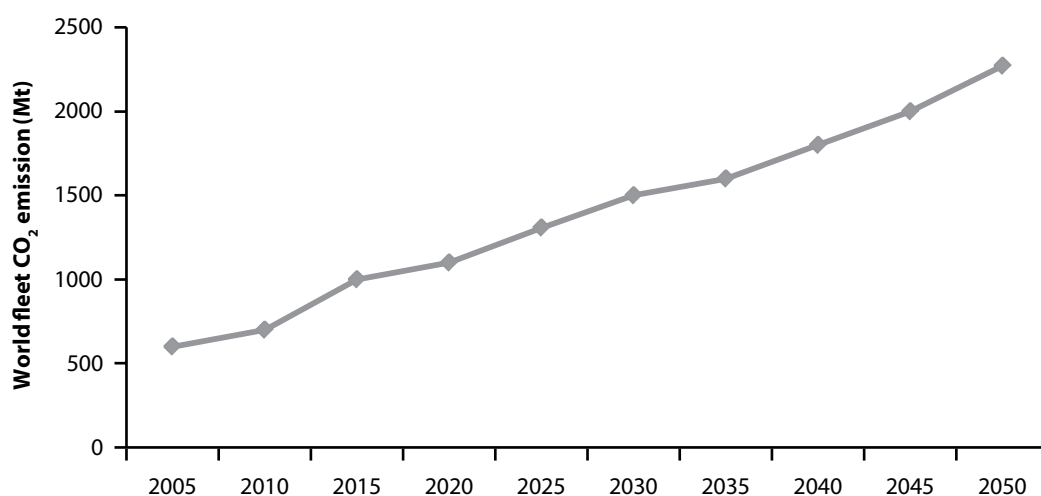


Figure 7 World fleet CO₂ emissions based on IPCC A2 Scenario and extrapolation of trends giving 30% growth by 2020

GLOBAL ENVIRONMENTAL IMPACT OF MARITIME SECTOR

Pollutants emitted to air from ship are often chemically transformed to secondary species. Mixing with ambient air takes place and dry deposition or rainout occurs. Ship emissions might affect the levels of ozone (causing climate change, adverse impact on health), sulfate (causing acidification, climate change, adverse impact on health), nitrate (causing acidification, eutrophication), NO₂ (increasing pollution, ozone precursors, nitrate), NMVOCs (polluting environment, ozone precursors), SO₂ (environmental pollution, sulfate precursor), OH and its effect on methane (causing change in climate condition), and aerosols (causing pollution, climate change) (Endresen, Eide, Dalsøren, *et al.*, 2008).

Accordingly, outcomes were reviewed from various research studies on models, for example, global and regional chemical transport models (CTMs) to calculate some of the above-mentioned compounds, weather prediction models or climate models for CTM calculation using meteorological data (winds, temperature, precipitation, clouds, etc.) as inputs, satellite observations to assess NO_x concentrations along major shipping lanes, and chemical box model to understand subgrid-scale processes taking place within fresh undiluted plumes and during the first stages of dilution

(Kasibhatla, Levy II, Moxim, *et al.*, 2000; Song, Chen, Hanna, *et al.*, 2003; von Glasow, Lawrence, Sander, *et al.*, 2003; Beirle, Platt, von Glasow, *et al.*, 2004; Richter, Eyring, Burrows, *et al.*, 2004; Chen, Huey, Trainer, *et al.*, 2005). It is possible that some models might overestimate the effects of ship emissions on the NO_x , OH, and ozone budget and one way to overcome this issue is to multiply with a reduction factor (effective emission) or introduce plume chemistry in the global models.

Primary components, such as CO , NO_2 , NMVOCs, and SO_2 , may potentially cause problems in harbours and coastal areas with heavy traffic because of their impact on human health at high concentrations (Saxe and Larsen, 2004; U.S. EPA, 2003). Secondary species formed from the effluents in the ship emissions are transported in the atmosphere and contribute to air quality problems on land. This is applicable for ozone and the deposition of sulfur and nitrogen compounds, causing acidification of natural ecosystems and freshwater bodies and threatening biodiversity through excessive nitrogen input (eutrophication) (Vitousek, Aber, Howarth, *et al.*, 1997; Bouwman, van Vuuren, Derwent, *et al.*, 2002; Galloway, Dentener, Capone, *et al.*, 2004).

NO_2 is found close to the regions with heavy traffic around the North Sea and the English Channel. Studies undertaken by Lawrence and Crutzen (1999), Endresen, Sørsgard, Sundet, *et al.* (2003), Dalsøren, Endersen, Isaksen, *et al.* (2007), and Eyring, Stevenson, Lauer, *et al.* (2007) found NO_2 to be more than doubled along the major world shipping lanes.

Ozone is regarded as the third major greenhouse gas (GHG) contributing to warming since the pre-industrial era (Ramanathan, Crutzen, Kiehl, *et al.*, 2001). For ozone formation, the abundance of NO_x ($\text{NO} + \text{NO}_2$) is crucial, but the number of ozone molecules formed is also dependent on CO and NMVOCs. Exposure to high ozone levels leads to the aggravation of existing respiratory problems, such as asthma, increased susceptibility (infections, allergens, and pollutants), inflammation, chest pain, and coughing (Mauzerall and Wang, 2001; U.S. EPA, 2003; WHO, 2003; HEI, 2004). Repeated long-term exposure could possibly lead to premature lung aging and chronic respiratory illnesses, such as emphysema and chronic bronchitis. Elevated ozone levels during the growing season may result in reductions in agricultural crops and commercial forest yields, reduced growth, increased susceptibility for disease, and visible leaf damage on vegetation (Emberson, Ashmore, Murray, *et al.*, 2001; Mauzerall and Wang, 2001).

INITIATIVES FOR SUSTAINABLE DEVELOPMENT

There has been steady expansion of maritime activities as a result of growing efficiency of technical and human resources. The merchant navy, offshore oil sector, commercial fishery, and cruise companies are part of the industry of the future, and the maritime sector is already a key catalyst for socio-economic development and international competitiveness in a changing world, with new companies and organizations emerging and establishing operations in Europe, Asia, and North America.

Emissions control options for marine vessels can generally be classified into three categories (Han, 2010). They include replacing or upgrading old, less efficient, or high polluting engines with more efficient and lower emitting propulsion systems to reduce both local and global emissions, undertaking operational changes to reduce local emissions by modifying how vessels operate while entering and docking in the harbour, and implementing market-based programmes, such as variable port fees and emissions trading. These are discussed in detail as follows:

- I. Technological strategies:* The lack of adequate pollution control regulation for engines and vessels and low fuel quality have led to the poor performance of the marine sector with respect to air emissions. Strategies for reducing ship emissions, such as the use of a lower sulfur fuel for engine improvement and exhaust after-treatment, have been demonstrated in ocean-going vessel types. The focus is on reducing NO_x or SO_x emissions because they are currently the only internationally regulated ship air pollutants. NO_x emissions can be reduced by upgrading engines aimed at reducing combustion temperatures, for example, adding water at different stages of the combustion process or re-circulating exhaust gas. NO_x reduction can also be achieved by the use of exhaust after-treatment such as selective catalytic reduction (SCR). Reduction in SO_x emission can be achieved by adopting strategies, such as switching to lower sulfur marine fuels and using seawater scrubbing. These strategies can also help reduce PM emissions substantially. Vessels use auxiliary engines and sometimes main engines for heating, cooling, and electricity, as well as loading and unloading when they are docked at the port. Emissions produced at dock, called hotelling emissions, contribute significantly to local emission inventories and pose potential health risks due to harmful pollutants. Three strategies have been proposed to reduce local emissions. They include the use of lower sulfur alternative fuels in auxiliary engines, electrification with a shore-based power supply, and shore-based emission treatment. Compared to the heavy fuel oil, the use of lower sulfur marine diesel oil or pure distillate marine gas oil (MGO) can significantly reduce SO_x and PM.
- II. Operational strategies:* Although technology improvements can help reduce emissions under cruising and hotelling conditions, most operational changes for emission reduction mostly focus on measures taken while ships are at the port. The potential emission reductions from operational changes can improve local air quality and reduce the exposure of nearby population to harmful pollutants. When ships are operated under port jurisdiction, port operators have to use specific control technologies, such as cold ironing and the use of low sulfur fuels, and other emission control technologies. There is often intense competition between ports to capture as much cargo as their capacity permits. This makes local ports reluctant to implement local environmental requirements as it will put them at a disadvantage relative to other nearby ports. Despite concerns for competitiveness and lack of national or international consensus on controlling ship emissions, several ports have adopted local pollution control measures, including operational changes.
- III. Market-based strategies:* Besides regulatory measures, market-based strategies should also be considered to reduce environmental impacts of the shipping sector. Emission reduction programmes based on market incentives or structured for variable industry responses allow shipping companies to tailor compliance actions. These approaches can help maintain optimum balance between technology and operational controls. Market-based programmes can be implemented locally by imposing variable fees designed to reward low-emission and high-efficiency vessels and conversely penalize high-emission and low-efficiency vessels or internationally through an emission cap-and-trade system.

Voluntary differentiation in port dues is a successful market-based approach to reduce air pollution from ship. Here, less polluting ships are eligible for reduction in fairway and port dues in participating ports. Baseline dues are levied proportional to the gross tonnage of each vessel. Individual vessels can qualify for reduction in baseline dues based on their emission performance. As the programme was devised with a focus on revenue neutral, baseline fairway dues were first increased to create room for fee reductions without an overall loss of revenues. The assessment of reduction in the fee for NO_x performance is based on vessel emissions in grams per kilowatt-hour (g/kWh), and it is carried out by an independent body. Fee reduction in case of SO_x performance is determined based on the sulfur content of the fuel used. Currently, the maximum reduction in fees is offered to ships emitting 0.5 g/kWh of NO_x or less and using fuel with sulfur content less than or equal to 0.2%.

Another market-based mechanism to reduce GHG emissions is the cap and trade system or emission trading. In this system, economic incentives for achieving reduction in pollutant emissions are provided to control pollution. A central authority, usually a government or international body, sets a limit on the amount of a pollutant that can be emitted. Companies or other groups are issued emission permits and required to hold an equivalent number of allowances or credits, which represent the right to emit a specific amount. Allowances and credits cannot exceed the cap, thus limiting the total emissions to that level. Companies can increase their emission allowance by buying credits from less polluting ones. The transfer of allowances is referred to as trade. The buyer pays a charge for polluting, while the seller is rewarded for having reduced emissions by more than was needed. Cap and trade approach offers flexibility to the industry and allows the market to determine where and how emission reductions can be achieved in the most cost-effective manner. Therefore, this approach has become popular in a variety of regulatory contexts over the last decade. Vessel operators that can reduce emissions less expensively can sell excess emission credits or allowances to vessel operators that would otherwise face higher costs to implement reductions. The mitigation strategies for ships are given in Table 3.

Table 3 Emission mitigation options for ships

Measure type	Measure	Description
Technological strategies	Decrease sulfur fuel	- Marine residual or bunker with sulfur content at 1.5% or below (44% SO_x reduction, 18% PM reduction) - Marine distillate and gas oil with sulfur content at 0.1% or below (>90% SO_x reduction, >80% PM reduction)
	Reduce vessel speed	Speed within harbour is reduced to lower engine load and NO_x production (4-8% reduction)
Operational strategies	Shore-side power	Land-based power for docked ships (100% reduction in at-port emissions)
	Environmentally differentiated fees	- Fee reductions based on vessel environmental performance - Emission benefits depend on the extent of participation and implemented technologies
	Cap and trade mechanism	A government or trade body first sets a limit or 'cap' on the amount of environmental degradation or pollution permitted in a given area and then allows firms or individuals to trade permits or credits to meet the cap

Source: Han (2010)

Maritime Sector and Energy Sustainability

The maritime transportation sector has its share of responsibility to reduce carbon emission and take innovative measures on a global scale to minimize energy use. According to International Maritime Organization (IMO), in the absence of new policies, the total emissions from the shipping sector may increase from 150% (compared to 2007 levels) to 250% as the industry continues to grow. Shipping was estimated to have emitted 870 Mt of CO₂ in 2009, which accounted for 2.7% of all global GHG emissions in the same year. Vergara, McKesson, and Walczak (2012) projected energy consumption and carbon emissions of different marine transportation types in 2050 and applied the model of stabilization wedges to explore activities and technologies to formulate policies that would lead to sustainable marine propulsion. The authors deduced that 3% of the global emissions reduction should result from the maritime sector to keep the temperature under 2°C above the current levels. Technical and operational measures may enhance the sector's energy efficiency, which would help reduce GHG rates between 25% and 75% per ton-kilometre below current levels. Although many of these measures appear to be cost-efficient, non-financial barriers may impact implementation.

It is technically feasible to replace oil-based fuels with renewable energy, such as energy generated via solar cells and wind power. However, the solution is only partial because of uneven intensity and peak power levels of their natural sources. Fuels with lower CO₂ emissions, such as biofuels and liquefied natural gas (LNG), may also be a possible replacement for oil-based fuels. But the use of first-generation biofuels may pose some onboard storage and handling challenges (e.g., plugging of filters, microbial growth) along with issues of limited availability and uncompetitive prices. However, LNG has the best chance of becoming economically viable, principally for ships operating within emission control areas and where LNG is available.

The following measures will help make the maritime sector sustainable:

- Changing to a diverse mix of energy sources, using resources more efficiently and responsibly, and dramatically reducing greenhouse gas intensity
- Providing safe, healthy, and secure work environment in shipping
- Developing financial solutions that reward sustainable performance and enable large-scale adoption of innovation, technology, design, and operational efficiencies

The adoption of suitable technologies to reduce emissions in the maritime sector is long waited.

In India, the government has taken a lot of initiatives to develop and sustain growth of the sector. As part of the government's push to fast-track investment in the sector, a host of business-friendly policies have been introduced ranging from modernizing the existing port infrastructure and creating new ones to promoting green energy, IT development, and developing skills to sustain the operation of the structure. There are clear signs that the Indian maritime sector is set for steady growth. The progress could be faster if the focus is on the following key areas:

- I. *Speedy modernization/improvement of infrastructure*: An efficient intermodal system is vital to the success of a port as it supports seamless movement of cargo across all modes – ship, rail, and truck. A government report reveals that due to poor port infrastructure and productivity, India's trans-shipment cargo is handled at South Asian hubs like Colombo or Singapore, which costs Indian ports around US\$230 million in revenue annually.
- II. *Pursuing 'Make in India'*: The 'Make in India' initiative offers tremendous opportunities in the maritime sector, particularly in shipbuilding and ship repair industry. It plays a strategic role

in tapping all vessel requirements within the country and the benefits of a vibrant shipbuilding industry cannot be overemphasized. A cost-effective and skilled manpower base, established steel industry, technology know-how, and an increased demand in domestic shipbuilding could enhance India's global shipbuilding share from 1% to 5% by 2020.

- III. *Partnerships for technology and manpower with successful maritime countries:* Partnerships and collaborations with successful maritime clusters in areas of ship design, automation, technology, and so on will lead to cost reduction and delivery improvement. Such collaborations can improve efficiency and enhance competitiveness. In the wake of the recent regulations by International Maritime Organization to control emissions from ships, there will be a growing need to collaborate for environment-friendly technologies and solutions, such as LNG-powered vessels. Partnerships and technological assistance of maritime countries will enhance training and development of manpower and expose frontline workforce to world class manufacturing techniques and processes.
- IV. *Active development of maritime clusters:* Clusters induce innovations, create employment opportunities, attract foreign investors, and also encourage new ideas. Major maritime nations practise concepts such as shipbuilding clusters and maritime parks. The government has identified two major maritime clusters in Tamil Nadu and Gujarat similar to the global success stories in Japan and South Korea. These clusters will focus on developing various components of the maritime cluster, such as shipbuilding and ancillary services, maritime services, promoting maritime tourism, and marine products. Given the manufacturing strength, size of ports, and synergies with other steel ancillaries, both the identified maritime clusters can attract business and improve the overall economics for cluster participants.

For the sustainability of the maritime sector, various policy implications may be explored. Increased public awareness of the environmental impact of the routine ship activities will be pivotal to reduce emission. Public relations and education will also play an important role in the mitigation of environmental problems resulting from the shipping industry. Training programmes should also be conducted for all staff to improve and protect the environment. There is a need to examine the actual conditions of environmental pollution from ship and the port area and develop an environmental evaluation scheme for regular monitoring. In this regard, development of green shipping evaluation index can be very useful for shipping companies.

In developed countries, the incentive-based approach for the industry's voluntary participation is preferred over legal regulation to mitigate air pollution in shipping and port sectors. As legal regulations impede the level playing field among shipping companies, monetary incentive or penalty based on the market mechanism is highly recommended in most major shipping countries. One of the common strategies to curb ship emissions in the developed countries is the collaboration between public and private sectors and across a wide number of stakeholders. The best practice should be shared with shipping companies, terminal operators, local residents, and government for addressing both local air quality concerns and global warming.

CONCLUSION

The maritime industry assumes huge importance in terms of natural resources and energy, trade and industry, sciences, and leisure activities. Shipping activity has increased significantly over the last century and it is currently a major contributor to global emissions of pollutants and greenhouse

gases. Despite this, information about the historical development of energy consumption and emissions is limited, with little data published pre-1950 and large deviations in estimates covering the last three decades. It is difficult to quantify the total value of the world maritime industry and the economic relevance of the sector that affects a wide range of aspects of modern societies and their development.

During the last century, as the fleet expanded by 72,000 motor ships to a total of 88,000 in the year 2000, the total fuel consumption and emissions from the ocean-going civil world fleet increased significantly. The corresponding increase in gross tonnage was from 130 million GT in 1960 to 558 million GT in 2000.

Although ocean-going vessels are considered as the most environmental-friendly transport mode, they generate substantial quantities of greenhouse gases. As discussed previously, global ship CO₂ emission in 1870 was 30 Tg, which increased to about 206 Tg in 1913. The major development during this period was the transition from sail to steam-powered ships. Global ship CO₂ emissions estimated based on sales of bunkers were 229 Tg in 1925, about 270 Tg in 1955, and 600 Tg in 2005. The corresponding SO₂ emissions were approximately 2.5 Tg in 1925, about 3.8 Tg in 1955, and 8.0 Tg in 2005. The main developments during this period were the replacement of coal by oil and the transition to a diesel-powered fleet.

Pollution emissions from international ocean-going vessels already have a significant impact on air quality and public health, especially in coastal communities. Moreover, emissions from the shipping sector are expected to continue to grow strongly as the global economy expands and as international trade plays an ever larger role. As progress is made in reducing emissions from land-based sources, the ship contribution as a percent of NO_x, SO_x, and PM inventories is likely to grow even faster than absolute emissions. The status of pollution control measures and programmes implemented to date in the shipping sector is reviewed in this article.

Moreover, the need to understand the global ecosystems and environment, as well as their necessary conservation, and to find the more efficient mechanisms to deal with phenomena such as climate change, ecosystem disruption, deforestation, depletion of the ozone layer, and rising sea levels have made research and study of the maritime environment a high priority issue.

Further researches in this sector are urgently needed to reduce bottlenecks. First, methodology for assessing the cost-effectiveness of three emission control strategies for reducing air pollution from ship should be developed. The benefits of cost-effectiveness approach for regulatory development are that the resulting regulations will be based on a sound rationale and that pertinent costs imposed by new requirements may be defended based on achievable emission deduction. Second, clean air programme for port operation also should be examined because air pollution reduction efforts will be more effective when they are carried out both at sea and in port.

As the maritime sector grows to be one of the major economies in the world, India will require a vibrant and strong maritime industry for both economic and strategic reasons. There are many factors that contribute to the development of a robust and sustainable maritime sector. Finally, it will depend on how the different stakeholders utilize the opportunities presented to them to transform the sector into an engine of growth for India. Therefore, while 2016 was viewed as the year for enabling the transformation of the maritime sector, it seems India is on the cusp of major maritime revolution that will play out over the next couple of years.

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Media Review

Media on Energy and Environmental Issues

Climate change impacts monsoon flooding in India

Forbes, October 15, 2019

This year's monsoon season in India saw the highest amount of rain in more than 25 years. Normally, the rains retreat by September 1st, but the India Meteorological Department doesn't expect this year's rains to retreat until at least October 10. That makes 2019 the latest withdrawal of the monsoon in India's recorded history.

Biodiversity change happening faster in marine ecosystems than on land

The Week, October 18, 2019

Biodiversity loss is happening at a faster rate in the tropical regions of the world, with changes in marine ecosystems outpacing those on land, according to a study that can help prioritize global conservation strategies. The findings of the study, published in the journal *Science*, revealed that there were both negative and positive changes in ecosystems across the world, and while on average the number of species living in each place was not changing, many regions were either gaining or losing species.

India hikes tariff by 3% in latest wind energy tender

CleanTechnica, October 28, 2019

Struggling to attract sufficient bids for its wind energy tenders, India has decided to increase the maximum tariff bid by 2.8% for its latest national-level tender. The Solar Energy Corporation of India recently issued key amendments to the

ninth national wind energy tender. SECI had issued the tender in September offering 1.8 GW of capacity. The maximum bid allowed under the initial terms was Rs 2.85/kWh (4.02US¢/kWh), which has now been increased to ₹2.93/kWh (4.13US¢/kWh). Issues related to land acquisition, adequate transmission infrastructure, and timely payments seem to have emerged as major challenges for project developers over recent months. Several states have threatened to cancel or renegotiate power purchase agreements with renewable energy generators. More than a billion dollars of unpaid dues to the generators have limited developers' ability to afford new investments. It, therefore, comes as no surprise that the government has been forced to amend the terms of existing tenders. To make the tenders attractive, the Ministry of New and Renewable Energy recently issued revised guidelines for wind energy tenders. The revised guidelines offered reduced penalty for generation shortfall, increased tariff for generation resulting from early commissioning, and more time to commission projects.

Millions of people are more vulnerable to rising seas than previously thought

USA Today, October 29, 2019

Worldwide, some 300 million people live where dangerous climate-triggered flooding will occur by mid-century, a new study suggests. That is three times higher than previous estimates of 80 million. Most of the people at risk live in Asian countries such as China, India, Bangladesh, Vietnam, and Indonesia.

Air pollution in India linked with higher risk of stroke and heart disease: study

The Hindu Business Line, November 12, 2019

Exposure to high levels of ambient and household air pollution in India is associated with an increased risk of cardiovascular diseases such as heart attack and stroke. A team led by the Barcelona Institute for Global Health (ISGlobal) in Spain is the first to explore the association between ambient and household air pollution and carotid intima-media thickness (CIMT) – a marker of atherosclerosis or thickening of arteries – in a population of a low and middle income country. The study, performed in a peri-urban area in Hyderabad, Telangana, shows that people most exposed to fine particles have a higher CIMT index, which means they are at higher risk of developing cardiovascular diseases such as stroke or heart attack. The study, published in *International Journal of Epidemiology*, was performed with 3372 participants. The team measured CIMT and estimated exposure to air pollution using an algorithm called land use regression (LUR), which is frequently used to predict the amount of fine particles – suspended particles with a diameter under 2.5 micrometres – in high-income countries.

New digital library features sustainable buildings around the world

Facility Executive, November 19, 2019

The World Green Building Council (WorldGBC) launched a digital Case Study Library showcasing examples of the world's most cutting-edge sustainable buildings. Each case study demonstrates enhanced performance in relation to health benefits or to achieve net zero operational carbon, as verified by established certification programmes, rating tools, or other third-party verification. WorldGBC has launched

the case study library in recognition of growing market demand to highlight the 'best in class' buildings that excel in key areas of sustainability and the role of certification schemes to provide third-party assurance of performance.

Climate impacts 'to cost world \$7.9 trillion' by 2050

The Economic Times, November 21, 2019

Climate change could directly cost the world economy \$7.9 trillion by mid-century as increased drought, flooding, and crop failures hamper growth and threaten infrastructure. The Economist Intelligence Unit's Climate Change Resilience Index measured the preparedness of the world's 82 largest economies and found that based on current trends the fallout of warming temperatures would shave off three per cent of global GDP by 2050.

Western Ghats carbon footprint caused floods in Karnataka and Kerala in last two years

The New Indian Express, November 21, 2019

Large-scale forest degradation and improper carbon sequestration is one of the causes of the recent flooding witnessed in most parts of Karnataka and Kerala over the last 2 years. Carbon sequestration is a natural/artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form. Researchers at the Indian Institute of Science, in their latest study report on Carbon Sequestration Potential of the Forest Ecosystems in the Western Ghats: a Global Biodiversity Hotspot, have found large-scale land cover shaved off, leading to deforestation with degradation, causing 20–25% of anthropogenic (human-related) carbon emissions, resulting in regional impact on climate patterns. The loss of forest cover has also modified the local rainfall pattern.

Indian states must provide clean air and water or pay damages, Supreme Court rules

The Guardian, November 26, 2019

The Indian Supreme Court has declared that state governments will have to pay their citizens compensation if they fail to provide clean air and water. The judges, who have been vocal in their condemnation of state governments that have repeatedly failed to address the issue, said that people had the constitutional right to live free of pollution. The court judges expressed outrage that this ruling appeared to have been entirely ignored, with crop burning shown to have in fact increased. The Supreme Court has recently made rulings to try to get state governments to act, including issuing an order to stop all crop stubble burning, which in states such as Punjab and Haryana remain rampant and is a huge contributor to Delhi's pollution.

Retrofit electric autos launched in Chennai

The Times of India, November 29, 2019

Tamil Nadu chief minister launched Mauto Electric mobility's electric autorickshaw – touted as India's first retrofit electric auto – in Chennai. Dubai-based KMC group and Mauto Electric Mobility will convert petrol-run autorickshaws into electric vehicles with an investment of ₹100 crore and offer job opportunities to 5000 people. The driving range per full charge of three hours will be 100 km. The aim is to introduce 4000 electric rickshaws in the city, 100 by a month to reduce air pollution to a large extent. The autos are fitted with CCTV surveillance, panic button, and television. It is highly safe for children going to school and women.

With electric buses, West Bengal makes an ambitious push for curbing city pollution

The Indian Express, December 2, 2019

Aiming to bring down the air pollution caused by buses operated in the Kolkata city, the West Bengal government has introduced around 80

electric buses; in the next 10 years, it plans to introduce more than 5000 such buses. As a result, the state government has already bagged the C40 Cities Bloomberg Philanthropies Award in the 'Green Mobility' category. The government also plans to increase the number of charging stations in and around the city. If things go as per plan, the transport department would convert its entire bus fleet to electric models in a few years from now.

HC directs authorities to remove forest encroachments, mitigate dust to reduce air pollution

Business Standard, December 2, 2019

In a bid to reduce air pollution, the Delhi High Court has directed authorities to remove encroachments from forest areas and mitigate dust in the national capital. On National Pollution Control Day, the court directed the Delhi government to prepare an action plan for removing encroachments from the forest areas after carrying out a survey to identify the encroached sites and to submit it before the special task force, which is under the supervision of the Supreme Court.

Thermal power plants worked at 49% their capacity in April–October 2019

Business Standard, December 3, 2019

The plant load factor (PLF) – a power plant's output when compared with its maximum capacity – has been declining consistently for India's thermal power plants since the start of this financial year. The average PLF of these plants (except gas-fired ones) slumped from 64.71% in April to 49.18% at the end of October. The thermal plants' PLF had seen an uptrend towards the second half of 2018–19. In October 2018, their average load had stood at 63.75%. State-owned thermal power stations recorded the sharpest drop in PLF – to 40.92% in October 2019 from 60.4% in the same month

last year – data from the Central Electricity Authority (CEA) showed. Private sector utilities were better performers, recording an average PLF of 64.91%. Independent power producers (IPPs) operated at a load of 51.01%. An industry source attributed the drop in load at thermal power plants to intermittent disruptions in coal supplies and a weakening power demand.

Migratory birds shrinking as climate warms, new analysis of four-decade record shows

UMichiganNews, December 4, 2019

North American migratory birds have been getting smaller over the past four decades, and their wings have gotten a bit longer. Both changes appear to be responses to a warming climate. Those are the main findings from a new University of Michigan led analysis of a dataset of some 70,000 North American migratory birds from 52 species that died when they collided with buildings in Chicago.

Measuring pollution: how government is ramping up air quality monitoring stations according to Indian standards

The Economic Times, December 7, 2019

India's long fight against rising pollution in the cities has made little progress. Now experts are questioning if the ad hoc preventive and controlling mechanism put in place to fight pollution of air and water the state has adopted is to blame. Most solutions to battle pollution are imported from foreign shores. Instruments for both measuring and monitoring air quality and cleaning it up are calibrated mostly to European standards and attuned to their climatic conditions. National Physical Laboratory (NPL) officials point out that it is only when the air quality monitoring equipment is calibrated to Indian conditions can the air purifier industry also be held to account on its claims.

Oceans losing oxygen at unprecedented rate, experts warn

The Guardian, December 7, 2019

Oxygen in the oceans is being lost at an unprecedented rate, with 'dead zones' proliferating and hundreds more areas showing oxygen dangerously depleted, as a result of the climate emergency and intensive farming, experts have warned. Sharks, tuna, marlin, and other large fish species were at particular risk, scientists said, with many vital ecosystems in danger of collapse. Dead zones – where oxygen is effectively absent – have quadrupled in extent in the last half-century, and there are also at least 700 areas where oxygen is at dangerously low levels, up from 45 when research was undertaken in the 1960s.

With 2081 deaths last year, India 5th most vulnerable to climate change

Business Standard, December 9, 2019

India is the fifth most vulnerable of 181 countries to the effects of climate change, with its poorest being the most at risk, according to a new report. Japan is most vulnerable, followed by the Philippines, Germany, and Madagascar. India had the most (2081) deaths in 2018 due to extreme weather events caused by climate change – cyclones, heavy rainfall, floods, and landslides – found the 15th edition of the Global Climate Risk Index 2020 prepared by Germanwatch.

India among top 10 nations on climate change performance index

Indian Express, December 10, 2019

India is among the top 10 performing nations as per the Climate Change Performance Index. The index is based on criteria such as the country's energy use, its per capita emissions, its emission reduction targets for 2030, its national and international climate

policy, renewable energy deployment, and past trends of emissions. It assigns every country scores on each of these indicators to assess its overall ranking. This assumes significance in view of India's resolve to reach 175 GW of clean energy capacity by 2022. The country has already achieved around 84 GW of clean energy capacity, including 32 GW of solar and 37 GW of wind energy. At present, India's total installed power generation capacity is around 365 GW. The Climate Change Performance Index report assesses the climate programmes of 57 countries and the European Union, which together account for more than 90% of the global greenhouse gas emissions.

India installed 47.86 GW renewable energy capacity in last 6 years

Indus Dictum, December 13, 2019

The Minister of State (MoS) for New & Renewable Energy and Power stated in Parliament that a total of 47.86 GW of renewable energy capacity has been installed in the country during the last 6 years, that is, March 2014 to October 2019. The initiatives taken by the government to explore new and renewable energy sources in the country inter alia include permitting foreign direct investment (FDI) up to 100% under the automatic route, waiver of inter-state transmission system (ISTS) charges and losses for inter-state sale of solar and wind power for projects to be commissioned up to December 2022, notification of standard bidding guidelines to enable distribution licensee to procure solar and wind power at competitive rates in cost-effective manner, declaration of trajectory for Renewable Purchase Obligation (RPO) up to the year 2022, launching of new schemes, such as PM-KUSUM, solar rooftop Phase II, 12,000 MW CPSU scheme Phase II, and so on. The government has set a target of installing 175 GW of renewable energy capacity by the year 2022, which includes 100 GW from solar, 60 GW from wind, 10 GW from biomass, and

5 GW from small hydro. All major programmes and schemes being implemented by the Ministry have established mechanisms to monitor the implementation of these schemes. The provisions inter alia include physical verification by state implementing agencies, periodic inspections by the officials of Ministry of New and Renewable Energy (MNRE), and third party evaluation.

Govt set to develop organic farming corridor along Ganga to arrest pollution

The Indian Express, December 15, 2019

To check non-point source of pollution from agriculture, the government may launch a special programme to develop an organic farming corridor along the Ganga, and a proposal of this effect was discussed in the National Ganga Council meeting chaired by the Prime Minister. According to sources, the idea of organic farming corridor was mooted by the National Mission for Clean Ganga and received a positive response from the Council. The Prime Minister is learnt to have underlined the importance of sustainable agriculture in the Ganga basin. Agricultural run-off is a major non-point source of pollution in the Ganga. Although organic farming has been taken up by Ministry of Agriculture and Farmers Welfare in a few clusters, there is a need to consider a special programme of organic farming on 5 km stretch along both sides of the river and riverbed agriculture should be only organic.

To cut vehicular pollution by 2024, govt shifts focus to e-vehicles

The Indian Express, December 24, 2019

A quick rollout of 5000 e-autos and getting online commerce companies to press more battery-operated bikes into service are the immediate objectives that the Delhi government seeks to achieve through its electric vehicle policy. The policy also makes it mandatory for all new private households and business establishments

to keep 20% of their parking area for charging infrastructure for e-vehicles.

India has installed 84 GW of renewable energy capacity till November 2019: MNRE

Energetica-india.net, December 31, 2019

India's renewable energy (RE) capacity had traversed 84 GW mark by the end of November 2019, fresh data released by the MNRE revealed. "A total of 6083.48 MW of renewable energy capacity has been added during the year 2019–2020, taking the cumulative installed

RE capacity to 84.39 GW as on November 2019," stated the monthly report released by MNRE. The installed RE capacity of 84.39 GW includes 37.28 GW from wind energy, 32.52 GW from solar, 9.94 GW from bio-power, and 4.65 GW from small hydro plants. At present, 31.68 GW capacity projects are at various stages of implementation and 18.68 GW capacity projects are under various stages of bidding. The Ministry has so far paid out around 53% or ₹2788.44 crore of its total budget allocation for the present financial year.

TECHNOSCAN

FROM NEWSPAPERS, MAGAZINES, AND TRADE JOURNALS

A new concept could make more environmentally friendly batteries possible

Science Daily, September 30, 2019

Researchers from Chalmers University of Technology, Sweden and the National Institute of Chemistry, Slovenia have developed a new concept for an aluminum battery that has twice the energy density as previous versions, is made of abundant materials, and could lead to reduced production costs and environmental impact. The idea has potential for large-scale applications, including storage of solar and wind energy. Using aluminium battery technology could offer several advantages, including a high theoretical energy density and the fact that there already exists an established industry for its manufacturing and recycling. Compared with today's lithium-ion batteries, the researchers' new concept could result in markedly lower production costs. The material costs and environmental impacts envisaged from this new concept are much lower than what we see today, making them feasible for large-scale usage. Previous designs for aluminium batteries have used the aluminium as the anode (the negative electrode) and graphite as the cathode (the positive electrode). But graphite provides too low an energy content to create battery cells with enough performance to be useful. But in the new concept, the graphite has been replaced by an organic, nanostructured cathode made of the carbon-based molecule anthraquinone. The advantage of this organic molecule in the cathode material is that it enables storage of positive charge carriers from the electrolyte, the solution in which ions move between the electrodes, which makes possible higher energy density in the battery.

Engineers develop a new way to remove carbon dioxide from air

Science Daily, October 25, 2019

A new way of removing carbon dioxide from a stream of air could provide a significant tool in the battle against climate change. Most methods of removing carbon dioxide from a stream of gas require high concentrations, such as those found in the flue emissions from fossil fuel-based power plants. A few variations have been developed that can work with the low concentrations found in air, but the new method is significantly less energy intensive and expensive, the researchers say. The device is essentially a large, specialized battery that absorbs carbon dioxide from the air (or other gas stream) passing over its electrodes as it is being charged up and then releases the gas as it is being discharged. In operation, the device would simply alternate between charging and discharging, with fresh air or feed gas being blown through the system during the charging cycle and then the pure, concentrated carbon dioxide being blown out during the discharging.

Researchers design an improved pathway to carbon-neutral plastics

Science Daily, November 20, 2019

Researchers from the University of Toronto Engineering and Caltech have designed a new and improved system for efficiently converting CO₂, water, and renewable energy into ethylene – the precursor to a wide range of plastic products, from medical devices to synthetic fabrics – under neutral conditions. The device has the potential to offer a carbon-neutral pathway to a commonly used chemical while enhancing storage of waste carbon and excess renewable

energy. Their published research on a class of molecules known as arylpyridiniums suggested that adding them to the catalyst could favour the production of ethylene over other side products. Adding a thin layer of this molecule to the copper catalyst surface significantly increased the selectivity of the reaction for ethylene. It also led to another benefit: lowering the working reaction pH from basic to neutral.

Microwave treatment is an inexpensive way to clean heavy metals from treated sewage

Science Daily, December 5, 2019

A team of Florida State University researchers studying new methods to remove toxic heavy metals from biosolids – the solid waste left over after sewage treatment – found the key is a brief spin through a microwave. The method removed three times the amount of lead from biosolids compared to the conventional means and could reduce the total cost of processing by more than 60%, making it a possible engineering solution to help produce fertilizer and allow more people to live with clean soil and water. As the human population of the planet grows and more people move to cities, sewage treatment plants around the world are producing more biosolids. Those by-products are often disposed of in landfills or incinerators, but there are drawbacks to those solutions, such as high costs or secondary pollution from the treatment process itself. Another option is to compost the biosolids, using them as an ingredient in fertilizer that finds a second life in agriculture.

New method to remove dust on solar panels: Researchers look to the lotus leaf for self-cleaning innovation

Science Daily, December 9, 2019

In a new study, researchers confirmed that modifying the surface properties of solar panels may greatly reduce the amount of dust remaining on the surface and significantly increase the

potential of solar energy harvesting applications in the desert. Dust adhesion on solar panels is a major challenge to energy harvesting through photovoltaic cells and solar thermal collectors. New solutions are necessary to maintain the maximum collection efficiency in high dust density areas, such as the Negev Desert in Israel. The researchers explored the effect of modifying a silicon substrate (Si), a semiconductor used in photovoltaic cells, to mimic the self-cleaning properties of the lotus leaf, as water rolls down the leaves and removes contamination. It is known that superhydrophobicity reduces the friction between water droplets and the surface, thus allowing water drops to slide clean particles from surfaces. However, the forces that attach and detach particles from surfaces during the self-cleaning mechanism and the effect of nanotextures on these forces are not fully understood. To shed light on these forces and the effect of nanotexture on them, the researchers prepared four silicon-based samples relevant to solar panels: (1) smooth hydrophilic surface, (2) nanotextured hydrophilic surface, (3) smooth hydrophobic surface, and (4) nanotextured hydrophobic surface. This was achieved by wet-chemical etching of the surface to create nanowires on the surface and additionally applying a hydrophobic coating. Particle removal increased from 41% on hydrophilic smooth Si wafers to 98% on superhydrophobic Si-based nanotextured surfaces. The researchers confirmed these results by measuring the adhesion of a micron-sized particle to the flat and nanotextured substrate using an atomic force microscope. They found that the adhesion in water is reduced by a factor of 30.

Solar power from 'the dark side' unlocked by a new formula

Science Daily, December 18, 2019

Most of today's solar panels capture sunlight and convert it to electricity only from the side facing the sky. If the dark underside of a solar

panel could also convert sunlight reflected off the ground, even more electricity might be generated. A new thermodynamic formula reveals that the bifacial cells making up double-sided panels generate on average 15–20% more sunlight to electricity than the monofacial cells of today's one-sided solar panels, taking into consideration different terrain, such as grass, sand, concrete, and dirt. The formula, developed by researchers, can be used for calculating in minutes the most electricity that bifacial solar cells could generate in a variety of environments, as defined by a thermodynamic limit. The formula involves just a simple triangle, but distilling the extremely complicated physics

problem to this elegantly simple formulation required years of modeling and research. This triangle will help companies make better decisions on investments in next-generation solar cells and figure out how to design them to be more efficient. The researchers use the formula to recommend better bifacial designs for panels on farmland and the windows of buildings in densely populated cities. Transparent, double-sided panels allow solar power to be generated on farmland without casting shadows that would block crop production. Meanwhile, creating bifacial windows for buildings would help cities to use more renewable energy.

Abstracts of Current Research

- Abstracts grouped under 40 headings
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<i>Environmental Pollution</i>	2019: 255(Part 2)
<i>Environmental Research</i>	2019: 181
<i>Environmental Science & Policy</i>	2019: 92-101

<i>Environments</i>	2019: 5(9) & 6(12)
<i>Estuarine, Coastal and Shelf Science</i>	2019: 229
<i>Fuel</i>	2019: 250
<i>Global Ecology and Conservation</i>	2019: 20
<i>Global Environmental Change</i>	2019: 59
<i>Global Food Security</i>	2019: 23
<i>Groundwater for Sustainable Development</i>	2019: 9
<i>ICT Express</i>	2019: 5
<i>Indian Journal of Environmental Protection</i>	2019: 39 (7-12)
<i>International Journal of Hydrogen Energy</i>	2019: 44
<i>International Journal of Hygiene and Environmental Health</i>	2019: 222 (8):1068–1076
<i>Journal of Arid Environments</i>	2019: 172 : 104018
<i>Journal of Atmospheric and Solar-Terrestrial Physics</i>	2019: 195
<i>Journal of Cleaner Production</i>	2019: 210-244
<i>Journal of Energy Storage</i>	2019: 21
<i>Journal of Environmental Management</i>	2019: 251
<i>Journal of the Air & Waste Management Association</i>	2019: 69 (12)
<i>Land Use Policy</i>	2019: 89
<i>Marine Pollution Bulletin</i>	2019: 148 & 149
<i>Ocean Engineering</i>	2019: 191
<i>Procedia CIRP</i>	2018: 78 ; 2019: 80
<i>Procedia Computer Science</i>	2018: 143 ; 2019: 152
<i>Renewable and Sustainable Energy Reviews</i>	2019: 114-116
<i>Renewable Energy</i>	2019: 139-143
<i>Renewable Energy Focus</i>	2019: 31
<i>Resources, Conservation and Recycling</i>	2019: 148
<i>Science of The Total Environment</i>	2019: 690 & 691
<i>Structural Change and Economic Dynamics</i>	2019: 50
<i>Sustainable Cities and Society</i>	2019: 51
<i>Sustainable Computing: Informatics and Systems</i>	2018: 19-23
<i>Sustainable Energy Technologies and Assessments</i>	2019: 35-36
<i>The Electricity Journal</i>	2019: 32
<i>The Lancet Planetary Health</i>	2019: 3
<i>Trends in Ecology & Evolution</i>	2019: 34
<i>Urban Climate</i>	2019: 30
<i>Utilities Policy</i>	2019: 61
<i>Waste Management</i>	2018: 79 & 2019: 86
<i>Waste Management & Research</i>	2019: 37 (11):1063–1076
<i>Water</i>	2019: 11 (11): 2350
<i>Wind Energy</i>	2019: 22 (1)
<i>World Development</i>	2019: 123

OTHER SYNTHETIC AND NATURAL FUELS

[14742]

Gupta A, Kumar A, and Khatod D K. 2019

Energy **183**: 716–732

Department of Hydro and Renewable Energy (HRED)
(formerly Alternate Hydro Energy Centre (AHEC)),
Indian Institute of Technology Roorkee, Roorkee,
Uttarakhand, 247667, India

Optimized scheduling of hydropower with increase in solar and wind installations

The existing hydropower plants that were built to serve the base load in the past are now made to run as standby units to take up the variation in generation caused due to the increasing solar and wind energy in the grid. This reduces the generation as well as the revenue of these plants and creates a conflict of interest between generating companies and system operators. Thus, there arises a need to revise the operating policies of existing hydropower plants, not only for the present capacities of solar and wind but also taking future additions into the account. This problem is taken up in this study on behalf of the state power generating company for their existing hydropower plants. The optimization is carried out using two algorithms, that is, non-linear optimization and logical optimization. The optimization results provide certain operational observations on many powerhouses, following which the generation could be increased without any additional investment. The algorithms, when used for the future additions of solar, wind, and thermal, are found to be quite sensitive to the reservoir inflow data. The critical comparison of the used algorithms reveals that rule of thumb can also perform very well when compared with the true optimization. (14 Figures, 5 Tables, 66 References)

BIOMASS

[14743]

Abriyantoro D, Dong J, Hicks C, and Singh S P. 2019

Energy **169**: 515–526

Business School, Newcastle University, 5 Barrack
Road, NE1 4SE, UK

A stochastic optimisation model for biomass outsourcing in the cement manufacturing industry with production planning constraints

There is a comprehensive literature on biomass production and conversion, but little attention has been paid to biomass logistics in the cement industry. We propose the use of cement distribution trucks to collect biomass on their return journeys. Compared with the use of specialist biomass suppliers, the collection of biomass via cement distribution networks has greater uncertainties in delivery times, volume, and quality. This is because biomass collection is a secondary activity and is subject to cement order quantities and the random geographical locations of cement customers. To cope with these uncertainties, additional on-site storage and handling equipment is required. This paper proposes a stochastic programming model to measure the cost-effectiveness of collecting biomass using returning cement distribution trucks in comparison with purchasing biomass from specialized biomass suppliers. A numerical experiment based on a real-word dataset was conducted to verify the effectiveness of the developed model. (8 Figures, 8 Tables, 38 References)

[14744]

Banerjee S, Rout S, Banerjee S, Atta A, and Das D.

2019

Energy Conversion and Management **195**: 844–853

Advance Technology Development Center, Indian

Institute of Technology, Kharagpur 721302, India

Fe₂O₃ nanocatalyst aided transesterification for biodiesel production from lipid-intact wet microalgal biomass: a biorefinery approach

Biodiesel production from non-edible feedstock such as microalgae is gaining importance in present day, as they do not interfere with global food economy in addition to higher photosynthetic efficiency as compared to plants. Freshwater grown *Neochloris oleoabundans* UTEX 1185 is considered as a potential source for biodiesel production. The present study investigated different direct lipid extraction processes from wet microalgal biomass through autoclaving, microwave, and ultrasonication pretreatments. Autoclave treatment showed a higher efficiency for lipid extraction as compared to other two pretreatments. Furthermore, transesterification process was carried out in presence of Fe₂O₃ catalyst and compared with the conventional acid (HCl) and base (NaOH) catalysts. Fe₂O₃ nanoparticles used were synthesized from the extract of *Hibiscus rosa-sinensis* by green procedure. The synthesized Fe₂O₃ catalyst played an important role in improving the biodiesel yield up to 81%, which is higher than that obtained with HCl (64%) and NaOH (48%). Thereafter transesterification process parameters such as catalyst content, reaction temperature, and reaction time were optimized and finally 86% biodiesel yield was obtained. Fatty acid methyl esters (FAME) profile analysis and fuel properties revealed the suitability of algal lipid for biodiesel production. The 20.2% w/w of carbohydrate present in lipid extracted microalgal biomass was further converted into biohydrogen by dark fermentation and

bioethanol under anaerobic condition using acidogenic mixed consortia and *Saccharomyces cerevisiae* (INVSC-1), respectively. The life cycle assessment study of the overall process was also done. (10 Figures, 2 Tables, 58 References)

[14745]

Dang A T N, Nandy S, Srinet R, Luong N V, Ghosh S, and Kumar A S. 2019

Ecological Informatics **50**: 24–32

Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), Dehradun 248001, India

Forest aboveground biomass estimation using machine learning regression algorithm in Yok Don National Park, Vietnam

Forest biomass is one of the key measurements for carbon budget accounting, carbon flux monitoring, and climate change studies. Hence, it is essential to develop a credible approach to estimate forest biomass and carbon stocks. Our study applied Sentinel-2 satellite imagery combined with field-measured biomass using Random Forest (RF), a machine learning regression algorithm, to estimate forest aboveground biomass (AGB) in Yok Don National Park, Vietnam. A total of 132 spectral and texture variables were extracted from Sentinel-2 imagery (7 February 2017) to predict AGB of the National Park using RF algorithm. It was found that a combination of 132 spectral and texture variables could predict AGB with an R^2 value of 0.94, RMSE of 34.5 Mg/ha, and %RMSE of 18.3%. RF regression algorithm was further used to reduce the number of variables in such a way that a minimum number of selected variables can be able to estimate AGB at a satisfactory level. A combination of 11 spectral and texture variables was identified based on out-of-bag (OOB) estimation to develop an easy-to-use model for estimating AGB. On validation, the model developed with 11 variables was able to predict AGB with $R^2 = 0.81$,

RMSE = 36.67 Mg/ha, and %RMSE of 19.55%. The results found in the present study demonstrated that Sentinel-2 imagery in conjunction with RF-based regression algorithm has the potential to effectively predict the spatial distribution of forest AGB with adequate accuracy. (8 Figures, 3 Tables, 62 References)

[14746]

Goswami G, Sinha A, Kumar R, Dutta B C, Singh H, and Das D. 2019

Energy **189**: 116136

Department of Biosciences & Bioengineering, Indian Institute of Technology, Guwahati, Assam, 781039, India

Process engineering strategy for cultivation of high density microalgal biomass with improved productivity as a feedstock for production of bio-crude oil via hydrothermal liquefaction

The process engineering strategy involved a combinatorial approach of: (i) optimization of CO₂ concentration in the inlet gas stream and aeration rate, (ii) growth kinetic driven feeding recipe for limiting nutrients, and (iii) dynamic increase in light intensity. The strategy was tested by growing the cells on laboratory grade BG11 medium. With an attempt to reduce the cultivation cost, the growth performance of the organism was then evaluated on commercial grade BG11 medium. Finally, hydrothermal liquefaction was carried out for direct conversion of microalgal slurry into bio-crude oil. Cultivation on laboratory grade BG11 medium resulted in biomass titer and overall productivity of 8.41 g/L and 575.9 mg/L/day, respectively. Significant improvement in biomass titer (13.23 g/L) and overall productivity (731.6 mg/L/day) was observed when grown on commercial grade BG11 medium. Higher fraction of hydrocarbon in the bio-crude oil depicted better oil quality. Thermal gravimetric analysis revealed that the maximum distillate fraction lies within the boiling point range of 200–300 °C, which

is suitable for conversion into diesel oil, jet fuel, and fuel for stoves. (8 Figures, 4 Tables, 40 References)

[14747]

Hakkim H, Sinha V, Chandra B P, Kumar A, Mishra A K, Sinha B, *et al.* 2019

Science of The Total Environment **689**: 295–304

Department of Earth and Environmental Sciences, Indian Institute of Science Education and Research Mohali, Sector 81, SAS Nagar, Manauli, Punjab, 140306, India

Volatile organic compound measurements point to fog-induced biomass burning feedback to air quality in the megacity of Delhi

Measurements of acetonitrile (biomass burning (BB) tracer), isoprene (biogenic emission tracer in daytime), toluene (a traffic exhaust tracer), and benzene (emitted from BB and traffic), together with soluble and reactive oxygenated VOCs such as methanol, acetone, and acetaldehyde, were performed during the winters of 2015–16 and 2016–17, using proton transfer reaction mass spectrometry. Remarkably, ambient VOC composition changes during fog were not governed by solubility. Acetaldehyde, toluene, sum of C8-aromatics (e.g., xylenes), and sum of C9-aromatics (e.g., trimethyl benzenes) decreased by $\geq 30\%$ ($>95\%$ confidence interval), whereas acetonitrile and benzene showed significant increases by 20% ($>70\%$ confidence interval), even after accounting for boundary layer dilution. During fog, the lower temperatures appeared to induce an emissions feedback from enhanced open BB within Delhi for warming, releasing both gaseous and aerosol pollutants with consequences for fog chemistry, sustenance, and intensity. The potential feedback is important to consider for improving current emission parameterizations in models used for predicting air quality and fog in such atmospheric environments. (6 Figures, 2 Tables, 54 References)

[14748]

Makut B B, Das D, and Goswami G. 2019

Algal Research **37**: 228–239

Department of Biosciences & Bioengineering, Indian Institute of Technology, Guwahati, Assam 781039, India

Production of microbial biomass feedstock via co-cultivation of microalgae-bacteria consortium coupled with effective wastewater treatment: a sustainable approach

A sustainable process was demonstrated towards production of biomass feedstock coupled with wastewater treatment. Sustainability was endeavoured to be achieved via symbiotic growth of microalgae and bacteria coupled with utilization of wastewater as the cheap source of nutrient and water. The best microalgae-bacteria consortium consisted of two microalgae *Chlorella sorokiniana* strain DBWC2 and *Chlorella* sp. strain DBWC7 and two bacteria *Klebsiella pneumoniae* strain ORWB1 and *Acinetobacter calcoaceticus* strain ORWB3. When the consortium was characterized on artificial wastewater and raw dairy wastewater, a significant improvement in the microalgal growth, total biomass titer, chemical oxygen demand (COD), and nitrate removal efficiency was observed as compared to microalgae alone. Total biomass titer, nitrate removal, and COD removal efficiency was found to be 2.84 g/L, 93.59%, 82.27% and 2.87 g/L, 84.69%, 90.49% in artificial wastewater and raw dairy wastewater, respectively. The selected microalgae-bacteria consortium may be a potential platform towards sustainable production of microbial biomass using wastewater. (6 Figures, 4 Tables, 52 References)

[14749]

Mudhoo A, Torres-Mayanga P C, Forster-Carneiro T, Sivagurunathan P, Kumar G, Komilis, D, et al. 2018 *Waste Management* **79**: 580–594

Department of Chemical and Environmental Engineering, Faculty of Engineering, University of Mauritius, Réduit 80837, Mauritius

A review of research trends in the enhancement of biomass-to-hydrogen conversion

This review revisits the recent progress reported in biomass-based hydrogen synthesis in the associated disciplines of microbial cell immobilization, bioreactor design and analysis, ultrasound-assisted, microwave-assisted and ionic liquid-assisted biomass pretreatments, development of new microbial strains, integrated production schemes, applications of nanocatalysis, subcritical and supercritical water processing, use of algae-based substrates, and inhibitor detoxification. The main observations from this review are that cell immobilization assists in optimizing the biomass fermentation performance by enhancing bead size, providing for adequate cell loading and improving mass transfer; there are novel and more potent bacterial and fungal strains that improve the fermentation process and impact on hydrogen yields positively; application of microwave irradiation and sonication and the use of ionic liquids in biomass pretreatment bring about enhanced delignification, and supercritical water biomass processing and dosing with metal-based nanoparticles also assist in enhancing the kinetics of hydrogen synthesis. The research areas discussed in this work and their respective impacts on hydrogen synthesis from biomass are arguably stand-alone. Further work is still required to explore the possibilities and techno-economic implications of combining these areas for developing robust and integrated biomass-to-hydrogen synthetic schemes. (1 Figure, 2 Tables, 205 References)

[14750]

Nayak M, Swain D K, and Sen R. 2019

Science of The Total Environment **682**: 475–484

Department of Biotechnology, Indian Institute of Technology Kharagpur, West Bengal 721302, India

Strategic valorization of de-oiled microalgal biomass waste as biofertilizer for sustainable and improved agriculture of rice (*Oryza sativa* L.) crop

This study reports sustainable and improved agriculture of rice crop (cv. IR 36) by valorizing de-oiled microalgal biomass waste (DOMBW) of *Scenedesmus* sp. as the eco-friendly fertilizer. The microalga (MA) was cultivated in open raceway pond using wastewater and flue gas. Performance evaluation and comparison of DOMBW with respect to growth and yield of rice plants vis-à-vis commercial chemical fertilizers (CF) and vermicompost (VC) applied individually or together established the superiority of the former. The experiment comprised five nutrient management treatments (CF_{100} , VC_{100} , MA_{100} , $MA_{50} + CF_{50}$, and $MA_{50} + VC_{50}$) meeting 100% nitrogen (N) recommendation either through a single source or the combined application in the soil. Combining the application of microalgal-based organic fertilizer with chemical fertilizer ($MA_{50} + CF_{50}$) showed the highest performance in terms of plant height, tiller number, biomass, and grain yield. At the harvest stage, $MA_{50} + CF_{50}$ also resulted in the maximum plant dry weight, panicle weight, and 1000-grain weight in comparison to other treatments. This study revealed that the application of DOMBW as a biofertilizer is potentially sustainable and effective in improving the yields of rice crop with the reduced use of chemical fertilizer. (5 Figures, 7 Tables, 54 References)

[14751]

Pandey B, Prajapati Y K, and Sheth P N. 2019
International Journal of Hydrogen Energy **44**(47):
25384-25415
Department of Mechanical Engineering, National
Institute of Technology Uttarakhand, Srinagar
(Garhwal), Uttarakhand, 246174, India

Recent progress in thermochemical techniques to produce hydrogen gas from biomass: a state of the art review

This survey highlights the current approaches, relevant methods, technologies, and resources adopted for high yield hydrogen production. Prominent thermochemical methods, that is, pyrolysis, gasification, supercritical water

gasification, hydrothermal upgrading, followed by steam gasification, bio-oil reforming, and pyrolysis in-line reforming have been discussed thoroughly in view of the current research trend and latest emerging technologies. Influences of important factors and parameters on hydrogen yield, such as biomass type, temperature, steam-to-biomass ratio, retention time, biomass particle size, and heating rate, have also been extensively studied. Catalyst is a vital integrant that has received enough attention due to its encouraging influence on hydrogen production. Literature confirms that hydrogen obtained from biomass has high-energy efficiency and potential to reduce greenhouse gases. Hence, it deserves versatile applications in the coming future. The study also reveals that hydrogen production through steam reforming, pyrolysis, and in-line reforming delivers a considerable amount of hydrogen from biomass with higher process efficiency. It has been identified that high temperature, suitable steam-to-biomass ratio, and catalyst type favour useful hydrogen yield. Nevertheless, hydrogen is not readily available in the sufficient amount and production cost is still high. Tar generation during thermochemical processing of biomass is also a concern and requires consistent efforts to minimize it. (18 Figures, 8 Tables, 251 References)

[14752]

Pathak S, Saxena P, Ray A K, Großmann H, and Kleinert R. 2019
Journal of Cleaner Production **233**: 893-902
Department of Paper Technology, Indian Institute
of Technology Roorkee, Saharanpur Campus,
Saharanpur, 247001, U.P., India

Irradiation based clean and energy efficient thermochemical conversion of biowaste into paper

A key element of paper industry is the raw material (wood, bamboo, and nonwood agricultural residues such as bagasse and straws) from which pulp is produced. The pulp is then utilized for the production of paper.

There are many pulping processes to prepare pulp of various qualities. For fine grade pulp, chemical pulping is used. The chemical pulp is produced by soda, kraft, and sulphite pulping processes. However, for newsprint grade pulp, stone ground wood (SW), thermomechanical (TMP), chemi-thermomechanical (CTMP), chemi-mechanical (CMP) or refiner mechanical (RMP) corresponding pulping processes are employed. The method of pulp preparation (pulping process) consumes large amounts of energy and chemicals. A new pulping process with electron irradiation using biowaste (bagasse) as a raw material is discussed in this work. Bagasse pulping process is found to reduce about 50% of energy consumption during pulping process. The process is referred to as ECTMP (Energy Efficient Chemi-Thermo Mechanical Pulping). The paper produced from the aforesaid method also reflected no loss of strength properties with respect of TMP reference pulps. Henceforth, preliminary calculation based on experimental results shows that the proposed bagasse ECTMP process explored the scope of energy savings of the order of 50%. (13 Figures, 6 Tables, 41 References)

[14753]

Perkins G, Batalha N, Kumar A, Bhaskar T, and Konarova M. 2019

Renewable and Sustainable Energy Reviews **115**: 109400

School of Chemical Engineering, The University of Queensland, Brisbane, 4072, Australia

Recent advances in liquefaction technologies for production of liquid hydrocarbon fuels from biomass and carbonaceous wastes

The liquefaction of biomass and carbonaceous wastes using hydro-pyrolysis, hydrothermal liquefaction, and liquefaction using water and hydrocarbon solvents are promising thermochemical methods for producing renewable fuels and chemicals. New combinations of unit operations and possibly novel reactors will

likely be required to economically convert biomass feedstock into partially upgraded bio-crudes. While some techno-economic assessments show that biofuels from fast pyrolysis may be competitive with petroleum fuels in future, the conventional pyrolysis produces a poor quality bio-crude and is suitable only for dry, homogeneous feedstock, such as woody biomass and agricultural waste (corn stoves, wheat stalk, and rice husk). It is desirable to produce high-quality bio-crudes and to be able to process high-moisture feedstock, such as algae, organic waste (food residues), bio-solids, and bio-sludge into transportation fuels using the liquefaction approaches. Increased awareness of the environmental damage from burning fossil fuels is driving national and international reduction targets for CO₂ emissions. Liquefaction technologies aimed at producing alternatives to fossil-based transportation fuels/hydrocarbons are likely to receive continued support in the future and the most promising ones could be developed to full commercial scale. This review provides a summary of the current state of development of these technologies and also some of the challenges faced to develop commercially viable transportation fuels via liquefaction routes. This review compares liquefaction routes and provides a summary of techno-economic analyses where data is available and discusses the challenges and opportunities associated with commercial scale-up. (12 Figures, 10 Tables, 160 References)

[14754]

Prakash M, Sarkar A, Sarkar J, Chakraborty J P, Mondal S S, and Sahoo R R. 2019

Energy **167**: 379–390

Department of Mechanical Engineering, Indian Institute of Technology (B.H.U.), Varanasi, Uttar Pradesh, 221005, India

Performance assessment of novel biomass gasification based CCHP systems integrated with syngas production

The systems, instead of using the chemical energy of the gasification products, use the

thermal energy to operate both Rankine and refrigeration cycles in three configurations, namely, steam Rankine cycle with organic Rankine cycle and ejector refrigeration cycle (Cycle-1), binary Rankine cycle with ejector refrigeration cycle (Cycle-2), and steam Rankine cycle with combined power ejector refrigeration cycle (Cycle-3). Syngas (a mixture of hydrogen and carbon monoxide gas), which has the potential for various domestic applications, has been obtained as the gasification product. The effects of different operating parameters, such as water-to-biomass ratio, total biomass–water mass flow rate, mass flow rate of refrigerant, generator pressure, gasification temperature, and types of biomass material have been studied on the syngas and hydrogen yields, as well as coefficient of performance and overall performance index of the system. The study shows that Cycle-2 is more effective in terms of coefficient of performance and refrigeration effect, whereas Cycle-1 is best for higher performance index. Hence, either Cycle-1 or Cycle-2 can be preferred depending on the requirement. (17 Figures, 3 Tables, 17 References)

[14755]

Roy D, Samanta S, and Ghosh S. 2019
Journal of Cleaner Production volume **225**: 36–57
 Department of Mechanical Engineering, Indian
 Institute of Engineering Science and Technology,
 Shibpur, Howrah 711103, West Bengal, India

Techno-economic and environmental analyses of a biomass based system organic Rankine cycle

This paper presents a techno-economic and environmental assessment of a biomass gasification based power plant integrating a solid oxide fuel cell module, an externally fired gas turbine, and an organic Rankine cycle. The proposed biomass-based system is nonparallel with the conventional biomass based power generation system because biomass gasification, solid oxide fuel cell, externally fired gas turbine, and organic Rankine cycle have been combined

in a single system. The thermodynamic and economic performances of the plant have been investigated under the varying operating and design parameters. The maximum energetic and exergetic efficiencies of the system are computed to be 49.47% and 44.2%, respectively. Exergy analysis predicts that the biomass gasifier unit contributes the highest amount of exergy destruction (38.91%) in terms of the total exergy destruction of the system, followed by solid oxide fuel cell (21.24%) and secondary heat exchanger (13.11%). Economic analysis forecasts that the minimum levelized unit cost of electricity would be 0.086 \$/kWh. A performance comparison with other conventional biomass based power generation systems shows that the proposed system exhibits better efficiency and cost of electricity than others. Environmental analysis predicts that the maximum CO₂ emission reduction potential is computed to be 3564 t CO₂/year compared to the fossil fuel based power plant. (20 Figures, 14 Tables, 94 References)

[14756]

Sahoo U, Kumar R, Singh S K, and Tripathi A K. 2018
Applied Thermal Engineering **145**: 685–692
 National Institute of Solar Energy, MNRE, Gurugram,
 Haryana 122003, India

Energy, exergy, economic analysis and optimization of polygeneration hybrid solar-biomass system

In this paper, the optimized values of energy efficiency, exergy efficiency, vapour absorption refrigeration cooling output, desalination output, and the total output of the polygeneration system are achieved to 49.85%, 20.94%, 7278 kW, 4405 kW, and 14,606 kW, respectively. The payback period of the polygeneration hybrid solar biomass system is 1.5 years at the electricity tariff rate of Rs. 7.45/kWh, which is less than that of solar thermal and hybrid solar biomass power plant. (8 Figures, 6 Tables, 23 References)

[14757]

Shanthi M, Rajesh Banu J, and Sivashanmugam P.

2019

Fuel **250**: 194–202

Department of Chemical Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu 620015, India

Synergistic effect of combined pretreatment in solubilizing fruits and vegetable residue for biogas production: hydrolysis, energy assessment

The present study focusses on the liquefying potential of fruits and vegetable residue through dimethyl sulphoxide (DSMO) combined ultrasonic pretreatment (DCUP). Ultrasonic power input variation, solid concentration, soluble organic release (SOR), and specific energy (SE) input were used as parameters to assess the pretreatment efficiency. At optimized condition (ultrasonic power 90 W; solid concentration 30 g/L, and surfactant dosage 0.008 g/g SS), greater percentage of SOR rate of 22% was achieved in DCUP than ultrasonic pretreatment (UP) (17%) with specific energy consumption of 5400 kJ/kg TS. Biofermentation assay in terms of volatile fatty acids (VFA) indicates higher VFA production in DCUP (1800 mg/L) than UP (1200 mg/L). Biochemical methane potential assay showed significant methane yield of about 190 mL/g COD through non-linear regression model, and the achieved energy ratio was found to be 0.8 for DCUP. Thus, dimethyl sulphoxide combined ultrasonic pretreatment is considered as the energetically efficient process. (7 Figures, 1 Table, 48 References)

[14758]

Sunil, Sinha R, Chaitanya B, Rajan B K, Agarwal A, Thakur A D, and Raj R. 2019

Energy **185**: 148–157

Thermal and Fluid Transport Laboratory, Department of Mechanical Engineering, Indian Institute of Technology Patna, Bihar, 801103, India

Design, fabrication, and performance evaluation of a novel biomass-gasification-based hot water generation system

Design and development of a novel hot water generation system comprising a biomass gasification unit in the core and an integrated fire-tube water heat exchanger in the annulus is reported. Producer gas from the gasifier is combusted in a burner and the resulting hot flue gases are routed back through the helical tube to heat the water contained within the annular shell. This allows recovery of the thermal energy typically lost from the outer surface of a conventional gasification system. The simple design improvisation leads to a doubling of the overall efficiency (48%) compared to a standard system with physically separated gasifier and heat exchanger units (24%). The developed system holds promise in domestic and industrial water heating applications. Overall, this integrated design presents an efficient and environment-friendly waste-to-value concept and proposes a meaningful use of the underutilized 36 EJ/annum potential of biomass from crop residue globally. (7 Figures, 4 Tables, 31 References)

[14759]

Thangavelu S K, Rajkumar T, Pandi D K, Ahmed A S, and Ani F N. 2019

Waste Management **86**: 80–86

Faculty of Engineering, Computing and Science, Swinburne University of Technology, 93350 Kuching, Sarawak, Malaysia

Microwave assisted acid hydrolysis for bioethanol fuel production from sago pith waste

The energy consumption for microwave hydrolysis at different energy inputs and acid concentration were calculated. The overall energy consumption for bioethanol fuel production from SPW was assessed. A maximum of 88% glucose yield and 80% ethanol yield (3.1 g ethanol per 10 g SPW) were

obtained using 1.0 mol/L H_2SO_4 . Microwave hydrolysis using 1.0 mol/L H_2SO_4 consumed the minimum energy of 8.1 kJ to produce 1 g glucose from SPW when energy input was fixed at 54 kJ (900 W for 1 min). In general, 1 g glucose can produce 16 kJ. The overall energy consumption for fuel grade bioethanol production from SPW was 31.77 kJ/g ethanol, which was slightly higher than the lower heating values of ethanol (26.74 kJ/g ethanol). (5 Figures, 6 Tables, 40 References)

[14760]

Torres-Mayanga P C, Lachos-Perez D, Mudhoo A, Kumar S, Brown A B, Tyufekchiev, M., et al. 2019 *Biomass and Bioenergy* **130**: 105397
School of Food Engineering, University of Campinas (FEA/UNICAMP), Rua Monteiro Lobato 80, 13083-862, Campinas, SP, Brazil

Production of biofuel precursors and value-added chemicals from hydrolysates resulting from hydrothermal processing of biomass: a review

In this review, an assessment has been made of recent research findings and reservations in regard to the synthesis of subcritical and supercritical hydrolysates and the production of platform chemicals, namely, ethanol, butanol, furfural, hydroxymethylfurfural, lactic acid, levulinic acid and its derivatives, succinic acid, sorbitol, and xylitol. This review also proposes a number of future research-oriented directions to harness the findings of primary research-oriented efforts for developing technically and economically feasible large-scale systems. (7 Figures, 3 Tables, 316 References)

[14761]

Trivedi T, Jain D, Mulla N S S, Mamatha S S, Damare S R, Sreepada R A, et al. 2019 *Renewable Energy* **139**: 326-335
Biological Oceanography Division, CSIR-National Institute of Oceanography, Goa, 403004, India

Improvement in biomass, lipid production and biodiesel properties of a euryhaline *Chlorella vulgaris* NIOCCV on mixotrophic cultivation in wastewater from a fish processing plant

In this study, the changes in biomass productivity, wastewater treatment, lipid production, and biodiesel properties from mixotrophic cultivation of *Chlorella vulgaris* NIOCCV in untreated wastewater from a fish processing plant over F/2 medium were reported. A significant sixfold increase in biomass productivity (257.87 $\pm$ 1.27 mg/L/day) and 1.3-fold in lipid accumulation (48%) was recorded for *C. vulgaris* NIOCCV cultivated in wastewater enrichment of 15% (v/v) over F/2 medium. The biomass productivity was significantly higher in wastewater enrichment up to 50% (v/v) and salt concentration 5% (w/v) than in F/2 medium. The fatty acid methyl esters based theoretical calculation for biodiesel properties from the microalgal biomass cultivated in wastewater enriched medium were found to be superior to the same from the F/2 medium. The resultant biodiesel properties (CN value, oxidation stability, and kinematic viscosity) were in compliance with both ASTM D6751 and EN 14214 fuel standards. The cultivation of *C. vulgaris* NIOCCV in wastewater resulting in a significant decrease in nutrient levels is another advantage. Therefore, *C. vulgaris* NIOCCV can effectively be cultivated in untreated fish processing industry wastewater without addition of nutrients. Further, *C. vulgaris* NIOCCV can efficiently be utilized as bioresource for biodiesel production. (3 Figures, 2 Tables, 58 References)

[14762]

Tyagi U, Anand N, and Kumar D. 2019 *Bioresource Technology* **289**: 121675
University School of Chemical Technology, Guru Gobind Singh Indraprastha University, New Delhi, India

Simultaneous pretreatment and hydrolysis of hardwood biomass species catalyzed by combination of modified activated carbon and ionic liquid in biphasic system

The study highlights one-pot conversion of hardwood biomass into total reducing sugars (TRS) and 5-hydroxymethyl furfural (5-HMF). Synergistic effect of dilute H_2SO_4 and ionic liquid in a reaction time of 60 min at 120 °C was examined. Hydrolysis of Catalpa (*Catalpa bignonioides*), Indian rosewood (*Dalbergia sissoo*), chinaberry (*Melia azedarach*), and babool (*Acacia nilotica*) catalyzed by modified activated carbon leads to significant product yield. Maximum yield was obtained using Catalpa wood, that is, 92.67% TRS and 70.36% 5-HMF under optimized conditions. Biomass before and after pretreatment subjected to FTIR, XRD, and compositional analysis determined the structural changes. Further, the effect of electrolytes, namely, AlCl_3 , MgCl_2 , NaCl , and KCl , were evaluated. Results revealed that using the optimized concentration of each electrolyte promoted the conversion to 96.56% (TRS) and 86.23% (5-HMF) using AlCl_3 (4 wt%) for Catalpa wood. Addition of DMSO with optimized electrolyte concentration improves the partition coefficient (3.3) and yield to 88.29% (5-HMF). (6 Figures, 4 Tables, 42 References)

SOLAR ENERGY

[14763]

Dasari H P, Desamsetti S, Langodan S, Attada R, Kunchala R K, Viswanadhapalli, Y, et al. 2019 *Applied Energy* **248**: 354–371

Physical Sciences and Engineering Division, King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia

High-resolution assessment of solar energy resources over the Arabian Peninsula

This study presents a high-resolution spatial

and temporal assessment of the solar energy resources over the Arabian Peninsula (AP) from 38 years (1980–2017) reanalysis data generated using an assimilative Weather Research and Forecasting Solar model. The simulations are performed based on two two-way nested domains with 15 km and 5 km resolutions using the European Centre for Medium-Range Weather Forecasts as initial and boundary conditions and assimilating most of available observations in the region. Simulated solar energy resources, such as the global horizontal irradiance (GHI), direct normal irradiance (DNI), and diffuse horizontal irradiance (DHI), are first validated with daily observations collected at 46 in situ radiometer stations over Saudi Arabia for a period of 4 years (2013–2016). Observed and modelled data are in good agreement with high correlation coefficients, index of agreements, and low normalized biases. The total mean annual GHI (DNI) over the AP ranges from 6000 to 8500 Wh/m^2 (3000 to 6500 Wh/m^2) with significant seasonal variations. The diffuse fraction (the ratio of the DHI to the GHI) is high (low) over the northern (southern) AP in winter, whereas it is high (low) over the central to southern (northern) AP during summer, indicating a significant modulation of the sky clearness over the region. Clouds over the northern AP in winter and the aerosol loading due to desert dust over the central and southern AP in summer are the major factors driving the variability of the DHI. The effects of dust and clouds are more pronounced in the diurnal variability of the solar radiation parameters. Our analysis of various solar radiation parameters and the aerosol properties suggests a significant potential for solar energy harvesting in the AP. In particular, the areas from southeastern to northwestern Saudi Arabia are identified as most suitable to exploit solar energy with a minimum cloud coverage over the region. (15 Figures, 88 References)

[14764]

Haghghi M A, Pesteei S M, Chitsaz A, and Hosseinpour J. 2019

Applied Thermal Engineering **163**: 114329

Department of Mechanical Engineering, School of Engineering, Urmia University, Urmia, Iran

Thermodynamic investigation of a new combined cooling, heating, and power (CCHP) system driven by parabolic trough solar collectors (PTSCs): a case study

A new solar-based, combined cooling, heating, and power system is designed and developed for the School of Engineering at Urmia University in Urmia, Iran. The proposed arrangement consists of a solar subsystem with parabolic trough solar collectors, an organic Rankine cycle, two heating processes, and two single-effect absorption chillers. The system is thermodynamically studied for the summer air conditioning requirements, considering genuine energy demand and variable solar radiation in three different operational modes (solar, solar and storage, and storage modes). The influences on the system performance are assessed by varying three main variables, namely, the number of days, organic Rankine cycle pump inlet temperature, and organic Rankine cycle turbine inlet pressure. The results demonstrate that the highest cooling, heating, and electrical loads in the summer air conditioning are 896.9 kW, 228.5 kW, and 1500 kW, respectively. The energy load is provided by employing 449–1625 numbers of PTSCs throughout the year. Furthermore, for summertime, the energetic and exergetic analyses reveal that the energy efficiencies of the system in the solar mode, solar and storage mode, and storage mode are found to be 98%, 47.3%, and 98%, respectively. Accordingly, the exergy efficiencies are equal to 17%, 8.3%, and 17%. (12 Figures, 4 Tables, 33 References)

[14765]

Maisanam A K S, Podder B, Biswas A, and Sharma K. 2019

Sustainable Energy Technologies and Assessments **36**: 100558

Department of Mechanical Engineering, National Institute of Technology Silchar, Assam, 788118, India

Site-specific tailoring of an optimal design of renewable energy system for remote water supply station in Silchar, India

In this study, site-specific solar resource assessment using statistical parameters, HOMER-based techno-economic assessment, and environmental impact analysis are done to design an optimal solar PV–battery based system for water supply station of a remote area of Silchar, India. The results show that 2 years' average daily accumulated global solar radiation is 3.67 kWh/(m² day) and the clearness index reveals that 73.5% of the days have partly clear or complete clear sky conditions. The Linke turbidity factor ranges from 3.5 to 5.5. The HOMER simulation results show that 257,014 kWh of energy is produced annually by the PV–battery system and the per unit cost of energy is found to be \$0.307/kWh. The environmental analysis shows that a maximum 98.16% reduction in CO₂ emission can be achieved when compared to the conventional fuel-based plant. This study provides a realistic approach using site-specific solar resource data to optimize a renewable energy system design for the remote area application. (14 Figures, 16 Tables, 49 References)

[14766]

Palanivel B, Perumal S D M, Maiyalagan T, Jayarman V, Ayyappan C, and Alagiri M. 2019

Applied Surface Science **498**: 143807

Department of Physics and Nanotechnology, SRM Institute of Science and Technology, Kattankulathur, Kancheepuram 603203, Tamil Nadu, India

Rational design of $\text{ZnFe}_2\text{O}_4/\text{g-C}_3\text{N}_4$ nanocomposite for enhanced photo-Fenton reaction and supercapacitor performance

The construction of heterostructure with better visible light active photocatalyst and enriched charge storage electrode material for supercapacitor has played an important role in the field of energy and environmental remediation research. The facile sol-gel followed calcination method has been adopted to synthesize the effective heterostructure ($\text{ZnFe}_2\text{O}_4/\text{g-C}_3\text{N}_4$) nanocomposite. The physiochemical characteristics of the synthesized nanomaterials were examined through different analytical techniques. The heterostructure formation between ZnFe_2O_4 and $\text{g-C}_3\text{N}_4$ was confirmed by high resolution transmission electron microscopy. Compared to the pure ZnFe_2O_4 and $\text{g-C}_3\text{N}_4$, the composite catalyst shows the enhanced photocatalytic activity and high electrochemical specific capacitance of 103 F/g at 10 A/g of current density due to the synergistic effect between the nanoparticles. The photocatalytic active radicals and the possible reaction mechanism were demonstrated by elemental trapping experiment, which showed that OH^* radicals play the major role and O_2 has a minor role in the degradation process. The augmented capacitance of the composite electrode suggests the improved ion diffusion rate and increased active redox site for pseudocapacitive behaviour. The 5% of degradation efficiency was maintained after five cycles of the photocatalytic activity under direct sunlight and 94% of capacitance was retained at the current density of 10 A/g after 500 cycles, demonstrating the stability of the composite catalyst. Hence, this heterostructure could be used as an auspicious candidate for the energy and environmental remediation application for practical use. (11 Figures, 2 Tables, 67 References)

[14767]

Reddy K S, Singla H, and Natraj. 2019

Energy **189**: 116065

Heat Transfer and Thermal Power Laboratory,
Department of Mechanical Engineering, Indian
Institute of Technology Madras, Chennai 600036,
Tamil Nadu India

Gravity & wind load analysis and optical study of solar parabolic trough collector with composite facets using optimized modelling approach

This comparative study reveals that the solar parabolic trough collector with its facets made of the woven jute/glass fibre-reinforced polyester hybrid composite material yields $\gamma_{\max} = 0.957$ for avg. SDP = 1.34 mrad in stiff case and $\gamma_{\max} = 0.955$ for avg. SDP = 1.349 mrad in elastic case under gravity load, and $\gamma_{\max} = 0.866$ for avg. SDP = 3.78 mrad in stiff case and $\gamma_{\max} = 0.863$ for avg. SDP = 3.81 mrad in elastic case under both wind and gravity loads, resulting to be the best among considered models. Maximum weight reduction of up to 30% in stiff case and up to 4.5% in elastic case has also been observed compared to the conventional glass collector for hybrid composite model, thus reducing the tracking power and producing a cost-effective system. (47 Figures, 12 Tables, 29 References)

[14768]

Satsangi K P, Das D B, Sailesh Babu G S, and Saxena A K. 2019

Energy for Sustainable Development **52**: 40–51

Department of Electrical Engineering, Faculty of
Engineering, Dayalbagh Educational Institute, Agra,
Uttar Pradesh 282005, India

Real time performance of solar photovoltaic microgrid in India focusing on self-consumption in institutional buildings

In this paper, performance of a rooftop solar photovoltaic microgrid is presented with special emphasis on self-consumption

and grid interaction in the Indian scenario. Energy performance with various energy flow parameters, for a period of 1 year, is also presented. In contrast to various simulation studies of residential PV systems available, this study is a real time analysis of self-consumption with a low-resolution data from an educational institute. Besides, correlation coefficients between different parameters are also derived. Unlike residential systems, institutional buildings consume mostly when solar energy is available. The results show that the microgrid under study has the highest self-consumption of 89% with battery storage compared to other systems reported across the world. This makes a case for the need of deployment of such microgrids on institutional rooftops to bridge the gap in reaching the 40 GW rooftop target by 2022, provided appropriate incentives are introduced for the consumers to compensate for the extra cost incurred on storage. (19 Figures, 5 Tables, 33 References)

WIND ENERGY

[14769]

Bartolomé L and Teuwen J. 2019

Wind Energy 22: 140–151

Department of Aerospace Structures and Materials,
Faculty of Aerospace Engineering, Delft University
of Technology, Kluyverweg 3, HS, Delft 2629, The
Netherlands

Prospective challenges in the experimentation of the rain erosion on the leading edge of wind turbine blades

In this review work, the main issues for the wind industry in the experimentation with respect to erosion are examined. After a historical and general overview of erosion, this review focuses on the rain erosion on the leading edge of the wind turbine blades giving prominence to (1) the rain simulations, (2) experimental erosion facilities, and (3) variables to characterize erosion.

These three factors have to be improved to establish a research field enabling the prediction of erosion behaviour and providing useful information about how the rainfall affects the leading edge of the wind turbine blades. Moreover, these improvements in the experimentation of the erosion would be a first step to understand and predict the erosion damage of the wind turbine blades. Finally, this review work also will help to cope with experimental investigations and results in the rain erosion on the leading edge with a deeper critical thinking for future researchers. (8 Figures, 2 Tables, 98 References)

[14770]

Bortolotti P, Bottasso C L, Croce A, and Sartori L.

2019

Wind Energy 22: 65–79

Wind Energy Institute, Technical University of Munich,
Garching b. München, Germany

Integration of multiple passive load mitigation technologies by automated design optimization—The case study of a medium-size onshore wind turbine

The study is conducted with the help of a comprehensive automated design optimization procedure, which eases the generation and comparison of consistent solutions, each satisfying the same overall requirements. Passive load mitigation is here obtained by inducing bend-twist coupling to the blades. The coupling is generated by rotating the fibers of anisotropic laminates by the aerodynamic sweeping of the blade and by offsetting the spar caps in opposite directions on the pressure and suction sides. The first two solutions yield significant benefits, while the third, for this particular wind turbine, is ineffective. In addition, the typical power losses associated with bend-twist coupled blades are reduced by a novel regulation strategy that varies the fine pitch setting in the partial load region. After having considered each load mitigation technology by itself, fiber rotation

and sweeping are combined together and used to design a rotor with a larger swept area. The final design generates cost of energy savings thanks to a large-diameter, highly coned, soft-in-bending rotor that results in lower turbine costs and a higher energy capture compared with the baseline design. (6 Figures, 7 Tables, 31 References)

[14771]

Ghadirian A and Larsen G C. 2019

Wind Energy 22: 109–123

DTU Wind Energy, DTU Risø Campus, Frederiksborgvej 399 Roskilde, Denmark

Comparing rotor plane induction determined from full-scale measurements and CFD simulations

This paper investigates the flow field in the rotor plane of a full-scale operating wind turbine using full-scale light detection and ranging (LiDAR) measurements for the first time. Comparison of the measured flow field with results from large eddy simulations (LES) combined with an actuator line approach is also presented for in-depth study of the induction field in the rotor plane. The measurements include data from two synchronized LiDAR systems scanning the undisturbed upstream inflow field and measuring in the rotor plane. The standard deviation of the mean of velocity time series is presented as a measure of reliability. The method for calculating the axial velocity based on the line-of-sight velocity is explained and the uncertainty of such method is presented. The process of calculating the yaw misalignment is described. The time-averaged and phase-averaged axial velocity and induction factors are presented relative to radius and azimuth, and the general behaviour is described relative to the flow regimes around the blades, tower, and nacelle. Simulations and measurements are compared with special emphasis on the flow structures in the vicinity of the individual rotor blades. A convincing agreement between

measurements and simulations is demonstrated. The uncertainties originated from the imprecise positions and angles of the measurement instruments are shown. The uncertainties are limited to the middle parts of the blades between 15 m and 25 m from the root. In addition, longer selected time series show smaller uncertainties. This proves the reliability of the application of the methodology for even longer time series. (13 Figures, 5 Tables, 5 References)

[14772]

Kalverla P, Steeneveld G-J, Ronda R, and Holtslag A A M. 2019

Wind Energy 22(1): 34–48

Wageningen University and Research, Meteorology and Air Quality Section, Wageningen, The Netherlands

Evaluation of three mainstream numerical weather prediction models with observations from meteorological mast IJmuiden at the North Sea

In this paper, we use unique met mast and Lidar observations up to 315 m from met mast “IJmuiden,” located in the North Sea 85 km off the Dutch coast, to evaluate the representation of wind and other relevant variables in three mainstream meteorological models, namely, ECMWF-IFS, HARMONIE-AROME, and WRF-ARW, for a wide range of weather conditions. Overall performance for hub-height wind speed is found to be comparable between the models, with a systematic wind speed bias <0.5 m/s and random wind speed errors (centered RMSE) <2 m/s. However, the model performance differs considerably between cases, with better performance for strong wind regimes and well-mixed wind and potential temperature profiles. Conditions characterized by moderate wind speeds combined with stable stratification, which typically produce substantial wind shear and power fluctuations, lead to the largest misrepresentations in all models. (9 Figures, 1 Table, 47 References)

[14773]

Kumar R, Agrawal H P, Shah A, and Bansal H O. 2019
Sustainable Energy Technologies and Assessments
36: 100533
 Power Electronics & Drives Lab, Birla Institute of
 Technology and Science, Pilani, Rajasthan, 333031,
 India

Maximum power point tracking in wind energy conversion system using radial basis function based neural network control strategy

In this paper, a neural network tuned controller for maximum power point tracking (MPPT) in wind energy conversion system (WECS) is proposed. This technique utilizes radial basis function-based neural networks (RBF-NN) and tracks the MPP using duty cycle control. The WECS is based on permanent magnet synchronous generator (PMSG). The rectifier output voltage and power are measured and fed into an RBF-NN controller. The MPPT algorithm controls the duty cycle of a DC-DC boost converter to extract the maximum power. The output of the boost converter is tied to the grid using a voltage source inverter (VSI). Unlike the conventional methods, MPPT using the proposed method does not require knowledge of wind turbine power characteristics, thus minimizing the need for various measuring instruments. The method implemented is also compared with other commonly used MPPT techniques, such as fuzzy logic control (FLC), perturb and observe (P&O), and back-propagation (BP) based NN. The proposed system provides better results as compared to other relevant results available in the literature. The proposed method is implemented using MATLAB/Simulink and then validated in real-time using digital simulation hardware OPAL-RT 4510. (27 Figures, 3 Tables, 27 References)

[14774]

Mishra S P, Dhar S, and Dash P K. 2019
Journal of Energy Storage **21**: 418–434
 Siksha O Anusandhan (Deemed to be University),
 Bhubaneswar, Odisha 751030, India

An effective battery management scheme for wind energy systems using multi Kernel Ridge regression algorithm

Battery energy storage (BES) systems are adequate alternative for any wind power generation system (WPGS) for achieving greater operational flexibility by compensating the generation volatility. An efficient local energy management (LEM) for wind/battery energy storage (BES) system is described in this chapter to reduce the prediction error and improve the associated battery life. Error in prediction impacts on distributed generation (DG) control reference and system stability for local energy management. BES life degrades by prediction error in terms of battery power loss and temperature. A doubly-fed induction generator (DFIG) based WPGS is considered as the primary DG, where DC link voltage stability challenges due to wind speed volatility, as well as prediction error, is addressed with lithium-ion (Li-ion) BES stacks. A new online multi kernel ridge pseudo inverse neural network (MK-RPINN) algorithm is proposed to obtain an impactful decrease in the prediction error. A new secondary controller is proposed here for addressing the temperature effect of the battery. A model reference (MR) based battery temperature plan, linked to rule-based switching characteristics of battery stacks with temperature tolerance, is being incorporated in the proposed secondary controller. The effectiveness of this model is represented in various observations through TMS320C6713 and MATLAB platform. (12 Figure, 3 Tables, 37 References)

[14775]

Pedersen M D. 2019
Wind Energy **22**: 124–139
 ITK, NTNU, O.S. Bragstads plass 2D,
 Trondheim 7034, Norway

Steady and transient inflow dynamics with actuator disk vortex theory

The actuator disk is a well-known and widely used theoretical tool in wind engineering. This work proposes a new theory based on an actuator

surface, capable of treating time-varying vectorial load distributions and yaw/pitch misalignment. A simplified representation of vortex motion is used to arrive at a tractable problem. The theory is not restricted to disks; arbitrary coplanar (optionally disjoint) actuator surfaces may be modeled. Some of the theoretical novelties used in the modeling include use of the fractional Laplacian and extensive use of the Fourier transform on R^2 . Promising experimental validation based on pitch-step experiments at the Tjæreborg turbine is furnished. Comparisons are also made to existing methodologies. Analysis and numerical work shows that the model encapsulates Coleman's vortex theory. (8 Figures, 31 References)

[14776]

Raju V S N N, Premalatha M, and Rao D V S K. 2019
International Journal of Hydrogen Energy **44**(51):
27907-27920

Department of Energy and Environment, National
Institute of Technology, Tiruchirappalli, Tamil Nadu
620015, India

A novel approach for reactive power compensation in hybrid wind-battery system using distribution static compensator

This paper proposes a novel algorithmic approach to compensate the reactive power using distribution static compensator (DSTATCOM) for wind energy conversion system (WECS). Three-phase bidirectional converter is utilized to exchange real and reactive power in both directions. The plug-in hybrid electric vehicle (PHEV) is enabled to consume during excess power availability. The battery is connected through a separate bidirectional DC-DC converter to adjust the power at the desired range. The compensated reference current is being generated based on the load requirement, wind power generations, and state of charge (SOC) status. The proposed algorithmic approach helps to stabilize the grid by injecting accurate compensating current at the point of common

coupling (PCC). Thereby, the proposed approach ensures the grid at balanced states under all operating cases. In order to validate the proposed approach, different case studies have been considered and validated through simulation results using PSCAD/EMTDC software. (9 Figures, 2 Tables, 48 References)

[14777]

Rui X, Yin W, Dong Y, Lin L, and Wu X. 2019

Wind Energy **22**: 49-64

School of Energy, Power and Mechanical Engineering,
North China Electric Power University, Beijing
102206, China

Fractional order sliding mode control for hybrid drive wind power generation system with disturbances in the grid

This paper synthesizes a new-type fractional-order sliding mode controller (FOSMC) with a load torque observer (LTO) for the high-accuracy speed control of permanent magnet synchronous motor (PMSM) in SRDM. Taking advantage of ridge regression algorithm, related parameters including rotational inertia and viscous friction coefficient of speed regulating system are calculated accurately. Finally, comparative experiments are carried out under four cases of mean of 5, 10, 13, and 21 m/s wind speeds to verify the satisfactory performances of designed FOSMC with LTO. Comparative experimental results show that FOSMC with LTO can effectively eliminate undesirable chattering effect. Additionally, under operating conditions of changing wind speeds, SSR, and sudden load fluctuation in power grid, the output speed of SRDM that corresponds directly to the frequency output of SG can be steadily and accurately regulated by using proposed control scheme. SRDM equipped with designed controller enables the power frequency to meet the National Standard of PR China perfectly. (16 Figures, 4 Tables, 43 References)

[14778]

Shankar C G and Behera M R. 2019

Ocean Engineering **191**: 106509

Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai, Maharashtra, 400076, India

Wave Boundary Layer Model based wind drag estimation for tropical storm surge modelling in the Bay of Bengal

The present study is aimed at analysing the most reliable wind drag evaluation method for real-time predictions of storm surge. In an attempt to examine the same, two tropical cyclones (Thane and Vardah) eventuated in the Northern Indian Ocean were modelled. Four most widely used linear empirical and quadratic relations along with the enhanced Wave Boundary Layer Model (WBLM) were executed for the estimations of wind drag coefficient. The surge was subsequently simulated (using the coupled hydrodynamic circulation and wave model: ADCIRC and SWAN, respectively) individually for each of the above wind stress methods to obtain the corresponding water levels and wave features. The modelled values were further validated with the observed water level and wave data. It was quite intuitively observed that WBLM outperformed (i.e., significantly correlated with the observed values) its linear counterparts since the former pragmatically includes the effects of air-sea interface at high wind speeds in the model. However, due to insufficiency of the observed parameters, water levels obtained at locations of maximum wind speeds could not be satisfactorily validated. The WBLM-based computation of significant wave heights in deep as well as shallow water nevertheless enabled efficient and reasonably reliable estimations of the peak incidents (along with relative wave directions and energy densities). Although this study essentially includes cyclonic wind velocities, it was identified that with given wind field that includes the 'pre-existing' wind-wave

climate in the relevant domain (i.e., before the cyclone genesis), the modelled estimates could be more precise. (14 Figures, 2 Tables, 63 References)

[14779]

Smilden E, Bachynski E E, Sørensen A J, and Amdahl J. 2019

Wind Energy **22**: 89–108

Centre for Autonomous Marine Operations and Systems, Department of Marine Technology, Norwegian University of Science and Technology, Trondheim, Norway

Wave disturbance rejection for monopile offshore wind turbines

The dimensions of offshore wind turbine (OWT) support structures are governed by fatigue considerations. For 6–10 MW OWTs, wave loads are often dominating in terms of fatigue utilization. The present work proposes a control scheme to reduce the wave-induced fatigue loads in OWT support structures. The control scheme applies collective pitch control to increase both damping and stiffness of fore-aft vibration modes. With the conventional active tower damping, efficient wave disturbance rejection is restricted to a narrow frequency range around the first fore-aft modal frequency. The proposed control scheme achieves efficient wave disturbance rejection across a broader frequency range. Here, tower feedback control is implemented via an auxiliary control loop. Based on a low-fidelity model, the effect of the tower feedback loop on the stability margins of the basic controller is analysed. The results show that, within certain boundaries, the stability margins are improved by the stiffness term in the tower feedback loop. Consequently, the need to reduce the bandwidth of the basic controller to accommodate tower feedback control is relaxed. Based on time-domain simulations carried out in an aero-hydro-servo-elastic simulation tool, the lifetime effects of the proposed control scheme are analysed.

Compared with the conventional active tower damping, a more favourable trade-off between adverse side effects and the support structure's fatigue damage is achieved with the proposed control scheme. (12 Figures, 5 Tables, 60 References)

[14780]

Swytink-Binnema N, Godreau C, and Arbez C. 2019
Wind Energy 22: 80-88

Department of Research & Innovation, Nergica,
Gaspé, Canada

Detecting instrumental icing using automated double anemometry

In this paper, researchers propose several improvements to the standard double anemometry method for ice detection. In the double anemometry method, the wind speed measurement from a heated reference anemometer is compared with that of an unheated anemometer. A lower measurement from the unheated sensor suggests the presence of ice. First, researchers propose using a wind speed difference (not a ratio) because anemometers should not deviate significantly at any wind speed under ice-free conditions. Second, the threshold should vary with ambient temperature to account for cup anemometer slowdown caused by thickening bearing grease. Finally, sensitive thresholds should be used to overdetect ice and false events removed during postprocessing. We created an algorithm to automatically determine the required thresholds and tested it on seven wind turbines during a full winter at a cold climate site. When compared with ice thickness measurements from cameras, the algorithm was equal to or outperformed the manual double anemometry method across all seven turbines. (10 Figures, 4 Tables, 22 References)

ELECTRIC POWER ENGINEERING

[14781]

Akram V, Sahoo P K, and Jangam B P. 2019

Utilities Policy 61: 100977

Department of Liberal Arts, Indian Institute of
Technology Hyderabad, Kandi, Sangareddy,
Telangana, 502285, India

Do shocks to electricity consumption revert to its equilibrium? Evidence from Indian states

This study investigates the stationary properties of electricity consumption at the aggregate and user-group levels (agricultural, industrial, commercial, domestic, and miscellaneous) for 18 Indian states over the period from 1971–72 to 2015–16. Our analysis employs the two-step Lagrange Multiplier (LM) and the three-step Residual Augmented Least Square Lagrange Multiplier (RALS-LM) unit root tests. The results obtained suggest evidence of stationarity at aggregate and user groups in most states. The findings infer that shocks to electricity consumption in the Indian states have only a temporary effect. These results suggest that electricity demand can be modelled for forecasting and policymaking. (1 Figure, 8 Tables, 50 References)

[14782]

Riva F, Gardumi F, Tognollo A, and Colombo E. 2019

Energy 166: 32-46

Politecnico di Milano, Department of Energy, Via
Lambruschini 4, Milan, Italy

Soft-linking energy demand and optimisation models for local long-term electricity planning: an application to rural India

This study aims at soft-linking a bottom-up approach for short- and long-term forecasts of load profiles with an energy optimization model in a more comprehensive rural energy planning procedure. The procedure is applied to a small Indian community, and it is based

on three blocks: (i) a bottom-up model to project households' electrical appliances, which adopts socio-economic indicators to make long-term projections, (ii) a stochastic load profile generator, which employs correlations and users' habits for assessing the coincidence and load factors, and (iii) an energy optimization model based on OSeMOSYS to find the economic optimum. The simulations show that demand models based on socio-economic indicators lead to more structured and less arbitrary scenarios. The soft-link with the energy optimization model confirms that when accounting for short- and long-term variabilities of electricity demand together, the optimal capacities and costs can vary up to 144% and 50%, respectively. Integrating optimization tools to bottom-up models based on socio-economic indicators for forecasting electricity demand is therefore pivotal to set more reliable investment plans in rural electrification. (15 Figures, 4 Tables, 15 References)

ENERGY PLANNING AND POLICY

[14783]

Bhola M, Kumar N, and Ghoshal S K. 2018

Energy **162**: 158-170

Department of Mining Machinery Engineering, IIT (ISM) Dhanbad, Jharkhand 826004, India

Reducing fuel consumption of Front End Loader using regenerative hydro-static drive configuration-an experimental study

This paper highlights the effect of under-loading the engine and the hydraulic system of a Front End Loader (FEL). In this respect, a novel idea to modify load cycle of engine is applied in the conventional hydrostatic-split power transmission (CH-SPT) drive by incorporating additional load on the drive through the DC generator. The load on modified system, called Regenerative Hydrostatic-Split Power Transmission (RH-SPT) drive, is the loading

pump unit and DC generator unit used for equivalent duty cycle generation of the FEL and electrical energy generation, respectively. The excess load of the DC generator is varied through the controller depending on engine's optimal efficient torque and the load torque. This assists the engine to operate in its efficient zone during under-loading conditions. Also, a MATLAB®/Simulink model is made and validated experimentally. The validated model is analysed to compare the performances and fuel consumption of the conventional HST drive, CH-SPT drive, and RH-SPT drive. It is concluded that with increase in fuel consumption of the RH-SPT system by 10% and 56% of the CH-SPT and conventional drive system, the electric power regeneration through the DC generator increases by 21% and 200% of the maximum power generated in the respective systems. (14 Figures, 3 Tables, 21 References)

[14784]

Bindu E and Reddy B V R. 2019

Sustainable Computing: Informatics and Systems **23**: 136-143

GGSIIP University, Amity School of Engineering and Technology, New Delhi, India

A novel solution to energy efficiency in multi-user multi-carrier decode-and-forward wireless relay networks

This work proposes a new solution for maximizing energy efficiency in relay-assisted multi-carrier multi-user wireless networks. In this context, a new dynamic (optimal) power allocation algorithm for Decode-and-Forward relay is proposed here. The energy efficiency is optimized in terms of consumed energy per bit subjected to constraint of total power. From numerical results, it is observed that energy efficiency performance improves with proposed dynamic power allocation algorithm. (10 Figures, 2 Tables, 10 References)

[14785]

Chaudhari A and Mulay P. 2019

The Electricity Journal 32(10): 106674

Symbiosis Institute of Technology (SIT), Symbiosis International (Deemed University), Pune, Maharashtra 412115, India

Algorithmic analysis of intelligent electricity meter data for reduction of energy consumption and carbon emission

The gradational clustering is an essential way to accommodate the influx of new data seamlessly for accurate analysis. However, given the volume of IEM data and the number of data types involved makes the gradational clustering highly complex. Microsoft Azure provides the processing power necessary to handle gradational clustering analytics. The paper's aim is to develop a Distributed Log-likelihood Based Gradational Clustering Algorithm on Microsoft Azure for analysis of IEM data. This research uses the real dataset of Irish households collected by IEMs and related socio-economic data, including the geographic information, demographic data. It is apparent from the study that algorithmic analysis helps the household customers to monitor and improvise electricity consumption patterns and utility providers to reduce power outage and avoid capital expenses of building new plants. This research will be extremely useful for maintaining the environment by reducing pollution via carbon production by power plants. (11 Figures, 3 Tables, 26 References)

[14786]

Ch R, Singh A K, Pathak M K, Singh A,

Kesavachandran C N, Bihari V, et al. 2019

Chemosphere 226: 636-644

Analytical and Pesticide Toxicology Laboratories, Regulatory Toxicology Group, CSIR-Indian Institute of Toxicology Research (CSIR-IITR), MG Marg, Lucknow, 226001, Uttar Pradesh, India; UCL Institute of Neurology, Queen Square, London, WC1N 3BG, UK

Saliva and urine metabolic profiling reveals altered amino acid and energy metabolism in male farmers exposed to pesticides in Madhya Pradesh State, India

The study was aimed to establish non-invasive matrices, such as urine and saliva, as alternative diagnostic matrices to the occupational exposure studies. Saliva and urine samples were collected from 51 pesticide applicators and acquired metabolic profiles of urine and saliva samples using gas chromatography-mass spectrometry (GC-MS). Multivariate pattern recognition and pathway analysis were used to analyse and interpret the data. Investigation of endogenous metabolic profiles revealed remarkable discrimination in both saliva and urine samples of the exposed population, strongly suggesting the changes in metabolic composition within the identified metabolites (for urine samples: accuracy 0.9766, $R^2 = 0.9130$, $Q^2 = 0.8703$; for saliva samples, an accuracy of 0.9961, $R^2 = 0.9698$, $Q^2 = 0.9637$). Thirteen metabolites of urine samples and 16 metabolites of saliva samples were identified as differential metabolites specific to pesticide exposure. Pathway analysis of differential metabolites revealed that amino acid metabolism, energy metabolism (glycolysis and TCA cycle), and glutathione metabolism (oxidative stress) were found to affect in pesticide exposed population. The present study suggested that GC-MS based metabolomics can help to reveal the metabolic perturbations in human population after pesticide exposure. (3 Figures, 3 Tables, 14 References)

[14787]

Ghosh B and Chakma N. 2019

Ecological Indicators 102: 21-32

Khorad Amena High School, Barddhaman 713422, West Bengal, India

Composite indicator of land, water and energy for measuring agricultural sustainability at micro level, Barddhaman District, West Bengal, India

This paper aims to analyse agricultural sustainability at micro level by developing a composite indicator of land, water, and energy used for crop production. Cropland footprint (CF), water footprint (WF), and entropy overproduction (E_{op}) are selected as indicators of land, water, and energy, respectively, with the objective to explore man-land interaction by CF, while WF and E_{op} represent the impact of that interaction. In the study area, cropland surplus or deficit is inversely related with WF and E_{op} . Surplus crops such as paddy and potato have higher WF and E_{op} . Hence, they are responsible for agricultural unsustainability. WF and E_{op} are highest for paddy (8912 m³/ha) and potato (117,565 MJ/ha), respectively. Grey water footprint ($WF_{c, grey}$) is the highest for potato (3708 m³/ha). Pulses (with negative E_{op} of -9124 MJ/ha) are proved the most sustainable crop with the highest potentiality to boost agroecosystem sustainability. The results derived from the analysis indicate that increasing use of chemicals and more specialization of water and energy exhaustive crops are reducing agricultural sustainability. The study also suggests for necessary transformations of cropping pattern with special emphasis on incorporation of pulses, oilseeds, and so on and non-productive energy investment to reinstall natural quality of agroecosystem not only in the studied areas, but also in other areas facing similar site and situation. (17 Figures, 2 Tables, 74 References)

[14788]

Jat S L, Parihar C M, Singh A K, Kumar B, Choudhary M, Nayak H S, *et al.* 2019

Science of The Total Environment **664**: 659-668

ICAR-Indian Institute of Maize Research (IIMR), New Delhi 110012, India

Energy auditing and carbon footprint under long-term conservation agriculture-based intensive maize systems with diverse inorganic nitrogen management options

A greater energy grant in diesel-fed machinery driven farming substantiates the higher GHGs emission along with improper input (fertilizer, pesticide, and irrigation) use and intensive soil management. Conservation tillage, residue retention, and diversified crop rotations were advocated because of their multiple benefits. Hence, we explored the energy requirement and carbon footprint of conservation agriculture (CA) based maize production systems. Coated N fertilizer (sulphur coated urea (SCU) and neem coated urea (NCU)) were compared with unfertilized and uncoated prilled urea (PU) in the scenario of with and without residue retention on permanent beds (PB) under diversified maize systems (MMuMb: maize-mustard-mung bean and MWMb: maize-wheat-mung bean) in search of a sustainable and energy efficient production system with lesser carbon footprint. Results of the 4-year study showed that crops planted on permanent bed with crop residue (PB + R) registered 11.7% increase in system productivity compared to PB without residue (PB - R). N management through neem coated urea (NCU) recorded 2.3% and 10.9% higher system productivity compared with non-coated prilled urea plot under PB - R and PB + R, respectively. MMuMb was marginally superior than MWMb system in terms of cropping sequence yield, profitability, and energy and carbon use efficiency. Crop residue retention in zero tilled PB increased cost of cultivation by 125 and 147 USD/ha in MMuMb and MWMb systems, respectively. The quantified carbon footprint value was higher in MWMb system. In CA-based practices, crop residue management contributed the highest energy input (61.5–68.4%), followed by the fertilizer application (17–20%). Among N management practices, NCU significantly improved system productivity and profitability in all the residue applied plots compared to unfertilized and prilled urea (PU) applied plots. Similarly, higher energy output was also observed in NCU treated plots. However,

carbon footprint value was higher in PU (268–285 CO₂-e kg/mg) plots than NCU (259–264 CO₂-e kg/mg) treated plots. Thus, the study supports and recommends that the CA-based MMuMb system with efficient N management through NCU is an environmentally safe, clean, and energy efficient. Hence, it can reduce carbon footprint, will ensure food security, and will mitigate climate change. (3 Figures, 8 Tables, 57 References)

[14789]

Katre A and Tozzi A. 2019

Energy Research & Social Science 54: 129–139

University of Minnesota Duluth, Duluth, United States

Using hugs, carrots and sticks: how agents exercise power in the transition to community-owned energy systems in remote India

This paper contributes to the field of energy transition, examining the role of power to establish and govern long-lasting community-owned DRE systems. The study develops a novel conceptual framework that analyses power as a system, whose constituting components include entities (who), resources (what), instruments (how), motivations (why), and the spatial-temporal dimensions (where and when). Using qualitative methods, the framework is applied to examine 24 community-owned DRE systems implemented by a single solution provider in remote India that have been operational for many years. Learnings suggest that at the time of establishing the systems, the solution provider centrally mobilizes power, distributing hugs to bring actors together and generate consensus for the model. Conversely, while governing the systems, power is mobilized by multiple entities, each using different instruments to achieve the collective aim of building local capacities for technical and administrative tasks. While external actors support the communities using a mix of hugs, carrots, and sticks, local actors themselves engage in a virtuous cycle of learning by doing, leveraging their knowledge

and abilities to acquire the skills to ensure long-lasting solutions. This model requires carefully designed contractual agreements, enabling non-hierarchical relations, flexibility, and devolving responsibilities to the communities to devise and enforce contextually relevant rules. Retaining the power of alienation with external stakeholders acts as a deterrent, preventing elite capture and ensuring inclusivity. (7 Figures, 66 References)

[14790]

Keshari A, Sonsale A N, Sharma B K, and Pohekar S D. 2018

Procedia CIRP 78: 2–7

Department of Mechanical Engineering, Motilal Nehru National Institute of Technology, Allahabad, 211004, India

Discrete event simulation approach for energy efficient resource management in paper & pulp industry

To improve energy efficiency of a paper and pulp industry, full capacity utilization of the processing equipment and diverse energy source utilities are promoted, while at the same time processing of diverse raw materials, meeting of strict processing time requirements, seamless material flow, and obtaining required product quality are important concerns to be fulfilled. This is similar to a resource management problem while energy is considered as one of the measurable resources, wherein estimation of energy consumptions is a crucial/complicated aspect. Discretized form of energy consumption (approximate energy consumed by the unit amount of intermediate products at different intermediate processing stages) concept is utilized here with discrete event simulation for consumed energy estimation/analysis. The research deals with a real-time working paper and pulp industry resource management problem, wherein overall energy consumption rate and production rate were analysed for some commonly occurring situation of efficiency reduction of the processing station(s). Energy

efficient solutions are evaluated with varying production flow (varying the percentage of the raw material) and resource management options (turning on/off paper machines). Energy efficient solution that ensures minimum loss in production rate and minimizes disturbances in material flow is suggested for implementation. (10 Figures, 2 Tables, 10 References)

[14791]

Kumar A, Meena N K, Singh A R, Deng Y, He X, Bansal R C, *et al.* 2019

Applied Energy **253**: 113503

College of Electrical Engineering, Zhejiang University, Hangzhou 310027, PR China

Strategic integration of battery energy storage systems with the provision of distributed ancillary services in active distribution systems

In this paper, a new bi-level optimization framework is developed to optimally allocate the intense wind power generation units and battery energy storage systems with the provision of central and distributed ancillary services in distribution systems. Two battery energy storage systems and one shunt capacitor are strategically allocated for coordination of wind power generation. One of the batteries is deployed at a grid substation to participate in central ancillary services, whereas the second is participating in distributed ancillary services. At level-1, all the distributed energy resources are optimally allocated while minimizing the annual energy loss of distribution systems. Level-2 performs hourly optimal energy and ancillary services management of distributed resources deployed at level-1. The objectives considered at level-2 are the minimization of hourly load deviation, reverse power flow towards the grid, power loss, and node voltage deviation. The proposed framework is implemented on a real-life Indian 108-bus distribution system for different cases and solved by using a genetic algorithm. The comparison of simulation results reveals the promising advantages of the proposed

optimization framework. It provides more energy loss and demand deviation reduction, improved system voltage, and power factor at higher wind penetration as compared to the cases in which distributed ancillary services are ignored in the planning stage. (12 Figure, 3 Tables, 117 References)

[14792]

Pal M, Alyafi A A, Ploix S, Reignier P, and

Bandyopadhyay S. 2019

Applied Energy **238**: 1452–1470

Machine Intelligence Unit, Indian Statistical Institute, 203 Barrackpore Trunk Road, Kolkata 700108, West Bengal, India

Unmasking the causal relationships latent in the interplay between occupant's actions and indoor ambience: a building energy management outlook

The primary objective of this work is to demonstrate how the changes in occupants' actions towards Pareto-optimality can be beneficial for a better indoor ambience and thereby associating the users with the energy systems. The proposed approach considers the context, documented by sensors, of an office at Grenoble Institute of Technology, France. Utilizing this data, approximation-guided evolutionary multi-objective optimization algorithm (AGE-II) generates actions by minimizing thermal dissatisfaction, air quality dissatisfaction, heater energy consumption, and interference with the daily routine. The optimal and historical plans are compared to reveal the causality of the energy systems that are influenced by occupants' actions. These explanations develop awareness of the effect of changing occupants' actions to an optimal plan by presenting to the occupants the reasons for such changes. Hence, the proposed work helps occupants to perceive the impact of actions that allow them to adapt their habits to a more energy-efficient routine. (11 Figures, 2 Tables, 53 References)

[14793]

Sangwan K S and Sihag N. 2019

Procedia CIRP **80**: 67–72Birla Institute of Technology and Science, Pilani
Campus, Pilani 333031, India**Multi-objective optimization for energy efficient machining with high productivity and quality for a turning process**

This study is an attempt to obtain a suitable combination of the turning parameters to optimize material removal rate and power for different targeted values of surface roughness. The predictive model has been developed using response surface methodology. Model fitness and adequacy have been confirmed with analysis of variance. (4 Figures, 4 Tables, 33 References)

[14794]

Swaminathan J, Tow E W, Stover R L, and Lienhard J H. 2019

Desalination **470**: 114097Dr. Kiran C. Patel Center for Sustainable
Development, Mechanical Engineering Discipline, IIT
Gandhinagar, Gujarat 382355, India**Practical aspects of batch RO design for energy-efficient seawater desalination**

In this paper, we use a transient numerical model of the RO (reverse osmosis) process to investigate the impact of several practical loss mechanisms on the overall energetic performance of batch SWRO compared to a conventional continuous system. A critical variable that controls the energetic advantage of batch RO is the reset time between cycles. A large reset time necessitates higher operating flux and therefore results in increased energy consumption. On the other hand, ensuring a low cycle reset time requires higher energy for the refilling process. A batch SWRO design with an atmospheric pressure feed tank and pressure exchangers for energy recovery does not show promise for energy savings. Batch SWRO must be designed with a large number of short pressure vessels

(with fewer membranes each) and lower energy recovery losses (e.g., by using pressurized feed storage) in order to reduce energy consumption by up to 8%. These modifications are more complex and hence capital expenses would determine the overall feasibility of such designs to improve seawater desalination. (14 Figures, 2 Tables, 28 References)

[14795]

Wang Q, Jiang R, and Zhan L. 2019

Journal of Cleaner Production **229**: 806–817School of Economic and Management, China
University of Petroleum (East China), Qingdao,
Shandong 266580, People's Republic of China**Is decoupling economic growth from fuel consumption possible in developing countries? – A comparison of China and India**

To demonstrate the relationship between coupling/decoupling economy and energy in China and India better, this work has made the following contributions: (i) analyses the decoupling elasticity between economic growth and energy consumption by using the Tapio model, (ii) explores the five key effects (labour input, investment, energy structure, energy intensity, and technology level) of decoupling elasticity by combining the Cobb Douglas (C-D) function and Log-Mean Divisia Index (LMDI) method, and (iii) evaluates the decoupling efforts by applying decoupling efforts model in China and India between 1990 and 2015. The decoupling elasticity results show that China's decoupling elasticity curve is in an inverted U-shaped trend, and the decoupling elastic value is concentrated between 0 and 0.8 in most years, indicating a weak decoupling state. Furthermore, the decoupling state is strong during 2014–2015, indicating China has initially achieved the decoupling of economy and energy consumption. India's decoupling elasticity presents irregular fluctuations, indicating that

India's decoupling status is not very satisfactory. The decomposition results uncover that major effects of decoupling in China and India are similar; that is, the investment effect is the biggest driver, which contributed to a cumulative increasing impact in energy consumption in China and India by 3017.10 million tonnes oil equivalent and 675.18 million tonnes oil equivalent, respectively. The energy intensity effect is the greatest inhibiting factor, which contributed to a cumulative reduction in energy consumption in China and India by 1437.81 million tonnes oil equivalent and 139.21 million tonnes oil equivalent, respectively. The decoupling efforts results show that decoupling effort in China is better than that in India. Improving energy efficiency is the leading contributor to China's decoupling efforts, while advancing technology is the major contributor to India's decoupling effort. (11 Figures, 2 Tables, 68 References)

ENERGY CONSERVATION, CONSUMPTION, AND UTILIZATION

[14796]

Ameer R, Rolly R M, and Jacob J. 2018
Procedia Computer Science **143**: 827–834
Rajagiri School of Engineering and Technology, Kochi
682039, Kerala, India

Dynamic base station or relay station deployment and small cells on/off strategy for green ultra dense networks

In this paper, the researchers develop model that considers both energy consumption and efficiency. This can be stated as two subproblems: dynamic deployment of base station or relay station at the centroid depending on the user distribution and dynamic small cells on/off approach to reduce the unwanted energy consumption of underutilized cells. This paper also examines a comparison between the existing system and some of the modified systems

in terms of energy consumption, efficiency, complexity, and cost. Simulation results shows that the energy consumption can be reduced up to 14% and efficiency can be increased up to 87.5%. (8 Figures, 1 Table, 5 References)

[14797]

Bhamare D K, Rathod M K, and Banerjee J. 2019
Energy and Buildings **198**: 467–490
Mechanical Engineering Department, Sardar
Vallabhbhai National Institute of Technology, Surat,
Gujarat 395007, India

Passive cooling techniques for building and their applicability in different climatic zones—The state of art

A major part of the building energy is consumed in providing thermal comfort to occupants. Passive cooling techniques can be a promising alternative to satisfy the cooling requirements of the building and reduce the building energy consumption. Selection of suitable passive cooling technique is dependent on many factors, including climatic conditions, building space constraints, and performance of the passive technique. Thus, in order to adopt a suitable passive cooling technique for a given building, a thorough knowledge of different passive cooling techniques along with their applications and performance parameters is necessary. The objective of this article is to provide a comprehensive review on passive cooling techniques along with their classification, working, applications, and recent developments and to analyse the influence of significant parameters such as building cooling load and indoor temperature on the performance of passive cooling techniques. The review establishes that passive cooling techniques have the potential to maintain the indoor temperature within the comfort range while reducing the building cooling load. (14 Figures, 14 Tables, 255 References)

[14798]

Biswas T, Kuila P, and Ray A K. 2019

Engineering Science and Technology, an International Journal **22**: 646–655Department of Computer Science & Engineering,
National Institute of Technology Sikkim, 737139,
India**A novel resource aware scheduling with multi-criteria for heterogeneous computing systems**

The proposed work is analysed and validated by extensive simulations with synthetic and benchmark data sets. Through the simulation results, it is observed that the proposed work has considerable improvements over Min–Min, MCT, genetic algorithm (GA), and priority based performance improved algorithm (PPIA). A statistical hypothesis test analysis of variance (ANOVA) and *post hoc* test are performed to demonstrate the effectiveness of the proposed work. (6 Figures, 15 Tables, 26 References)

[14799]

Dewangan B K, Agarwal A, Venkatadri M, and Pasricha A. 2019

Procedia Computer Science **152**: 204–211University of Petroleum and Energy Studies, Energy
Acres, Bidholi, Dehradun, 248007, India**Self-characteristics based energy-efficient resource scheduling for cloud**

Energy optimization in cloud computing is more attractive. Most of the existing methodologies for scheduling of resources focus on cost and execution time. In fact, the resource failures also distract the execution of cloud resource provisioning, which results in more operative cost and time. In this paper, the self-optimized energy efficient resource management strategy has been considered, which gives the optimal solution to maximize the resource utilization and identify the faulty resources to avoid misleading of scheduling. This strategy allocates the resources to the workloads submitted by the cloud user by the fulfillment of the QoS with less SLA violation

rate and maximizes the resource utilization at low cost. (4 Figures, 5 Tables, 31 References)

[14800]

Jiang Q, Chen S, Deng X, Feng Y, Reddy N, Zhu Q, et al. 2019

Journal of Cleaner Production **210**: 646–652Key Laboratory of Textile Science & Technology,
Ministry of Education, College of Textiles, Donghua
University, Shanghai, PR China**A sustainable low temperature yarn reinforcing process to reduce water and energy consumptions and pollution in the textile industry**

In this research, a low temperature alkaline treatment was developed to reinforce pure cellulose or cellulose blended warp yarns with the low molecular weight components directly dissolved from yarns. This treatment eliminates the need for the conventional sizing and desizing processes, leading to substantial reduction in the water pollution and the consumption of water and energy. The morphology, hairiness, chemical structure, crystallinity, mechanical properties, abrasion resistance, dyeability, and weavability of the yarns after the low temperature alkaline treatment were investigated in comparison to starch and starch/poly(vinyl alcohol) sized yarns. The results indicated that this new treatment could permanently remove 94% harmful hairiness of warps, provide comparable reinforcement in the tenacity (31% enhancement), abrasion resistance (27 cycles), and better retention in elongation (6%) and enhanced dyeability (92% higher in K/S value). Notably, the fabrics with the treated warps did not require any desizing process and showed softness similar to the desized fabrics. Taking into account the low cost, short process, reduced water and energy consumptions, and less pollution, this new approach of warp treatment has great potential to promote sustainability and environmentally friendly processing in the textile industry. (7 Figures, 1 Table, 28 References)

[14801]

Kumar M and Sharma S C. 2018

Sustainable Computing: Informatics and Systems **19**: 147-164

IIT Roorkee, Roorkee - Haridwar Highway, Roorkee, Uttarakhand 247667, India

PSO-COAGENT: cost and energy efficient scheduling in cloud environment with deadline, constraint

The rapid growth in demand of computational power invites the massive growth in cloud data centres and the requirement of large amounts of energy consumption in cloud data centres becomes a serious threat to the environment. To reduce the energy consumption and gain the maximum profit in cloud environment is a challenging problem due to incompatibility between workstation (physical machine) and unpredictable user demand. In this paper, we have proposed a resource allocation model for processing the applications efficiently and particle swarm optimization based scheduling (PSO) algorithm named as PSO-COAGENT algorithm that not only optimizes execution cost and time but also reduces the energy consumption of cloud data centres, considering deadline as the constraint. The developed PSO-COAGENT algorithm has been simulated at CloudSim and it is observed that it reduces the execution time, execution cost, task rejection ratio, and energy consumption and increases the throughput in comparison to PSO, honey bee, and min-min algorithm. (10 Figures, 13 Tables, 45 References)

[14802]

Kushwah S, Dhir A, and Sagar M. 2019

Journal of Cleaner Production **236**: 117519

Department of Management Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, Delhi 110016, India

Ethical consumption intentions and choice behavior towards organic food. Moderation role of buying and environmental concerns

This study investigated the factors driving ethical consumption intentions and choice behaviour among community-based buyers and non-buyers using the theory of consumption values. The moderating influence of buying involvement and environment concerns on all the studied relationships was also examined. Data were collected using structured questionnaire survey at different organic farmers' markets. A total of 282 community-centric organic buyers and 170 non-buyers participated in the study. Structural equation modelling approach was employed for data analysis. The results indicated the significant association of social, emotional, and epistemic values with ethical consumption intentions. Epistemic value was identified as the most important influencer towards both ethical consumption and choice behaviour. Buyers and non-buyers were not significantly different. However, consumers with varying levels of environmental concerns were statistically different when it came to the associations of epistemic and price-related functional values and ethical consumption intentions. The study results could be utilized by managers and practitioners to target this niche market and promote organic food among the mainstream market. This may, in turn, lead to increased adoption of the cleaner production practices in terms of organic farming, which is beneficial for both people and the planet. (2 Figures, 7 Tables, 92 References)

[14803]

Natesan G and Chokkalingam A. 2019

ICT Express **5**(2): 110-114

Sathyabama Institute of Science and Technology (Deemed to be University), Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai, Tamil Nadu 600119, India

Task scheduling in heterogeneous cloud environment using mean grey wolf optimization algorithm

In this study, researchers proposed mean grey wolf optimization algorithm to enhance the system performance, thereby depleting the

scheduling issues. The main objective of this method is minimizing the makespan and energy consumption. The objective of the proposed algorithms has been evaluated using CloudSim toolkit for standard workload. The outcome of the simulation result shows that the proposed mean GWO algorithm renders comparatively ample result than the other existing algorithms. (5 Figures, 1 Table, 9 References)

[14804]

Prashar A. 2019

Journal of Cleaner Production **235**: 977-996

Management Development Institute, Gurgaon,
Haryana 122007, India

Towards sustainable development in industrial small and medium-sized enterprises: an energy sustainability approach

The objective of this study is to develop an easy-to-implement managerial framework for guiding the visualization, implementation, and reporting of energy sustainability (ES) for industrial enterprises. To address this objective, a three-step ES framework was developed through a systematic literature review and an iterative process of longitudinal action research in two medium-sized industrial enterprises from geographical cluster of foundry and textile SMEs in India. The three core steps of the framework emphasize on energy management organization (with energy management function and roles), energy visualization and optimization (by understanding energy use patterns to identify ES opportunities), and ES reporting (internal and external reporting based on GRI guidelines). The ES framework was validated through action research at two medium-sized SMEs operating in the foundry and textile sector in India. While the foundry unit saved production costs of USD 9019/annum, mitigated CO₂ emissions of 100.29 t (CO₂)/annum, and improved employee retention by 32%, the post-implementation benefits gained

by the textile unit were cost saving of USD 2486/annum, emission mitigation of 41.36 t (CO₂)/annum, and an eco-label certification. The study contributes to the sustainability management literature by adopting an operative perspective of evaluating sustainability impact of shop-floor-level activities. Its contribution to the energy management literature is in expanding the scope of energy optimization initiatives to realizing holistic sustainability benefits. (11 Figures, 8 Tables, 76 References)

[14805]

Saini A, Kansal A, and Randhawa N S. 2019

Procedia Computer Science **155**: 803-808

Department of Electronics & Communication
Engineering, Calorx Teachers' University, Ahmedabad,
Gujarat 382481, India

Minimization of energy consumption in WSN using hybrid WECRA approach

The nodes are gathered for better communication and this is known as clustering. In clustering, the nearby nodes are situated in compatible cluster and send the information to the cluster head, which aggregates the information from various nodes and send it further to the sink. Different clustering algorithms and techniques have been developed for the enhancement of WSN. In the traditional approach, the central node in the network is preferred as the cluster head and this node is constrained for network transmission. This single node consumes more energy than other nodes. It follows the straight line route. Therefore, the route is overloaded, which consumes more energy with the reduction in lifetime of the network. We proposed an energy-efficient genetic algorithm based approach with the concept of virtual grid based dynamic routes adjustment (VGDR) that enhances the overall performance of wireless sensor networks. The proposed approach has better energy efficiency as compared to LEACH because it is dynamic approach not static, balances the load, and optimization

creates more chances of better result in a less number of loops, which are not possible in other techniques. The simulation result of the proposed approach is carried out in MATLAB. (3 Figures, 4 Tables, 67 References)

[14806]

Verma O P, Manik G, Suryakant, Jain V K, Jain D K, and Wang H. 2018

Sustainable Computing: Informatics and Systems **20**: 130-140

School of Electronics, KIIT University Bhubaneswar, Odisha 751024, India

Minimization of energy consumption in multiple stage evaporator using genetic algorithm

Maximization of the steam efficiency of a multiple stage evaporator employed for concentrating black liquor in pulp and paper mills carries immense significance and relevance in today's scenario. Nonlinear mathematical models of heptads' effects backward feed flow with various energy saving schemes, namely, steam-split, feed-split, feed-preheating and their hybrid operations have been developed. The steam economy as a cost function translates the problem into a nonlinear optimal search problem. The mass and heat balance equations act as nonlinear equality constraints, while vapour temperatures and liquor flows appear as inequality constraints. The formulated problem has been solved efficiently to attain optimal solution using genetic algorithm approach, which demonstrates advantages of convergence and relative less sensitivity towards initial values versus the conventional algorithms. The simulations indicate that a hybrid of steam-split, feed-split, and feed-preheating process arrangements with backward feed flow could provide the highest heat transfer across evaporator effects with an optimum steam economy of 6.47 and consumption of 6541.93 kg/h. (6 Figures, 12 References)

[14807]

Vooradi R, Bertran M-O, Frauzem R, Anne S B, and Gani R. 2018

Chemical Engineering Research and Design **131**: 440-464

Department of Chemical & Biochemical Engineering, Technical University of Denmark, DK-2800 Lyngby, Denmark

Sustainable chemical processing and energy-carbon dioxide management: review of challenges and opportunities

This paper presents a brief review of the available energy sources, CO₂ emissions and management, and sustainable chemical processing, where energy consumption, CO₂ emission, and economics and environmental impacts are considered. Not all available energy sources have been utilized efficiently, while the energy source causing the largest emission of CO₂ is being used in the largest amount. The CO₂ management is therefore looking at "curing" the problem rather than "preventing" it. Examples highlighting the synthesis, design, and analysis of sustainable chemical processing are presented in the areas of utilization of biomass-based energy-chemical production, carbon capture and utilization to produce value-added chemicals, and retrofit design of energy intensive chemical processes with significant reduction of energy consumption. These examples highlight issues of energy sustainable design, energy-CO₂ neutral design, energy retrofit design, and energy-process intensification. Finally, some perspectives on the status and future directions of carbon dioxide management are outlined. (15 Figures, 6 Tables, 184 References)

HEALTH EFFECTS

[14808]

Chaine S and Tripathy M. 2019

Alexandria Engineering Journal **58**(2): 579–590

Department of Electrical Engineering, Veer Surendra Sai University of Technology, Burla, Odisha 768018, India

Performance of CSA optimized controllers of DFIGs and AGC to improve frequency regulation of a wind integrated hydrothermal power system

The main objective of the work is to analyse the effects of integrating double fed induction generator (DFIG) based wind power to a standard two area power system in terms of the frequency regulation capability of the system. Wind power integration is done in the conventional automatic generation control (AGC) models of two area interconnected power system, first when both the areas have thermal generation (thermal-thermal) and then replacing hydropower in one of the areas (hydro-thermal). The effects of variations of system load power on the frequency regulation are studied in both the thermal-thermal and the hydro-thermal environment within AGC. The work proposes a simultaneous optimization of controller parameters of AGC and DFIG controllers with the help of Cuckoo Search Algorithm to improve the frequency regulation of the system. It was further found that it is more beneficial to utilize the available wind power resources in the hydro area instead of thermal area in a hydro-thermal power system. (13 Figures, 4 Tables, 26 References)

[14809]

Hazra S and Roy P K. 2019

Renewable Energy Focus **31**: 45–62

Department of Electrical Engineering, Central Institute of Plastics Engineering and Technology, West Bengal 721631, India

Quasi-oppositional chemical reaction optimization for combined economic emission dispatch in power system considering wind power uncertainties

In this article, chemical reaction optimization (CRO) is proposed to solve wind-based combined economic emission dispatch problem (WCEED) in order to minimize thermal-wind electrical energy cost and emissions from fossil fuel power plants, concurrently. Moreover, to improve the solution superiority and convergence speed, quasi-opposition based learning (QOBL) is included with basic CRO algorithm. The proposed CRO and QOCRO approaches are implemented to discover the optimal generation of wind and thermal generators in order to minimize the individual objectives of fuel cost and emission, and compromising solution is also evaluated. Wind power generation is modelled by the piecewise linear approximation method. The performance of CRO and QOCRO is evaluated through three test systems and the simulation results. Statistical results obtained by these methods along with different other algorithms available in the literature are presented to demonstrate the validity and effectiveness of the proposed CRO and QOCRO schemes for practical applications. Moreover, a non-dominated sorting CRO and QOCRO are employed to approximate the set of Pareto solution through the evolutionary optimization process. (7 Figures, 12 Tables, 54 References)

[14810]

Samal R K and Tripathy M. 2019

Renewable Energy **140**: 722–736

Veer Surendra Sai University of Technology Burla, Odisha 768018, India

A novel distance metric for evaluating impact of wind integration on power systems

The current study introduces a Capacity Factor Violation Index (CFVI) to evaluate the impact

of wind integration on capacity factor of thermal generators. A distance metric consisting of cost savings, emission reduction, network losses, and CFVI is proposed based on Compromise Programming (CP). Sensitivity analysis is performed by varying the wind penetration and turbine ratings and the impact on the distance metric is investigated. The proposed methodology is comprehensively demonstrated in 11 popular test power systems. (12 Figures, 14 Tables, 50 References)

TRANSPORT AND ENVIRONMENT

[14811]

Yadav M and Tandel B. 2019

Indian Journal of Environmental Protection **39**(11): 1038-1045

S. V. National Institute of Technology, Environmental Engineering Section, Department of Civil Engineering Department, Surat, Gujarat 395007, India

Exposure effect study of traffic noise on roadside shopkeepers in Surat City

The inconsistent and puzzling results in noise pollution exposure effect research on humans may partially be due to discrete differences between the individuals participating in different research studies. Following research, this article puts focus on noise exposure effects on roadside open shutter shopkeepers in busy commercial areas of Surat city, as they are directly exposed to traffic noise for more than 9–10 h daily. A total of 12 locations were selected for noise and traffic measurement. To study exposure effects, questionnaire survey in the form of the personal interview was done with 706 respondents. The equivalent noise level in the study area was 78 dBA due to high volume of traffic, which is very high and exceeds the governmental standard for a commercial area. The effects of environmental factors, such as ambient temperature and humidity, were also considered in the study. From the interview responses, it was concluded that people working in the study area

are less or moderately affected by noise pollution and they are satisfied with working in the same area. The reason, behind such a response, can be respondents' less awareness towards the effects of noise and their daily tasks, which are low level or non-cognitive. (7 Figures, 2 Tables, 27 References)

FOSSIL FUELS AND ENVIRONMENT

[14812]

Karmaker A K, Rahman Md M, Hossain Md A, and Ahmed Md R. 2020

Journal of Cleaner Production **244**: 118645

Department of Electrical and Electronic Engineering, Dhaka University of Engineering & Technology, Gazipur, Dhaka 1700, Bangladesh

Exploration and corrective measures of greenhouse gas emission from fossil fuel power stations for Bangladesh

Greenhouse gas emission is increasing alarmingly due to bulk electricity generation from fossil fuels, such as coal, gas, and oil, with their limited stock. While researchers are struggling to minimize the emission using suitable mitigation techniques including renewable energy sources, the Government of Bangladesh is setting up several coal-based power plants. This paper presents mathematical model of parameters related to greenhouse gas emission and demonstrates its emission rates resulting from various fuels used in Bangladeshi power plants. The greenhouse gas emission from the existing fossil fuel power plants is analysed using HOMER (Hybrid Optimization of Multiple Energy Resources) software in this research. The result shows that power plants of coal, diesel, and natural gas emit 0.90, 0.76, and 0.566 kg of CO₂ per kWh, respectively. Furthermore, several greenhouse gas mitigating procedures are proposed for fossil fuel-based power generating stations. (10 Figures, 5 Tables, 66 References)

RENEWABLE ENERGY AND ENVIRONMENT

[14813]

Azam M, Jahromy S S, Raza W, Raza N, Lee S S, Kim K-H, and Winter F. 2020

Environment International **134**: 105291

Institute of Chemical, Environmental and Bio Science Engineering, TU WIEN, Austria

Status, characterization, and potential utilization of municipal solid waste as renewable energy source: Lahore case study in Pakistan

In this study, the authors explore the generation, treatment, and characteristics of physical/chemical composition and assess the potential of MSW as a renewable energy source in Lahore, the second largest city in Pakistan. Based on the average generation rate of MSW (i.e., 0.65 kg/capita/day), the daily production of MSW in this city would reach 7150 tons/day. However, its disposal in a safely engineered way has been restricted due to the lack of: (a) pre-planning, (b) infrastructure, (c) political will, and (d) public awareness. Various samples of MSW considering socio-economic structure were collected. The physical components of MSW in Lahore were found to be in the descending order of biodegradable, nylon plastic bags, textile, diaper, and paper. The inductively coupled plasma optical emission spectroscopy (ICP-OES) technique was used to determine the heavy metal content and leachability of the MSW components to check for the environmental contamination risk. The proximate and ultimate analysis of this MSW was also carried out along with its heating values. The results of this study should be helpful for policymakers to develop a MSW management strategy for the potential renewable energy alternative. (4 Figures, 9 Tables, 54 References)

[14814]

Bray C D, Battye W H, and Aneja V P. 2019

Atmospheric Environment **218**: 116983

Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC, USA

The role of biomass burning agricultural emissions in the Indo-Gangetic Plains on the air quality in New Delhi, India

This study focuses on rice paddy residue burning and wheat residue burning. Emissions of reactive nitrogen species (ammonia (NH_3), nitrous oxide (N_2O), and oxides of nitrogen ($\text{NO}_x = \text{NO} + \text{NO}_2$)) were estimated for the study period using a suite of satellite products from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on the National Aeronautics and Space Administration (NASA) Aqua and Terra satellites. Emissions were compared against ambient concentrations of fine particulate matter ($\text{PM}_{2.5}$) in New Delhi, India, to help determine the impact that these agricultural burns have on $\text{PM}_{2.5}$, which is known to have numerous health and environmental impacts associated with prolonged exposure to elevated concentrations. Daily average measured concentrations of $\text{PM}_{2.5}$ in New Delhi range from 22.43 to 718.94 $\mu\text{g}/\text{m}^3$ (average $127.15 \pm 95.23 \mu\text{g}/\text{m}^3$), with the daily average $\text{PM}_{2.5}$ concentration exceeding the national ambient air quality standard of 60 $\mu\text{g}/\text{m}^3$ approximately 75% of the time. In addition to this, statistical regression models were created to predict average daily $\text{PM}_{2.5}$ concentrations in New Delhi, India, based on emissions of NH_3 and organic carbon (OC) in the IGP (Indo-Gangetic Plain) as well as meteorological conditions. The regression model predicted ambient $\text{PM}_{2.5}$ concentrations ranging from 35 to 719 $\mu\text{g}/\text{m}^3$. The average modeled concentrations of $\text{PM}_{2.5}$ in New Delhi, India, were 111 $\mu\text{g}/\text{m}^3$ (standard deviation: $\pm 23 \mu\text{g}/\text{m}^3$) during April/May and $207 \pm 87 \mu\text{g}/\text{m}^3$ during October/November. Both regression models (for wheat residue burning

and for rice paddy residue burning) were comparable to the average observations. (5 Figures, 4 Tables, 60 References)

[14815]

Kumar J S and Bapu B R. 2019

Indian Journal of Environmental Protection **39**(8): 734-739

Sathyabama Institute of Science and Technology,
School of Mechanical Engineering, Chennai 600 119,
Tamil Nadu, India

Comparison of performance and emission characteristics of DI diesel engine by using ajwain and cinnamon biodiesel blend with diesel

This study is focused mainly on comparing the performance and emission properties of cinnamon biodiesel fuel with ajwain biodiesel. Both biodiesels were blended in 10%, 20%, and 30% in volume with pure diesel fuel and 30 ppm of cerium oxide is added and tested in a four-stroke, single cylinder diesel engine, DI, under different engine brake powers (0.09, 0.9, 1.73, 2.62, 3.39 in kW) and 1500 rpm. Final results show that cinnamon biodiesel fuel (10% of cinnamon biodiesel and 90% pure diesel) gives better performance than all other combinations as well as the ajwain biodiesel. (8 Figures, 5 Tables, 13 References)

INDUSTRIAL POLLUTION

[14816]

Rai S, Tilwankar V, and Bajpai S P. 2019

Indian Journal of Environmental Protection **39**(8): 758-762

Amity University Madhya Pradesh, Department of
Environmental Science, Gwalior, Madhya Pradesh
474005, India

Seasonal profile of heavy metals in the water samples of Bhopal industrial area

The quality of water is degrading throughout the globe due to overexploitation, industrialization,

urbanization, and pollution. The surface and groundwater resources are contaminated with a number of pollutants, such as heavy metals, pesticides, and biological contaminants. The use of contaminated water for irrigation and domestic and household purposes would lead to various diseases and infections in humans and other organisms. The present investigation was undertaken to analyse the presence of various metals in the water samples of two industrial areas of Bhopal region, namely, Govindpura and Mandideep. All the samples were analysed for the presence of lead (Pb), copper (Cu), nickel (Ni), zinc (Zn), arsenic (As), mercury (Hg), and fluoride (F). The result shows the existence of Pb, Cu, and Zn in all the water samples, while Ni, As, Hg, and F were not detected in any sample. The seasonal variations in the concentrations of heavy metals were also found. (4 Figures, 1 Table, 20 References)

HAZARDOUS WASTE AND ITS MANAGEMENT

[14817]

Batcha K and Kirubakaran V. 2019

Indian Journal of Environmental Protection **39**(8): 669-672

Gandhigram Rural Institute (Deemed to be
University), Centre for Rural Energy, Gandhigram 624
302, Dindigul, Tamil Nadu, India

Devolatilization kinetics of sewage sludge

Solid waste management is the key element of 'Swachh Bharat Mission' of the Government of India. Many municipalities/industries installed sewage treatment for treating liquid waste. One of the by-product for sewage treatment is the sewage sludge. It is cumbersome in treating the solid sewage sludge. This paper analyses the possibility of using the sewage sludge as the fuel for combustor/gasifier. Also, the paper attempts to elucidate the kinetics of the sewage sludge. (7 Figures, 1 Table, 20 References)

[14818]

Dhanraj and Ganesha A. 2019

Indian Journal of Environmental Protection **39**(12): 1158–1165

Manipal Academy of Higher Education, International Center for Applied Science, Manipal 576 104, Karnataka

Artificial recharge practice of treated domestic sewage—its challenges and opportunities in Indian perspective: a mini systematic review

The main objective of the study is to develop baseline data for the recharge of treated sewage, which may ease the problem of disposal into the streams and provide an alternative means of disposal that will not only serve the purpose of replenishing groundwater but also generate a new form of disposal for all weather conditions. In this study, we are reviewing the state of problem in developing countries in terms of disposal of treated sewage and how it could be better managed by artificial recharge by reducing the level of treatment, which needs to be better understood to develop baseline data in future perspective. Through Boolean search, a systematic review with narrative synthesis was conducted. Relevant electronic bibliographic databases and references lists of pertinent review articles were searched. The entire article is based on the guidelines and checklists provided by PRISMA (preferred reporting items for systematic review guidelines). A total of six papers that included developing and developed countries were finalized for the study and the results reveal that no reviews have been done on the different stages of treatment on artificial recharge of treated domestic sewage in unconfined aquifer. This paper would provide valuable insights for India by generating baseline data for quality after recharge in unconfined aquifer. Although the relevance of the method adopted has been acknowledged, the different stages of treatment and its effect on quality after recharge needs attention. (3 Figures, 6 Tables, 42 References)

[14819]

Dowarah K, Devipriya S P. 2019

Marine Pollution Bulletin **148**: 123–133

Department of Ecology and Environmental Sciences, Pondicherry University, Puducherry 605014, India

Microplastic prevalence in the beaches of Puducherry, India and its correlation with fishing and tourism/recreational activities

The prevalence of microplastics in the sediments of six beaches of the Puducherry coast in India was studied and its correlation to fishing activities and recreational activities was analysed. On an average, 72.03 ± 19.16 microplastic particles per 100 g dry weight of sediments were found to be the microplastic abundance in the study. A strong positive correlation between fishing activity and microplastic abundance and a weak correlation between microplastic abundance and recreational activities were found. Majority (65.12%) of the microplastics belong to the size bracket of 300 μm –1 mm and only 34.88% were large microplastics (>1 mm). The polymers of the microplastics were identified as polypropylene, HDPE, LDPE, polystyrene, polyurethane, and so on using Raman spectroscopy. Microplastic fragments accounted for 56.32% of the total particles. In terms of colour of the microplastics, white (26.92%) was the most abundant. (13 Figures, 3 Tables, 47 References)

[14820]

Hossain M S, Sobhan F, Uddin M N, Sharifuzzaman S M, Chowdhury S R, Sarker S, and Chowdhury M S N. 2019

Science of The Total Environment **690**: 821–830

Institute of Marine Sciences, University of Chittagong, Chittagong 4331, Bangladesh

Email: hossainms@yahoo.com

Microplastics in fishes from the Northern Bay of Bengal

Microplastics were determined in pink Bombay-duck (*Harpadon nehereus*), white Bombay-duck (*H. translucens*), and goldstripe sardine (*Sardinella gibbosa*) collected from

the Northern Bay of Bengal in Bangladesh. Gastrointestinal tracts of fishes ($n = 25$ per species) were examined for microplastics following alkali digestion protocol, microscopic observations, and chemical analysis by micro-Fourier transform infrared spectroscopy (μ -FTIR). A total of 443 microplastic items were found in the intestines of *H. nehereus*, *H. translucens*, and *S. gibbosa*, averaging in the range of 3.20–8.72 items per species. Among various shapes, colours and types of microplastics, irregular (37–43%), white/transparent (26–68%), and fiber (50–55%) were dominant. The size fraction of microplastics ranging between 1 μ m and 5 mm was 68–84 items/kg biomass, and μ -FTIR analysis identified 13 particles of polyethylene terephthalate and 66 particles of polyamide. The study findings raised concern that microplastics in marine fish could be a threat to public health via the food chain. (9 Figures, 2 Tables, 84 References)

[14821]

Jahan R, Singh S K, Shankar P, Bhaskar K, Alam A, and Ghosh A K. 2019

Indian Journal of Environmental Protection **39**(7): 621–628

A.N. College, Department of Botany, Patna 800013, Bihar

Impact of municipal solid waste and groundwater quality assessment: a case study at landfill site near Rajendra Nagar, Patna

In several parts of India, groundwater is largely affected by the improper disposal of municipal solid waste, which deteriorates the groundwater quality. According to a UNESCO report, a majority of Indian population has no access to safe drinking water and about 66 million people rely on unsafe groundwater for consumption. The present work is aimed at assessing the impact of municipal solid waste on water quality near the landfill site at Rajendra Nagar, Patna. All the samples were analysed based on different parameters, such as pH, EC, TDS, TH, alkalinity,

calcium, magnesium, phosphate, sulphate, chloride, fluoride, and bacteriological test. All these parameters were analysed using APHA and the obtained results were compared with the Indian standard drinking water specification BIS:10500-2012. After analysis, it was observed that the groundwater was significantly contaminated around the study area. A large part of the sampling site of the study area had found poor and marginal water quality. In all the water samples, the parameters such as TDS, hardness, and alkalinity were found above acceptable limits as per BIS [3]. In bacteriological analysis, 25% of the total samples were found to be contaminated and hence unfit for drinking purpose. This study suggests that the analysis of water and its management practices should be carried out periodically for the protection of groundwater quality. (2 Figures, 4 Tables, 17 References)

[14822]

Karthikeyan L, Suresh V M, Krishnan V, Tudor T, and Varshini V. 2018

Environments **5**(9): 103

Centre for Natural Hazards and Disaster Studies, University of Madras, Chennai 600005, India

The management of hazardous solid waste in India: an overview

Due largely to economic development, industrialization, and changing lifestyles, quantity of hazardous waste in India is rising significantly. This is particularly true in mega cities, where populations are large and growing. Due to a range of factors including limitations in governance systems, inadequate treatment facilities, limitations in compliance and regulation, and limited trained and skilled stakeholders, the management of hazardous solid waste in the country is largely ineffective. One exception to this is the state of Gujarat, which has sought to implement a number of strategies to better manage the rising quantities of hazardous solid waste being produced. This article highlights the management of solid waste in the country for an

effective mitigation of various hazards. Further, this article focuses on adaptive technologies for the hazardous waste management all over the country, more specifically in the state of Gujarat. (1 Figure, 3 Tables, 16 References)

[14823]

Mathew J and Gopinath A. 2019

Marine Pollution Bulletin **149**: 110567

Department of Chemistry, St. Albert's College
(Autonomous), Kochi 682018, Ernakulam,
Kerala, India

Spatial and temporal variations of arsenic distribution in a tropical estuary along the west coast of India

Arsenic (As) contamination was studied and reported for the first time in the sediments of the Cochin estuary. Surface sediment samples were collected from 27 stations encompassing the entire estuary constituting south, central, and north estuaries. The degree of contamination assessed in terms of geochemical indices, such as contamination factor (CF), geoaccumulation index (I_{geo}), and enrichment factor (EF), unraveled the As contamination to be meager. The application of risk index factor and sediment quality guidelines showed that the As concentration in the estuary is below the background concentration. Pearson correlation analysis of As with iron and TOC exhibited significant weak and poor correlations with these variables. (5 Figures, 2 Tables, 52 References)

[14824]

Mishra S, Tiwary D, Ohri A, and Agnihotri A K. 2019

Groundwater for Sustainable Development **9**:
100230

Department of Chemistry, Indian Institute of
Technology (BHU), Varanasi 221005, Uttar Pradesh,
India

Impact of municipal solid waste landfill leachate on groundwater quality in Varanasi, India

This study assesses the impact of municipal solid

waste (MSW) landfill leachate on its surrounding groundwater quality of village Ramna, Varanasi, India. Leachate pollution index (LPI) of landfill leachate was evaluated with their physicochemical analysis that represents the overall leachate pollution potential and hazardous nature of MSW leachate. Physicochemical analysis of groundwater quality around the landfill site does not favour to drinking and domestic purposes as per the WHO and BIS standards. Factor analysis signifies positive loading of most of the toxic pollutants, presenting MSW leachate impact on groundwater quality. WQI results also revealed that most of the groundwater samples were deteriorated from good and excellent water quality in pre-monsoon to fair water quality in post-monsoon near the landfill site. This study suggests an urgent need for the sanitary landfill to control and minimize the impact of MSW leachate on groundwater quality around the MSW landfill site. (12 Figures, 9 Tables, 46 References)

[14825]

Pant G, Acharjee D, Shafras M, Chaitra, and Kumari Madhu. 2019

Indian Journal of Environmental Protection **39**(9):
787-792

Ramaiah College of Arts, Science and Commerce,
Department of Biotechnology and Genetics,
Bangalore 560054, India

Physico-chemical, microbial, heavy metals and pharmaceutical analysis of water samples from Bengaluru lakes

This study aims to evaluate the quality of potable drinking water from 12 lakes in and around Bengaluru. The physical properties of samples were assessed using standard methods for the examination of water and wastewater by the American Water Works Association. The evaluation of both heavy metal concentration and antibiotic resistance was carried out using standard methods. Total hardness in Hennur Lake has exceeded the

recommended range as specified by the Bureau of Indian Standards (BIS). The ammonium and phosphate concentrations were high in Varthur Lake, and chloride concentration in Hennur Lake has exceeded the permissible range. Microbial analysis showed the presence of seven dominant bacterial strains. Toxicity screening for heavy metals showed all the lakes were within the recommended BIS range for cadmium but have exceeded the permissible limits for lead and nickel. Antibiotic profiling of Hennur and Rachenahalli lake samples clearly highlighted the presence of diclofenac in both the lakes. Proper water management practices and constant monitoring of waterbodies should take place to sustain the ecosystem and aquatic life in the lake. (4 Tables, 20 References)

[14826]

Patterson J, Jeyasanta K I, Sathish N, Booth A K, and Edward J K P. 2019

Science of The Total Environment **691**: 727–735

Suganthi Devadason Marine Research Institute, Tuticorin, Tamil Nadu, India

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Profiling microplastics in the Indian edible oyster, *Magallana bilineata* collected from the Tuticorin coast, Gulf of Mannar, Southeastern India

The objective of this study is to quantify the extent of microplastic (MP) contamination in the Indian edible oyster (*Magallana bilineata*) and to understand how this relates to the MP contamination in its surrounding marine environment. Samples of water, sediment, and oysters of different sizes were collected from three sites along Tuticorin coast in Gulf of Mannar in Southeast India. Polyethylene (PE) and polypropylene (PP) fibers were the dominant MP types in oysters (92% and 4%, respectively) and in seawater (75% and 25%, respectively), with PE fibers, ranging from 0.25 to 0.5 mm, being the most common. Both PE and PP are low-density polymers

that are slow to sediment to the seafloor. This increases the potential of their availability in the environment and ingestion by oysters. The largest oysters (14–16 cm) contained the highest abundance and concentrations of MP, suggesting a greater proportion of MP in the water column is ingested with increasing size. The calculated microplastic index (0.02–0.99) also indicates that MP bioavailability increases with increasing size of oysters. Energy-dispersive X-ray spectroscopy analysis shows the presence of Ni and Fe in association with MP, and this probably indicates the fly ash pollution and the petroleum-related activities in the surrounding area. Being sessile animals, oysters are good candidates for use as sentinel organisms for monitoring MP in specific marine environments. (5 Figures, 1 Table, 59 References)

[14827]

Sadala S, Dutta S, Raghava R, Jyothsna T S, Chakradhar B, and Ghosh S K. 2019

Waste Management & Research **37**(11): 1063–1076

Environmental Consultancy, Ramky Enviro Services Private Limited, Hyderabad 500082, Telangana, India

Resource recovery as alternative fuel and raw material from hazardous waste

Industries in India, as major players in building the economy and GDP, generates about 7.4 million tons of hazardous waste annually, out of which around 3.98 million tons are recyclable for resource or energy recovery. India's scenario in the usage of alternative fuel and raw material is less than 1%, which reflects a huge quantum of hazardous waste for potential usage in alternative fuel and raw material. Uncontrolled waste management degrades land, groundwater, and air quality, leading to health risks to humans, animals, and the ecosystem. Presently, industrial waste in most cases is disposed to landfills after incineration, without utilizing the full potential of wastes through recirculation. The present study analysed the current

situation of treatment facilities for attaining a sustainable management system using waste as the alternative fuel and raw material for the disposal of hazardous waste. Through the alternative fuel and raw material concept, hazardous wastes can be used as a substitute for fossil fuels and raw material in a few types of industries. This will surely enhance the efficient recirculation of industrial wastes. This paper presents the overall view of Indian hazardous waste generating industries, their locations, the potential of wastes as alternate sources of fuel to other industries, the use of alternative fuel and raw material by cement industries, and applicable regulatory requirements. (7 Figures, 9 Tables, 51 References)

[14828]

Satheeswaran T, Yuvaraj P, Damotharan P, Karthikeyan V, Jha D K, Dharani G, Balasubramanian T, and Kirubakaran R. 2019
Marine Pollution Bulletin **149**: 110499
 Ocean Science and Technology for Islands, National Institute of Ocean Technology, Ministry of Earth Sciences (Govt. of India), Chennai 600100, India

Assessment of trace metal contamination in the marine sediment, seawater, and bivalves of Parangipettai, southeast coast of India

Industrial and domestic discharge into the coastal environment has driven us to propose an integrated approach to delineate stations contaminated with metals on the Parangipettai coast by collecting sediment and seawater samples monthly at 18 stations. Descriptive statistics revealed that the concentrations of some metals in the sediment and seawater samples were beyond the permissible level. Further, factor analysis showed a sampling adequacy of 0.90 with high positive loading for Ni (0.94), Cd (0.91), Co (0.90), Pb (0.89), and Zn (0.87) in sediment samples. The degree of contamination by metals was evaluated using pollution indices. The results of the contamination index revealed

that some stations in the study area were moderately polluted and those of the ecological index showed that open sea was under low risk while other stations were in the moderate to high risk categories. The results obtained are essential to establish the reference condition for a comparative study in similar environments in the tropical regions. (3 Figures, 7 Tables, 70 References)

[14829]

Vasanthan S and Murugesan A. 2019
Indian Journal of Environmental Protection **39**(7): 587-593
 Manonmaniam Sundaranar University, Centre for Research, Abishekapatti, Tirunelveli 627 012, Tamil Nadu, India

Contemporary condition of physico-chemical properties and heavy metal contamination in groundwater by tannery activities, Ambur, Vellore district

This study was focused to reveal the physico-chemical characteristics and the presence of heavy metals in groundwater samples. This research was done at the site of the tanneries at Ambur taluk in Vellore district Tamil Nadu to estimate the pollution indices and risk assessment of groundwater for human consumption. Flame atomic absorption spectrometer (AAS) technique was used to assess the heavy metal concentration. The analytical results showed the chromium concentration to be significantly higher in groundwater samples at the site of the tannery locality. Also, the concentration of lead (Pb), copper (Cu), and zinc (Zn) metals was found to be slightly high in groundwater at the site of the tannery. The calculated pollution indices, namely, contamination index (CI) and index of environmental risk (IER) for the heavy metals, suggest that majority of the studied groundwater samples are in the highly contaminated zone. (4 Figures, 8 Tables, 20 References)

HEALTH EFFECTS

[14830]

Akhtar N and Rai S P. 2019

Indian Journal of Environmental Protection **39**(9): 945-953

Bundelkhand University, Department of Earth Science, Jhansi 284 128, Uttar Pradesh

Heavy metals concentrations in drinking water and their effect on public health around Moth block of Jhansi District

The present study assessed the concentrations of heavy metals in the groundwater and their effects on the health of the residents around Moth block of Jhansi district, Uttar Pradesh. Forty groundwater samples were collected from the hand pump for analyses of Al, As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn and the results were compared with international and national standards such as World Health Organization and Bureau of Indian Standards. The results found maximum numbers of heavy metals of the study area to be in the acceptable limit except at few locations. The heavy metal concentrations of Cr, Cd, Co, Ni, and Pb of all groundwater samples are found within the acceptable limits, while those of As, Cu, Zn, and Mn are found below. The Fe and Al concentrations in the samples of majority of the localities are in acceptable limits, whereas few indicate high concentration, that is, carcinogenic, such as Mahluwa, Lohagad 2, Reb, Bamroli, Bangari, and Ata. This result is corroborated with the poor health of the residents around Moth block. (4 Figures, 3 Tables, 24 References)

[14831]

Alam M-U, Rahman M, Abdullah-Al-Masud, Islam M A, Asaduzzaman M, Sarker S, Rousham E, and Unicomb L. 2019

International Journal of Hygiene and Environmental Health **222**(8): 1068-1076

Environmental Interventions Unit, Infectious Disease Division, icddr, Bangladesh

Human exposure to antimicrobial resistance from poultry production: assessing hygiene and waste-disposal practices in Bangladesh

The unregulated use of antibiotics is linked with intensive poultry farming in developing economies. In low- and middle-income countries, the dissemination of antimicrobial resistance (AMR) has also been attributed to contamination, poor public health infrastructure, and inadequate waste disposal practices. There are limited data on hygiene and waste disposal practices in small-scale commercial and household poultry farming and market sales in Bangladesh. The objective of this study was to explore human exposures, hygiene, and waste disposal practices in poultry raising and processing to identify probable pathways for transmission of AMR bacteria. Mixed method approaches of in-depth interviews and structured observations to assess exposures, hygiene behaviours, and waste disposal practices relating to poultry production in Bangladesh were employed. Interviews ($n = 18$) were conducted with commercial poultry farmers, backyard poultry owners, and live poultry market workers. Structured observations were conducted for 6 h in five households, five commercial farms, and five urban live bird markets to assess the frequency of transmission/exposure events in these settings. Interviews highlighted existing practices that can contribute to transmission of antimicrobial resistant bacteria from poultry to humans. In households and farms, untreated poultry waste and carcasses were disposed of on agricultural fields and in waterbodies, which may contaminate surface water and soil with poultry faeces. Biosecurity precautions were not used, and hands were rarely washed with soap after handling poultry. In urban markets, live poultry slaughter and processing was done on site with bare hands, which were subsequently rinsed in water stored in containers without soap. Solid waste from poultry processing

was disposed into municipal waste disposal stations and liquid waste was discarded into open drains. (2 Figures, 1 Table, 51 References)

[14832]

Bodrud-Doza Md, Didar-Ul Islam S M, Hasan Md T, Alam F, Haque Md M, Rakib M A, Asad Md A, and Rahman Md A. 2019

Groundwater for Sustainable Development 9: 100219
Institute of Nuclear Science and Technology, Atomic Energy Research Establishment, Bangladesh
Atomic Energy Commission, G. P. Box-3787, Dhaka, Bangladesh

Groundwater pollution by trace metals and human health risk assessment in central west part of Bangladesh

To evaluate the trace element contamination level and human health risk in the study area, a total of 20 groundwater samples were collected and analysed. The results revealed that groundwater is slightly acidic in nature with the mean conductance of 686.10 $\mu\text{S}/\text{cm}$. Heavy metal evaluation index (HEI), the degree of contamination (C_d), and Nemerow pollution index (NI) were employed to estimate the pollution load, and it was found that 5%, 95%, and 75%, respectively, of samples exhibited the high degree of pollution. According to the spatial analysis, it was found that the south-central part of the study area was highly contaminated with trace elements. Moreover, Pearson correlation, principal component analysis (PCA), and cluster analysis (CA) were applied to identify the pollution source and factors controlling groundwater quality, and the results indicate that groundwater of the study area was influenced by both natural and anthropogenic factors. Chronic health risks as a result of exposure via both oral and dermal routes were also determined by calculating the hazard quotient (HQ) and hazard index (HI) for both adults and children. In the case of oral exposure, almost 85% of samples suggest the medium category of chronic risk for adult and 50% of samples were found at high risk for children. Results of sensitivity analysis

specified concentration show a high carcinogenic risk both for adults and children. (7 Figures, 12 Tables, 100 References)

[14833]

Islam A R Md T, Bodrud-Doza Md, Rahman Md S, Amin S B, Chu R, and Mamun H A. 2019

Groundwater for Sustainable Development 9: 100275
Department of Disaster Management, Begum Rokeya University, Rangpur 5400, Bangladesh

Sources of trace elements identification in drinking water of Rangpur district, Bangladesh and their potential health risk following multivariate techniques and Monte-Carlo simulation

The contamination of several trace elements (TEs) in groundwater is one of the most serious environmental issues associated with sustainable development in many countries, including Bangladesh. Therefore, this study aims to elucidate source apportionment of contamination and the potential health risks in Rangpur district in Bangladesh using multivariate statistics and Monte Carlo simulation. The results of the study showed that the average concentrations of iron, manganese, and barium exceeded the permissible limits for drinking water specified in WHO and Bangladesh standards. The carcinogenic risk value for As exposure surpassed the US EPA range of 1×10^{-6} to 1×10^{-4} , with a higher risk for children compared to adults. Arsenic in drinking water may pose health risks to some extent in local residents; thus, special attention and groundwater monitoring should focus on As contamination in groundwater of the study region. (11 Figures, 2 Tables, 64 References)

[14834]

Jaacks L M, Diao N, Calafat A M, Ospina M, Mazumdar M, Hasan Md O S I, Wright R, Quamruzzaman Q, and Christiani D C. 2019

Environment International 133(Part B): 105243
Department of Global Health and Population, Harvard T.H. Chan School of Public Health, Boston, MA, USA

Association of prenatal pesticide exposures with adverse pregnancy outcomes and stunting in rural Bangladesh

Pesticide exposure during pregnancy is thought to adversely affect fetal growth, which in turn may impact child growth, but results have been inconsistent across studies and few have explored these effects in developing countries. Eight pesticide biomarkers were quantified in urine collected from 289 pregnant women (aged 18–40 years) participating in a birth cohort study in Bangladesh. Anthropometry measurements were conducted on the index child at birth and approximately 1 and 2 years of age. Log-binomial regression was used to estimate the relative risk (RR) with 95% confidence intervals (CI). Women in the highest quartile of 4-nitrophenol were more than three times more likely to deliver preterm than women in the lowest quartile. Women in the highest quartile of 4-nitrophenol were also at increased risk of having a child born small for gestational age. There was no association between any of the pesticide biomarkers and stunting at 1 or 2 years of age. It was discussed that exposure to the insecticides parathion and diazinon during early pregnancy may increase the risk of adverse birth outcomes. (3 Tables, 76 References)

[14835]

Jaacks L M, Yadav S, Panuwet P, Kumar S, Rajacharya G H, Johnson C, Rawal I, Mohan D, Mohan V, Tandon N, Barr D B, Narayan K M V, and Prabhakaran D. 2019
Environment International 133(Part A): 105089
Harvard T.H. Chan School of Public Health, 677
Huntington Ave, Boston, MA 02115, United States
Email: jaacks@hsph.harvard.edu

Metabolite of the pesticide DDT and incident type 2 diabetes in urban India

The objective was to estimate the association of the *p,p'* isomer of DDE with incident type 2 diabetes in India. DDT is widely used in India

and the prevalence of type 2 diabetes is increasing in the country, but the association between these factors has not been explored to date. A nested case-control study was conducted in a representative prospective cohort of adults from two cities in India. Participants were enrolled in 2010–11 ($n = 12,271$) and followed for annual assessment of chronic diseases, including type 2 diabetes. Baseline plasma samples from incident cases of diabetes ($n = 193$) and sex-city-matched controls ($n = 323$) were selected for analysis of *p,p'*-DDE. Odds ratios (OR) and 95% confidence intervals (CI) were estimated using conditional logistic regression. Results suggest that levels of *p,p'*-DDE in Delhi are exceptionally high, but no significant association between *p,p'*-DDE and incident type 2 diabetes was observed. (1 Figure, 3 Tables, 46 References)

[14836]

Li Y, Mallinson P A C, Bhan N, Turner C, Bhogadi S, Sharma C, Aggarwal A, Kulkarni B, and Kinra S. 2019
Environment International 132: 105108
Department of Epidemiology and Health Statistics,
Hangzhou Medical College School of Public Health,
Hangzhou, China

Neighborhood physical food environment and cardiovascular risk factors in India: cross-sectional evidence from APCAPS

The authors conducted a cross-sectional analysis of the third wave follow-up of the Andhra Pradesh children and parents study in south India. They examined associations between the neighbourhood availability and accessibility of fruit/vegetable and highly processed/takeaway food vendors with 11 cardiovascular risk factors, including adiposity measures, glucose-insulin, blood pressure, and lipid profile. In fully adjusted models, higher density of fruit/vegetable vendors within 400 m of participant households was associated with lower systolic blood pressure and diastolic blood pressure. Higher density of highly processed/takeaway food vendors within 400 m of participant households was associated with

higher body mass index, waist circumference, systolic blood pressure, and diastolic. However, within 1600 m buffer, only association with blood pressure remained robust. No associations were found between neighbourhood accessibility and cardiovascular risk factors. Lower density of fruit/vegetable vendors and higher density of highly processed/takeaway food vendors were associated with adverse cardiovascular risk profiles. (3 Tables, 44 References)

[14837]

Lueker J, Bardhan R, Sarkar A, and Norford L. 2020
Building and Environment **167**: 106419
Massachusetts Institute of Technology, 77
Massachusetts Avenue, Cambridge, MA 02139, USA

Indoor air quality among Mumbai's resettled populations: comparing Dharavi slum to nearby rehabilitation sites

This study presents results from an experimental investigation of the severity and sources of household air pollution across two low-income housing archetypes in Mumbai. Experimentation was carried out in Dharavi—one of the world's largest slums—and two nearby communities representing Mumbai's current slum resettlement scheme. Household surveys were conducted to understand aspects of occupant behaviour that impact indoor air quality. Multi-pollutant logging sensors were installed inside units and in nearby outdoor locations to measure concentrations of particulate matter (PM_{2.5}) and CO₂. While rehabilitation architecture and gas cookstoves are often assumed to provide higher indoor air quality than in the traditional slums, field monitoring and occupant behaviour surveys demonstrated that indoor pollution levels were consistent across the two typologies even after infrastructure enhancements and ubiquitous gas cookstove usage. To minimize the impact of both indoor and outdoor pollutant sources while respecting culturally normative occupant behaviour, this study points to the need for architectural design guidelines and enhanced indoor air quality interventions. (11 Figures, 2 Tables, 48 References)

[14838]

Ramamohan H, Sudhakar I, and Prasad S V M. 2019
Indian Journal of Environmental Protection **39**(8):
719–727
Aditya Institute of Technology and Management,
Department of Civil Engineering, Tekkali, Srikakulam,
Kotturu, Andhra Pradesh 532201, India

Groundwater quality and its role in endemic kidney diseases—a case study at north-east coast (Uddanam) of Srikakulam District

The present research focused on kidney inflicted areas and compared the results with non-inflicted areas from March 2014 to February 2015 where majority of people were using groundwater as their potable source. The survey was conducted on basic water quality parameters, such as EC, TDS, and pH along with the depth to water table in both inflicted and non-inflicted areas. The in situ analysis was intended to perpetuate the water quality for pre-monsoon, monsoon, and post-monsoon seasons at the study area. Though both the divisions are meeting the required desirable limits, the division two seems to have more kidney patients. Specially TDS shows much influence on the function of kidneys. In division two, 33% of the stations are not meeting the required acceptable limits. However, it is not clear whether TDS is influencing the kidney failures or not. Some deviations are still observed in EC and TDS. (5 Figures, 4 Tables, 37 References)

[148039]

Shaikh R, Kazi T G, Afridi H I, Akhtar A, Baig J A, and Arain M B. 2019
Environmental Pollution **255**(Part 2): 113305
National Centre of Excellence in Analytical Chemistry,
University of Sindh, Jamshoro 76080, Pakistan

Geochemical exposure of heavy metals in environmental samples from the vicinity of old gas mining area in northern part of Sindh Pakistan. Adverse impact on children

The present study evaluated the undesirable effects of the toxic metals (lead and cadmium) via consuming groundwater for drinking and other

domestic purposes, especially in children of ≤ 5.0 years. For comparative purpose, groundwater of a non-industrial area (nonexposed) was also analysed and the impact on age-matched children was determined. Biological samples (scalp hair and blood) were collected from children of exposed and nonexposed areas. Cd and Pb in scalp hair and blood samples were determined by graphite furnace atomic absorption spectrometry. Cd and Pb in groundwater obtained from both areas were determined prior to the applied preconcentration method. It was observed that the concentrations of Cd and Pb in scalp hair and blood samples of children belonging to the exposed area were ≥ 2.0 -fold higher than the results obtained for age matched control children, indicating the exposure biomarkers of toxic metals. The children belonging to the exposed area are anemic and have poor health and low body mass index ($< 13 \text{ kg/m}^2$). A significant positive correlation among Cd and Pb concentrations in biological samples of exposed subjects and groundwater was observed. (2 Figures, 7 Tables, 45 References)

[14840]

Singh D D, Thind P S, Sharma M, Sahoo S, and John S. 2019

Water 11(11): 2350

Department of Civil Engineering, I.K. Gujral Punjab Technical University, Kapurthala 144601, India

Email: dapinder1111@gmail.com

Environmentally sensitive elements in groundwater of an industrial town in India: spatial distribution and human health risk

This paper presents the results of a study to assess the groundwater quality in an industrial town located in Punjab, India. A total of 99 samples of groundwater were analysed, which revealed the presence of numerous environmentally sensitive elements (ESEs), namely, arsenic (As), aluminum (Al), chromium (Cr), iron (Fe), mercury (Hg), nickel (Ni), selenium (Se), and lead (Pb). Geographic information system (GIS) based spatial interpolation

showed higher contamination levels around the industrial areas and the drainage channel where industrial effluent was generally discharged. Further, groundwater quality was assessed using the heavy metal pollution index (HPI) and the metal index (MI), which indicated poor drinkability of the groundwater. Human exposure to groundwater contaminated with ESEs can pose serious health risks; therefore, noncarcinogenic and carcinogenic health risks due to presence of these elements were also evaluated. Reported health risks to humans from exposure to contaminated groundwater indicate the importance of regular monitoring of groundwater for ESEs vis-à-vis industrial effluent disposal practices. (6 Figures, 6 Tables, 58 References)

[14841]

Yaparla D, Nagendra S M S, and Gummadi S N. 2019 *Journal of the Air & Waste Management Association* 69 (12): 1438-1451

Department of Civil Engineering, Environmental and Water Resources Engineering Division, Indian Institute of Technology Madras, Chennai, Tamil Nadu 600036, India

Characterization and health risk assessment of indoor dust in biomass and LPG-based households of rural Telangana, India

The present study deals with investigation of metal concentrations and morphological characteristics of indoor dust generated in varied fuel types, followed by estimation of health risks for women and children in rural households in Telangana, India. Indoor floor dust samples were collected from households using biomass and liquefied petroleum gas (LPG) as their cooking energy during winter to evaluate the morphological and chemical characteristics in the aforementioned dust samples. A morphological (SEM-EDX) analysis revealed the presence of carbonaceous particles in biomass-based households and mineral-rich crustal sources in LPG-based households.

As observed from ICP-OES analysis, there is a significant difference in mean concentrations of Al, Co, Cr, Fe, Zn, and Ni based on the fuel type, except for Mn and Pb. The health risks associated with these heavy metals to women and children were investigated using an EPA health risk model. The values from the model indicated that both non-carcinogenic and carcinogenic risks were within the safe levels for both subjects. This study not only establishes chemical and morphological characteristics of indoor dust, but also quantifies the role of the fuel type. (6 Figures, 7 Tables, 62 References)

CONTROL TECHNOLOGIES

[14842]

Purohit P, Amann M, Kiesewetter G, Rafaj P, Chaturvedi V, Dholakia H H, Koti P N, Klimont Z, Borken-Kleefeld J, Gomez-Sanabria A, Schöpp W, and Sander R. 2019
Environment International **133**(Part A): 105147
 International Institute for Applied Systems Analysis (IIASA), Schloßpl. 1, 2361, Laxenburg, Austria
 Email: purohit@iiasa.ac.at

Mitigation pathways towards national ambient air quality standards in India

This study explores pathways towards achieving the NAAQS in India in the context of the dynamics of social and economic development. In addition, to inform action at the subnational levels in India, the exposure to ambient air pollution in the current legislations and alternative policy scenarios based on simulations with the GAINS integrated assessment model is estimated. The analysis reveals that in many of the Indian states, emission sources that are outside of their immediate jurisdictions make the dominating contributions to (population-weighted) ambient pollution levels of $PM_{2.5}$. Consequently, most of the states cannot achieve significant improvements in their air quality and population exposure on their own without emission reductions in the surrounding regions, and any cost-effective strategy requires regionally coordinated approaches. Advanced

technical emission control measures could provide NAAQS-compliant air quality for 60% of the Indian population. However, if combined with national sustainable development strategies, an additional 25% population will be provided with clean air, which appears to be a significant co-benefit on air quality. (13 Figures, 1 Table, 61 References)

ENVIRONMENTAL PLANNING, MANAGEMENT, AND POLICY ISSUES

[14843]

Adnan S, Iqbal J, Maltamo M, Bacha M S, Shahab A, and Valbuena R. 2019
Environments **6**(12): 123
 School of Forest Sciences, University of Eastern Finland, P.O. Box 111, 80101 Joensuu, Finland

A simple approach of groundwater quality analysis, classification, and mapping in Peshawar, Pakistan

This study evaluated, classified, and mapped the quality of groundwater used for potable consumption with a simple approach in an urban area (Peshawar valley) of Pakistan. More than 100 groundwater samples were collected and analyzed for physio-chemical parameters in a laboratory. Hierarchical clustering analysis (HCA) and classification and regression tree (CART) analysis were sequentially applied to produce potential clusters/groups (groundwater quality classes), extract the threshold values of the clusters, classify and map the groundwater quality data into meaningful classes, and identify the most critical parameters in the classification. The HCA produced six distinct potential clusters. We found a high correlation of electrical conductivity with total hardness ($R^2 = 0.72$), alkalinity ($R^2 = 0.59$), and chloride ($R^2 = 0.64$) and total hardness with chloride ($R^2 = 0.62$), and alkalinity ($R^2 = 0.51$). The CART analysis conclusively identified the threshold values of the six classes and showed that total hardness was the most critical parameter in the classification. The majority of the groundwater was of worse

quality or good quality, and only a few areas had the worst groundwater quality. This study presents a simple tool for the classification of groundwater quality based on several aesthetic constituents and can assist decision-makers to develop and support policies and regulations to manage groundwater resources. (8 Figures, 1 Table, 71 References)

[14844]

Ahmad M, Cheng S, Yu Q, Qin W, Zhang Y, and Chen J. 2020

Atmospheric Research **234**: 104715

State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing 100875, China

Chemical and source characterization of PM_{2.5} in summertime in severely polluted Lahore, Pakistan

The PM_{2.5} chemical composition and sources in Lahore were investigated in this study in an effort to effectively mitigate the pollution of PM_{2.5} in Lahore. Principal component analysis (PCA), concentration weighted trajectory (CWT) calculation, and analysis of the spatial distribution of black carbon in Lahore obtained from MERRA-2 (Modern-Era Retrospective Analysis for Research and Applications, Version 2) reanalysis data were employed to identify the sources and contributing regions of PM_{2.5}. The fuel consumption situation in Pakistan was also examined to further identify the major contributing sectors to air pollution. The most abundant species in the identified mass of PM_{2.5} were carbonaceous compounds, followed by ionic species such as SO₄²⁻, NO₃⁻, Cl⁻, and NH₄⁺. Although secondary organic carbon showed a high percentage in OC (47%), primary organic carbon was still dominant in OC in Lahore. PM_{2.5} showed no correlation with meteorological parameters. Based on the CWT calculation and black carbon spatial distribution, it was found that local emission sources were the main contributors of air pollution in Lahore, with an additional contribution from

the western states of India. Overall, primary emissions from local sources showed a dominant contribution to PM_{2.5} pollution and controlling the emissions from industry, transportation, and power plants would show immediate effects for mitigating PM_{2.5} in Lahore. (4 Figures, 3 Tables, 68 References)

[14845]

Ali S, Fakhri Y, Golbini M, Thakur S K, Alinejad A, Parseh I, Shekhar S, and Bhattacharya P. 2019

Groundwater for Sustainable Development **9**: 100224

Department of Geology, University of Delhi, Delhi 110007, India

Concentration of fluoride in groundwater of India: a systematic review, meta-analysis and risk assessment

In this study, fluoride concentration data in groundwater across India by systematic searches conducted in various international search engines databases are collected. Here, we demonstrated a detailed meta-analysis and meta-regression of fluoride and evaluated health risk assessment. For this purpose, meta-analysis of 63 studies on fluoride in groundwater in India comprising 57,381 samples is included. We found that (i) the pooled concentration of fluoride in India is around 2.37 mg/L with 95% confident interval (1.46–3.28 mg/L), which is higher than WHO and national standards limit of 1.5 mg/L; (ii) the meta-analysis of data suggests that in rural parts of the country, fluoride concentration is 1.85 times higher than that in urban areas; and (iii) the concentration of fluoride in groundwater decreased significantly ($p < 0.05$) with increase in rainfall and longitude. The risk assessment via oral and dermal route exposure reveals that the consumers in majority of the regions are at considerable non-carcinogenic risk and children are at higher risk than adults (total hazard quotient > 1). The findings are helpful in identifying the affected areas of India and we recommend that the safer options of drinking water should be adopted. (8 Figures, 5 Tables, 106 References)

[14846]

Arun B S, Aswini A R, Gogoi M, Hegde P, Kompalli S K, Sharma P, and Suresh Babu S. 2019

Atmospheric Environment **218**: 117017

Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram 695022, India

Physico-chemical and optical properties of aerosols at a background site (~4 km a.s.l.) in the western Himalayas

This paper presents first of its kind results on the aerosol mass concentrations and size distributions, their chemical properties, and columnar aerosol optical depth (AOD) over a high-altitude background site of Lahaul and Spiti valley in the western Himalayas, obtained from collocated and concurrent measurements made from August (summer) to October (autumn). The results depicted very low values of columnar AOD (mean ~0.07) with ~4% contribution of BC (mean BC ~168 ng/m³) to near surface composite aerosol mass. The total suspended particulate (TSP) matter showed significant variations between 5 and 40 µg/m³, having dominance of mineral dust components (~67%) during the entire study period. The ratio of organic carbon (OC) to elemental carbon (EC) varied over a wide range from 7.8 to 18.9, with a mean value of 12.5 ± 2.95 . The higher fraction of water-soluble OC in the total OC component indicated the aged nature of the carbonaceous species. An enrichment factor estimated from the concentrations of trace elements also revealed the influence of anthropogenic source contribution. The regions located west and northwest of the measurement site, which includes the regional hotspots of Indo-Gangetic Plains, west Asia, and the Middle East, are possible source regions to modulate the aerosols over the observational site through long-range transport. These observations have far-reaching implications in view of the role of aerosols on regional radiative balance and impact on snow/glacier coverage. (11 Figures, 3 Tables, 111 Figures)

[14847]

Bodrud-Doza Md, Bhuiyan M A H, Didar-UI Islam S M, Quraishi S B, Muhib Md. I, Rakib M A, and Rahman M S. 2019

Groundwater for Sustainable Development **9**: 100212

Department of Environmental Sciences, Jahangirnagar University, Dhaka, 1342, Bangladesh

Delineation of trace metals contamination in groundwater using geostatistical techniques: a study on Dhaka City of Bangladesh

Due to overexploitation and unsustainable groundwater resource management, Dhaka, the capital city of Bangladesh, has posed an alarming risk of elimination in terms of quantity and its quality. Therefore, this study intended to evaluate the threat of groundwater contamination by geostatistical approach considering several major trace elemental concentrations. The results of best-fitted semivariogram model showed the moderate spatial dependence for Fe, NI, and HEI and weak spatial dependence for Mn. From the cross-validation result, it was found that ordinary kriging produces the most accurate distribution maps for Fe, Mn, NI, and HEI. Thematic maps showed the spatial distribution of Fe, Mn, NI, and HEI, which exhibited an increasing trend of pollution towards the western and the south-western part in the study area. Besides, probability maps were developed using the indicator and the probability kriging methods to assess the risk of groundwater pollution, which also illustrated almost similar trend like thematic maps. Therefore, it has been suggested that the geostatistical method can be used for planners and policymakers to develop strategies for sustainable management of groundwater resources and to minimize pollution. (11 Figures, 9 Tables, 82 References)

[14848]

Brauer M, Guttikunda S K, Nishad K A, Dey S, Tripathi S N, Weagle C, and Martin R V. 2019
Atmospheric Environment **216**: 116940
 School of Population and Public Health, University
 of British Columbia, Vancouver, British Columbia,
 V6T1Z3, Canada

**Examination of monitoring approaches
 for ambient air pollution: a case study for
 India**

With development and population growth, increases in ambient air pollution are anticipated. Combined with an aging population and increasing burden of chronic diseases, ambient air pollution will remain a concern for India well into the current century. Air quality measurements make critical contributions to the identification and prioritization of sources and locations of the greatest concern, benchmarking against standards and guidelines, and in the evaluation of effectiveness of actions to reduce emissions. To address these gaps between India and monitor densities of comparator countries will require 1600–4000 monitors (1.2–3 monitors/million persons) at an estimated capital (annual operating) cost of US\$212–540 (\$106–270) million. Even at these densities, only relatively basic information on common air pollutants at high temporal, but limited spatial, resolution would be available. Small-scale variability in air pollution levels within urban areas would not be well characterized, nor would there be information on chemical constituents useful for evaluating and improving simulations and forecasts or for characterizing source contributions. As a sufficiently dense traditional network is developed over time, the potential for an integrated monitoring framework to serve as a near-term complement to a traditional network is assessed. (3 Figures, 2 Tables, 74 References)

[14849]

Ganguly R, Sharma D, and Kumar P. 2019
Sustainable Cities and Society **51**: 101719
 Department of Civil Engineering, Jaypee University of
 Information Technology, Wanknaghat, District Solan,
 Himachal Pradesh 173234, India

**Trend analysis of observational PM₁₀
 concentrations in Shimla city, India**

The present study aims to evaluate the long-term trends of PM₁₀ at two monitoring stations in Shimla city in India. The highest daily mean concentrations were determined to be 176 and 152 µg/m³, respectively, at the urban and the background monitoring locations. Similarly, the annual mean concentrations at the monitoring locations were determined to be 59 and 45 µg/m³, respectively, for urban and background concentrations. Exceedance factors determined showed that at the urban monitoring location, the ranges varied between ‘moderate and high’, while at the background monitoring station, it remained at ‘moderate’ levels. Seasonal analysis study carried out revealed that higher concentrations were observed during summer in comparison to winter, with the least concentrations occurring during the monsoon season. A regression analysis was carried out to test the interdependency of the PM₁₀ with other pollutants and a positive correlation was observed between PM₁₀ and NO₂ and SO₂. Similarly, the correlation of PM₁₀ with meteorological parameters such as wind speed and temperature was found to be positive, while for parameters such as precipitation and relative humidity, it was negative. The paper also presents a critical discussion on the outcomes of the trend analysis study. This includes design and location of additional monitoring sites to adequately represent the actual ambient air quality conditions in Himachal Pradesh. (9 Figures, 9 Tables, 70 References)

[14850]

Garaga R, Chakraborty S, Zhang H, Gokhale S, Xue Q, and Kota S H. 2020

Atmospheric Research **232**: 104683

Department of Civil Engineering, Indian Institute of Technology Guwahati, Assam 781039, India

Influence of anthropogenic emissions on wet deposition of pollutants and rainwater acidity in Guwahati, a UNESCO heritage city in Northeast India

Guwahati, the largest urban corridor of Northeast India, is one of the United Nations Educational, Scientific and Cultural Organization (UNESCO) world heritage sites and one of the 200 ecoregions in the world. The present study investigates the characterization of chemical components and sources of precipitation samples collected in Guwahati. Acidic rain events occurred throughout the year, with a frequency of 64% and 87% during monsoon and non-monsoon seasons, respectively. Higher contributions of the acidic species (SO_4^{2-} and NO_3^-) coinciding with poor neutralizing capacity of crustal species (Ca^{2+} , K^+ , and Mg^{2+}) led to acid rain in this region. Isotope analysis ($\delta^{18}\text{O}$ and δD) indicated that monsoonal and non-monsoonal rains were of marine and non-marine origins, respectively. This is further supported by the back trajectory analysis as majority of the individual rain events during $d\text{-excess} < 10\text{‰}$ (i.e., monsoon) indicated their maximum contribution from ocean, while during $d\text{-excess} > 10\text{‰}$ (i.e., non-monsoon), the trajectories originated from water-inland. The enrichment factors (EF) for Pb, Zn, Co, and Cu were > 5 , indicating the dominance of anthropogenic sources in this region. The positive matrix factorization (PMF) along with isotope analysis identified marine (40%) as the major source in monsoon and industrial emissions (28%) in non-monsoon, indicating rainwater evaporation is more of ocean and

continental origin during monsoon and non-monsoons, respectively. This study suggests the need of further studies and implementation of stringent anthropogenic regulations not only at local but also at regional and global scales in this acid rain prone region. (7 Figures, 2 Tables, 85 References)

[14851]

Gopal V, Krishnamurthy R R, Chakraborty P, Magesh N S, and Jayaprakash M. 2019

Marine Pollution Bulletin **149**: 110520

Department of Applied Geology, University of Madras, Guindy Campus, Chennai 600 025, India

Trace element contamination in marine sediments along the southeast Indian shelf following Cyclone Gaja

In this study, 27 surface sediments were collected off Pushpavanam, Nagapattinam coast, southeast coast of India for understanding the sedimentological and geochemical behaviour after the Cyclone Gaja. The sediment samples were analysed for texture, organic matter (OM), carbonates, and trace metals such as Cr, Cu, Zn, Ni, Co, including Fe and Mn. The geoaccumulation index, contamination factor, enrichment factor, and pollution load index revealed high Cu, Zn, Ni, and Co contamination in the study area. The area was moderately to considerably contaminated with Fe and Cr, while there was no Mn contamination. The principal component analysis also confirms that the concentrations of Cu, Zn, Ni, and Co were mainly derived from the anthropogenic sources and related activities. A cyclone like Gaja often causes frequent ecological disturbance to the coastal environments and it distributes pollutants such as trace elements from the localized area of contamination to offshore. (5 Figures, 7 Tables, 44 References)

[14852]

Hegde P, Vyas B M, Aswini A R, Aryasree S, and Nair P R. 2020

Journal of Arid Environments **172**: 104018

Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum, Veli, Thiruvananthapuram, Kerala 695021, India

Carbonaceous and water-soluble inorganic aerosols over a semi-arid location in north west India: seasonal variations and source characteristics

This paper presents the seasonal features of major carbonaceous components in aerosols, their source characteristics, and the role of meteorology in influencing the chemical characteristics of aerosols at a semi-arid location in Udaipur, India. The samples were analysed for OC (organic carbon), EC (elemental carbon), CC (carbonate carbon), WSOC (water-soluble OC), WSTN (water-soluble total nitrogen), and water-soluble inorganic ions. Primary and secondary OC (POC and SOC), water-insoluble OC (WIOC), and water-soluble organic nitrogen (WSON) were also estimated. OC was found to be predominantly water insoluble and secondary in nature. Local anthropogenic/natural emissions and marine transported aerosols (by south-westerlies) contributed during wet period, while dry period is influenced by transported anthropogenic aerosols from IGP and northern India (by north/north-easterlies) along with mineral aerosols from desert regions (by westerlies). Monthly average contribution of the total carbonaceous aerosols was from 20% to 42% over a year, while the water-soluble ionic fraction varied from 16% to 36% of the PM_{10} mass. The unanalysed part, which is mostly mineral dust, contributed 39–55%. (11 Figures, 3 Tables, 45 References)

[14853]

Joshi M, Nakhwa A, Khandare P, Khan A, Mariam, and Sapra B K. 2019

Atmospheric Environment **217**: 116925

Radiological Physics and Advisory Division, Bhabha Atomic Research Centre, Mumbai 400 085, India

Simultaneous measurements of mass, chemical compositional and number characteristics of aerosol particles emitted during fireworks

Simultaneous measurements of mass, chemical composition, and number characteristics were made to study the impact of emissions from fireworks on ambient aerosol characteristics. These measurements were performed in a high-rise building of an Indian megacity during Diwali festival. The mass concentration of the total suspended particulate matter on Diwali night was found to be $364 \mu\text{g}/\text{m}^3$ and is comparable with a few other samples taken at different times. Average aerosol number concentration for Diwali day was lesser than a few other sampling days. On Diwali night, average aerosol number concentration consisted of 32.3, 36.6 and 31.1% particles of nuclei, Aitken and accumulation mode size ranges, respectively. For urban environment, it could be incorrect to link changes in single aerosol characteristic to emissions during fireworks. (9 Figures, 1 Table, 77 References)

[14854]

Mehra M, Zirzow F, Ram K, and Norra S. 2020

Atmospheric Research **234**: 104734

Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi 221005, India

Geochemistry of $PM_{2.5}$ aerosols at an urban site, Varanasi, in the Eastern Indo-Gangetic Plain during pre-monsoon season

Daily and weekly $PM_{2.5}$ samples were collected during pre-monsoon season from an urban site, Varanasi, located in the eastern Indo-Gangetic

Plain to study geochemical and morphological features of aerosols. $PM_{2.5}$ samples were analysed for their elemental concentration by means of an inductively coupled plasma-mass spectrometry (ICP-MS), whereas particle morphology and composition were ascertained by means of a scanning electron microscope (SEM) coupled with an energy dispersive X-ray (EDX) spectroscopy. $PM_{2.5}$ concentrations ranged between 22.2 and 70.5 $\mu\text{g}/\text{m}^3$ in daily samples, whereas it varied between 52.0 and 106.2 $\mu\text{g}/\text{m}^3$ in weekly samples. $PM_{2.5}$ concentrations, except in one daily sample, were found to be higher than the 24 h threshold limit of World Health Organization (WHO) standards (25 $\mu\text{g}/\text{m}^3$). Elemental concentrations of Pb and Zn were as high as ~2000 ppm and 3700 ppm, respectively, highlighting the impact of heavy metal pollution in Varanasi. The cluster analysis suggests that biomass burning emissions and air mass traversing through northern and western parts of India majorly contributed to high $PM_{2.5}$ concentration at Varanasi. In contrast, wind patterns did show lower velocities and different directions (from NW India to eastern parts of India) during the days with relatively lower $PM_{2.5}$ concentrations. Morphological features of individual particles reveal an irregular, aggregated, and flaky morphology, whereas the elemental composition revealed the dominance of aluminosilicates, soot, and tarball with inclusion of anthropogenic elements (e.g., Pb) at Varanasi. (7 Figures, 1 Table, 72 References)

[14855]

Murmu P, Kumar M, Lal D, Sonker I, and Singh S K.
2019

Groundwater for Sustainable Development 9: 100239

Centre for Geospatial Technologies, SIET, Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS) Naini, Prayagraj, India

Delineation of groundwater potential zones using geospatial techniques and analytical hierarchy process in Dumka district, Jharkhand, India

This study aims to delineate groundwater potential zones using an integrated approach of remote sensing, geographical information system (GIS), and analytical hierarchy process (AHP) method in Dumka district, Jharkhand, India. Multiple data such as lithology, lineament density, geomorphology, slope, soil, rainfall, drainage density, and land use/land cover were considered for delineating the groundwater potential zones. These thematic layers were assigned suitable weights on the Saaty's scale according to their relative importance in groundwater occurrence in the study area. The assigned weights of the thematic layers and their features were then normalized by using the AHP technique. Ultimately all thematic layers were integrated by a weighted linear combination method in a GIS environment to produce a groundwater potential zone map. The delineated groundwater potential zones in the study area were categorized as 'very good', 'good', 'moderate', and 'poor'. The results showed that the area along the Mayurakshi River (Rajmahal, Pipra, Lathipahar, Phitkoria, Jhajhapur, etc.), which is approximately 11% of the total study area, was delineated as an area having 'very good' potential for groundwater. The 'good zone' delineated encompassed approximately 38% of the study area and was found in the pediment-pediplain complex zone. The 'moderate zones' encompassed approximately 44% (1602.07 km^2) of the area. The 'poor zones' encompassed approximately 7% of the area, which included Raneshwar, Asanbani, Chichro, Sarni, and certain parts of Musna. Overall, this study provides a convenient approach of delineating the potential of groundwater availability that ultimately will aid in better planning and managing of groundwater resources. (14 Figures, 5 Tables, 79 References)

[14856]

Negi P S, Pandey C P, and Singh N. 2019

Atmospheric Environment **214**: 116879

Wadia Institute of Himalayan Geology, 33 GMS Road, Dehradun 248001, India

Black carbon aerosols in the ambient air of Gangotri Glacier valley of north-western Himalaya in India

The warming effect of equivalent black carbon (EBC) aerosols due to their light absorbing nature is a serious environmental concern, particularly in the eco-sensitive and glaciated Himalayan region. Moreover, baseline data on BC is rarely available from most of the glaciated Himalayan region. The monthly mean concentration of EBC was found to be minimum ($0.089 \pm 0.052 \mu\text{g}/\text{m}^3$) in August and maximum ($0.840 \pm 0.743 \mu\text{g}/\text{m}^3$) in the month of May. The observed seasonal mean concentrations of EBC are less than $0.566 \mu\text{g}/\text{m}^3$, whereas the annual mean is $0.395 \pm 0.408 \mu\text{g}/\text{m}^3$, indicating a pristine glacial and absence of EBC sources in the locality. Further, investigation on the occasional high values extricated that the seasonal cycle of EBC was significantly influenced by the emissions resulting from agriculture burning (in the western part of the country), forest fires (along the Himalayan slopes) in summer, and to some extent the contribution from long-range transport of pollutants in winter, depending on the prevailing meteorological conditions. (6 Figures, 2 Tables, 94 References)

[14857]

Ravindra K, Singh T, Mor S, Singh V, Mandal T K, Bhatti M S, Gahlawat S K, Dhankhar R, Mor S, and Beig G. 2019

Science of The Total Environment **690**: 717–729

Department of Community Medicine and School of Public Health, Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh 160012, India

Real-time monitoring of air pollutants in seven cities of North India during crop residue burning and their relationship with meteorology and transboundary movement of air

Air pollutant emissions due to the burning of crop residues could adversely affect human health, environment, and climate. Hence, a multicity campaign was conducted during the crop residue burning period in the Indo-Gangetic Plain (IGP) to study the impact on ambient air quality. Seventeen air pollutants along with five meteorological parameters were measured using state-of-the-art continuous air quality monitors. Amritsar had the highest average concentration of $\text{PM}_{2.5}$ ($178.4 \pm 83.8 \mu\text{g}/\text{m}^3$), followed by Rohtak and Sonipat, whereas Chandigarh recorded the lowest concentration. The concentrations of gaseous pollutants NO , NO_2 , NO_x , and SO_2 were also observed highest at Amritsar location, that is, 6.6 ± 2.6 ppb, 6.2 ± 0.7 ppb, 12.7 ± 3.0 ppb, and 7.5 ± 3.3 ppb, respectively. The highest average O_3 and CO were 22.5 ± 19.3 ppb and 1.5 ± 1.2 ppm, respectively, during the campaign. The level of gaseous pollutants and volatile organic compounds (VOCs), which can play an important role in the formation of secondary air pollutants, was found to be elevated during the campaign. The correlation of meteorology and air pollutants was also studied, and O_3 shows a significant relation with temperature and UV ($R = 0.87$ and 0.74), whereas VOCs show a significant correlation with temperature ($R = -0.21$ to -0.47). Air quality data was also analysed to identify sources of emissions using principal component analysis, and it identified biomass burning and vehicular activities as major sources of air pollution. (9 Figures, 4 Tables, 79 References)

[14858]

Roy A, Mukherjee I, Saha A, Bhattacharyya A, and Mukherjee A. 2019

Indian Journal of Environmental Protection **39**(12): 1075–1083

Calcutta Institute of Engineering and Management
24/1A, Chandi Ghosh Road, Kolkata 700040, West Bengal, India

Particulate matter and its influence on air quality for Mumbai and Agra

The present paper tries to highlight the dominance of the particulate fractions on the air quality of an area. The two sampling sites chosen were Agra (27°10'36.0120"N, 78°0'29.0592"E) and Mumbai (18°58'30"N, 72°49'33"E), both highly polluted and driven by intense traffic combustion. The other pollutants taken into consideration in the study are sulphur dioxide (SO₂) and nitrogen dioxide (NO₂). The dominance of the particulate fractions in the total air pollution in the two areas has been reflected in terms of the air pollution index (API) and exceedance factor (EF). In fact, it has been observed that throughout the 3 years, the API calculated with respect to PM₁₀ is about 2.688 and 1.476 times than those calculated considering the contribution of all the three pollutants together for Agra and Mumbai. As for the EF, the average EF for PM₁₀ has been found to be 2.666 for Agra and 1.825 for Mumbai over the 3 years of the study. Lastly, an attempt has been also made in the paper to present the seasonal variation of the pollutants over the 3 years of the study. (6 Figures, 6 Tables, 16 References)

SUSTAINABLE DEVELOPMENT

[14859]

Gupta D, Ghersi F, Vishwanathan S S, and Garg A. 2019

World Development **123**: 104623

Public Systems Group, Indian Institute of Management, Ahmedabad, Gujarat 380015, India

Achieving sustainable development in India along low carbon pathways: macroeconomic assessment

Achieving fast and inclusive economic growth concurrently with greenhouse gas (GHG) emission control could have wide-ranging implications for the Indian economy, predominantly fuelled by fossil energies. India faces high income inequality with the bottom 50% of its population owning only 2% of the total national wealth. Other developmental challenges include 304 million people living in poverty, 269 million without access to electricity, 92 million without access to safe drinking water, and around 2 million homeless. The authors demonstrate that low-carbon scenarios can accommodate yearly economic growth of 5.8% from 2013 to 2050, that is, perform close to, if not slightly higher than, the business-as-usual scenario, despite high investment costs. This result partly stems from improvement in the Indian trade balance via substantial reduction of large fossil fuel imports. Additionally, it is the consequence of significant shifts of sectoral activity and household consumption towards low-carbon products and services of higher value added. These transitions would require policies to reconcile the conflicting interests of entrenched businesses in retreating sectors such as coal and oil and the emerging low-carbon sectors and technologies such as renewables, smart grids, electric vehicles, modern biomass energy, solar cooking, carbon capture and storage, and so on. (7 Figures, 7 Tables, 17 References)

CLIMATE CHANGE: ISSUES AND POLICY

[14860]

Athira G, Bahurudeen A, and Appari S. 2019
Journal of Cleaner Production **236**: 117598

Department of Civil Engineering, Birla Institute of Technology and Science Pilani, Jawahar Nagar, Hyderabad 500078, Telangana, India

Sustainable alternatives to carbon intensive paddy field burning in India: a framework for cleaner production in agriculture, energy, and construction industries

Field burning of rice straw as a method of disposal by farmers is a major concern as the smoke and harmful emissions from it causes dangerous levels of pollution. Seven out of ten cities with the poorest air quality in the world are in India, and paddy field burning has been cited as one of the main reasons. Hazardous emission from paddy field burning is combined with greenhouse gas emissions from coal fired power plants and cement manufacturing units, causing severe respiratory illnesses and other fatal health issues. The recent literature indicates an increased interest in rice straw valorisation, possibly in response to the increasing concerns over paddy field burning. However, a systematic study that compiles and compares various rice straw valorisation routes is lacking in the existing literature. This paper provides a comprehensive review of the literature on various alternative uses of rice straw in energy and construction industries. Effective use of rice straw as a biomass fuel in the energy sector not only reduces the field burning, but also decreases the dependency on non-renewable fossil fuels. Moreover, the proposed utilization of secondary by-products from rice straw-based energy production in the construction industry can help to attain the goals of resource cascading. From the review of the literature and the findings of the present study, a sustainable framework has been developed with well-defined cleaner production pathways to create a seamless material flow chain between the agricultural, energy, and construction sectors. (14 Figures, 14 Tables, 144 References)

[14861]

Baltar F, Bayer B, Bednarsek N, Deppeler S, Escribano R, Gonzalez C E, et al. 2019
Trends in Ecology & Evolution **34**: 1022–1033
Department of Limnology and Bio-Oceanography,
Center of Functional Ecology, University of Vienna,
Althanstraße 14, 1090 Vienna, Austria

Towards integrating evolution, metabolism, and climate change studies of marine ecosystems

Global environmental changes are challenging the structure and functioning of ecosystems. However, a mechanistic understanding of how global environmental changes will affect ecosystems is still lacking. The complex and interacting biological and physical processes spanning vast temporal and spatial scales that constitute an ecosystem make this a formidable problem. A unifying framework based on the ecological theory that considers fundamental and realized niches, combined with metabolic, evolutionary, and climate change studies, is needed to provide the mechanistic understanding required to evaluate and forecast the future of marine communities, ecosystems, and their services. (5 Figures, 90 References)

[14862]

Knudson C and Guido Z. 2019
Climatic Change **157**(1): 171–187
Climate Assessment for the Southwest, Institute
of the Environment, University of Arizona, ENR2
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210137, Tucson, AZ 85721-0137, USA
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The missing middle of climate services: layering multiway, two-way, and one-way modes of communicating seasonal climate forecasts

The production and distribution of seasonal climate forecasts (SCFs) have been principal global climate service activities for decades. During this time, the climate service community has increasingly moved away

from using only one-way communication modes, like radio or bulletins, to also include multiway communication modes in the form of interactive models of science communication, like participatory workshops. The combination of such workshops with the more traditional unidirectional forms of communication helps climate service providers overcome many of the limitations that inhere in each form. However, important gaps remain even with the combination of one-way and multiway modes of communication. In this article, the authors draw on 17 workshops the authors convened in six locations that engaged with 406 small-scale coffee farmers. These workshops aimed to improve the farmer access to, and understanding of, weather and climate information. The authors argue that an intermediate form of communication between providers and users that takes place between workshops would help providers better tailor the one-way and multiway communication modes by evaluating in real time the users' understanding and use of the forecasts and by monitoring the dynamic context in which the users make decisions.

[14863]

Kulkarni S D. 2019

Journal of Cleaner Production **231**: 633–641

Research Centre in Chemistry, Department of Chemistry, Shikshan Prasarak Mandali's Sir

Parashurambhau College, Tilak Road, Pune 411 030, Maharashtra, India

A bottom up approach to evaluate the carbon footprints of a higher educational institute in India for sustainable existence

Carbon footprints are the measure of extent of greenhouse gases (GHGs) emitted from any organization or activity. Reporting of the extent of carbon footprints in terms of CO₂e from educational campus may be considered as a first step towards sustainable educational practices. The present study employs a bottom-up approach where carbon footprint due to

consumption of resources from each academic department is evaluated separately and net is obtained by adding contributions from individual departments. This method has the advantage of avoiding the potential overlaps in the calculation. Hence, this approach to calculate carbon footprints can lead to their precise carbon footprint evaluation. In order to justify the above hypothesis, CF evaluation was carried out at Shikshana Prasarak Mandali's Sir Parashurambhau College, Pune for three consecutive years. Out of all the emission sources identified, apart from human contribution through respiration, electricity (35%), biodegradable and non-biodegradable waste, stationary paper (7%), use of chemicals in the laboratories (5%), paper for official purpose (12%), LPG (3%), and transport (27%) were the main contributors. (7 Figures, 3 Tables, 40 References)

[14864]

Mehajan R K, Tewary A, and Gupta S. 2019

Current Science **117**(8): 1274–1280

Department of Science and Technology, Government of India, Technology Bhavan, New Mehrauli Road, New Delhi 110 016, India

E-mail: mehajan.rk@nic.in

Towards effective climate services: Indian context

The Global Framework for Climate Services formulated by the World Meteorological Organization envisages a transformative role for all the national meteorological and hydrological services to provide climate services. This article discusses why it is necessary for India Meteorological Department to broaden its functions beyond the traditional hydro-meteorological focus and what is required for it to transform to a world-class, weather-ready (already unparallel in South Asia), and climate-smart organization. (32 References)

[14865]

Owen G, Ferguson D B, and McMahan B. 2019
Climatic Change **157**(1): 151-170
 Climate Assessment for the Southwest, Institute
 of the Environment, University of Arizona, ENR2
 Building, 1064 E. Lowell Street, Room N582, PO Box
 210137, Tucson, AZ 85721-0137, USA
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**Contextualizing climate science: applying
 social learning systems theory to
 knowledge production, climate services,
 and use-inspired research**

Social interactions and relationships are essential elements for conducting use-inspired research, creating usable knowledge, and providing climate services. The Climate Assessment for the Southwest (CLIMAS) programme was founded on theories of use-inspired research and co-producing knowledge with non-academic partners. A recent programme evaluation illuminated gaps in these underlying programme models and led to the inclusion of social learning systems theory and communities of practice. Broader implications from the evaluation focus on the importance of establishing and maintaining relationships, increasing institutional and individual flexibility in response to change, and improving the practice of transdisciplinarity. These findings inform new programme evaluation metrics and data collection techniques. This paper contributes to current theory and practice of use-inspired science and climate services by identifying and demonstrating how social interactions inform climate knowledge production. The reconceptualization of the CLIMAS programme as part of a growing regional social learning system serves as an example for similar types of programmes. The authors encourage climate services and use-inspired research programmes to explore applications of this framework to their own operations. (1 Figure, 72 References)

[14866]

Tapiador F J, Moreno R, Navarro A, Sánchez J L, and
 García-Ortega E. 2019
Atmospheric Research **228**: 107-121
 Institute of Environmental Sciences (ICAM), Faculty of
 Environmental Sciences and Biochemistry, Earth and
 Space Sciences (ess) Group, University of Castilla-La
 Mancha (UCLM), Avda. Carlos III s/n, Toledo 45071,
 Spain

**Climate classifications from regional and
 global climate models: performances for
 present climate estimates and expected
 changes in the future at high spatial
 resolution**

Climate classifications based on temperature and precipitation measurements are increasingly being used for environmental and climate change studies. Using three classification methods (Köppen, Extended Köppen, and Holdridge) and one observational dataset for present climate (Climate Research Unit), the research shows that GCMs have bridged the gap that led to the emergence of RCMs 30 years ago, as GCMs can now provide global climate classifications whose accuracy and precision are comparable to those of regional outputs of the RCMs. Projections of high-resolution GCMs for future climates under the assumptions of three Representative Concentration Pathways can therefore be used as a primary source for climate change and global warming studies at high resolution. This paper provides comprehensive, model-derived climate classifications for the entire planet, using RCMs and two GCMs for present and future climate change scenarios, and discusses how well the models actually represent the climates of the world when compared with reference, ground validation data. It turns out that both GCMs and RCMs appear still limited to provide practical estimates of the world climates even for present climate conditions. The modeling of precipitation remains the Achilles heel of models and thus of multidimensional indices, which are very sensitive to this variable. The conclusion is

that model outputs at regional scale need to be taken with extreme caution without venturing into informing policies presenting potentially large societal impacts. Nonetheless, the role of models as privileged tools to advance the scientific knowledge of the Earth's system remains undisputed. (11 Figures, 2 Tables, 87 References)

[14867]

Thakuri S, Dahal S, Shrestha D, Guyennon N, Romano E, Colombo N, *et al.* 2019
Atmospheric Research **228**: 261–269
Central Department of Environmental Science,
Tribhuvan University, 44618 Kirtipur, Kathmandu,
Nepal, E-mail: info@cdes.edu.np

Elevation-dependent warming of maximum air temperature in Nepal during 1976–2015

Significant elevation-dependent warming (EDW) of maximum near-surface air temperature and diurnal temperature range (DTR) has been observed in Nepal (southern central Himalaya) over the last four decades (1976–2015). Maximum temperature increases have been observed during all seasons of the year. This warming pattern differs from the symmetrical one observed at the global level in the same period, and it is in contrast to more prominent minimum temperature increases observed in the north of Himalaya (Tibetan Plateau). Furthermore, the near-surface air temperature change observed in Nepal contrasts the global evidence of main increasing trends occurring during the winter months. The authors observe that this asymmetric warming pattern could have more serious impacts in Nepal than in other regions of the world, considering the consequences of associated warm maximum temperature extremes (heatwaves, hot days) on human life, increased primary production, and modifications in the hydrological cycle. The authors conclude that the observed EDW of maximum temperature

and the DTR could be attributed to the monsoon weakening, that is, to the reduced number of rainy days observed in the region during the last decades. These phenomena could have been accompanied by decreasing cloudiness and the consequent increasing of daytime shortwave and decreasing of nighttime long-wave incoming solar radiation. (7 Figures, 2 Tables, 59 References)

[14868]

Waheed R, Sarwar S, and Wei C. 2019
Energy Reports **5**: 1103–1115
School of Economics, Shandong University, 27
Shanda Nanlu, Jinan 250199, P.R. China

The survey of economic growth, energy consumption and carbon emission

The study aims to examine the survey of the earlier literature that deals with economic growth, energy consumption, and carbon emission, both single country studies and multi-country studies that cover the period till 2019. The main focus of this survey is on the coverage of countries, modeling methodologies, periods and empirical conclusions. The literature survey in this research paper is based on the causality's direction between (i) economic growth and carbon emission, (ii) economic growth and energy consumption, and (iii) energy consumption and carbon emissions. In case of the developed countries, carbon emission is not linked with economic development. In case of the developing countries, higher energy consumption leads to increase in the economic growth. For the developed countries, there is less evidence of relationship between energy consumption and economic growth. Lastly, in both developing and developed countries, higher energy consumption is reported as the main culprit for carbon emission. Focusing on the implications, the governments and industries have to replace the non-renewable energy sources with renewable sources to generate electricity, run industrial operations, operate transportation, and so on. Comprehending the literature survey

has provided the basis to design and implement effective environmental and energy policies. (6 Tables, 158 References)

[14869]

Yao S, Zhang S, and Zhang X. 2019

Journal of Cleaner Production **235**: 1338–1352

School of Economics and Business Administration,
Chongqing University, 400044, Chongqing, P.R.
China

Renewable energy, carbon emission and economic growth: a revised environmental Kuznets curve perspective

Renewable energy plays an important role in reducing global carbon emission. This paper builds a RER (renewable energy consumption rate) index to represent the energy structure of a country and proposes a U-shaped RKC (renewable energy Kuznets curve) hypothesis between RER and economic growth. The authors also examine the dynamic relationship between RER and the environmental Kuznets curve (EKC) hypothesis using two panel data sets of 17 major developing and developed countries as well as six geo-economic regions of the world during 1990–2014. Panel co-integration tests indicate that a long-run relationship exists among economic growth, RER, and carbon emission. The authors employ the fully modified ordinary least squares and the dynamic ordinary least squares techniques to estimate the co-integration coefficients of the panels and individual countries/regions, respectively. The results verify both EKC and RKC hypotheses, indicating that a 10% rise in RER would lead to a 1.6% carbon emission reduction. It is also found that the RKC turning points of individual countries and the entire samples in general take place before the turning points of the respective EKCs. It suggests that promoting renewable energy consumption to make RKC cross its turning point earlier can accelerate EKC to reach its turning point more quickly. This finding has important policy implications with

respect to the development and utilization of renewable energy and environmental protection. (6 Figures, 10 Tables, 78 References)

CLIMATE CHANGE: IMPACT, ADAPTATION, AND VULNERABILITY

[14870]

Adeloye A J and Dau Q V. 2019

Science of The Total Environment **687**: 554–566

Institute for Infrastructure and Environment, Heriot-Watt University, Edinburgh EH14 4AS, UK

Hedging as an adaptive measure for climate change induced water shortage at the Pong reservoir in the Indus Basin Beas River, India

This study investigated the adaptive capacity of static and dynamic hedging operating policies to shore up the performance, that is, reliability and vulnerability, in irrigation water supply of Pong reservoir in India during climate change. The policies were developed using genetic algorithm optimization and used to force reservoir simulations for different climate change perturbed inflow series, whence derive the performance. For static hedging, the hedging fraction remains constant throughout the year while for dynamic hedging, this fraction varies monthly or seasonally. Results showed that static hedging was effective at tempering the systems vulnerability from its high of $\geq 60\%$ to lower than 25%, while maintaining an acceptable volume-based reliability. Further simulations with dynamic hedging provided only modest improvements in these two indices. The significance of this study is its demonstration of the effectiveness of hedging as a climate change adaptation measure by limiting water shortage impacts. It also demonstrates that simple static hedging can match more complex dynamic hedging policies. (12 Figures, 3 Tables, 45 References)

[14871]

Aggarwal P, Vyas S, Thornton P, Campbell B M, and Kropff M. 2019

Global Food Security **23**: 41–48

CGIAR Research Program on Climate Change,
Agriculture and Food Security, Patancheru 502 324,
Telangana, India

E-mail: icrisat@cgiar.org

Importance of considering technology growth in impact assessments of climate change on agriculture

Many assessments of climate change impacts on global crop yields project declines as early as the 2020s. Losses are projected to increase with time, up to 50% by the 2080s. The authors carried out a systematic global review and compared published projections of climate change impacts from 34 studies and ~4500 data points for the 2020s for maize, rice, and wheat at the country level with observed and forecasted national crop yields for the same period based on available global crop statistics. The authors found that observed yield changes are considerably higher than the projected yield changes arising from climate change because technological improvements appear to have a large yield-enhancing impact compared with the negative effects of climate change, at least in the short term. Most assessments of climate change impacts on crop yields show low-latitude and low- and middle-income countries as highly vulnerable, but these countries have shown the largest growth in observed yields over the same reference time period. These discrepancies are due to incomplete consideration of technological growth in climate impact assessments and large yield gaps in these countries, uncertainties associated with the methodologies used, and regional variations in adaptation options considered. Appropriate consideration of technological growth can add considerable value and relevance to global impact assessments, contributing to investment

and development targeting at both large and small scales. (5 Figures, 58 References)

[14872]

Chandole V, Joshi G S, and Rana S C. 2019

Journal of Atmospheric and Solar-Terrestrial Physics
195: 105130

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& Engineering, The Maharaja Sayajirao University of
Baroda, Pratapgunj, Vadodara 390002, Gujarat, India
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Spatio-temporal trend detection of hydro-meteorological parameters for climate change assessment in lower Tapi river basin of Gujarat state, India

The present research aims to assess the climate change in the lower Tapi river basin (LTRB) of the state of Gujarat in India. The Mann-Kendall (MK) test with Sen's slope estimator and Sen's innovative trend analysis (ITA) have been used for detecting the trend of the hydrometeorological parameters – temperature and rainfall. The temperature trend during the period 1979–2014 has been analysed using MK test and ITA method. The annual maximum, annual minimum, and annual mean temperature analysis is carried out for five weather stations in the basin. Also, the trend has been analysed using MK test and ITA method for annual rainfall for nine rain gauging stations for three time periods, that is, 1928–2013, 1955–2013, and 1970–2013. Most of the results obtained from these two methods for trend detection of these hydrometeorological parameters are found to be matching. The magnitude of upward (positive) trend of annual rainfall is greater for the period of 1955–2013 and 1970–2013 in comparison to the period of 1928–2013. The results of spatio-temporal trend distribution over the study area have shown that the annual mean and annual minimum temperature indicates the upward (positive) trend over the whole river basin, while annual maximum temperature indicates

the upward (positive) trend over the basin except west coastal region of the river basin. The annual rainfall exhibits upward (positive) trend in all three time periods over the entire Tapi river basin. The trend (positive/negative) detected for mean temperature and annual rainfall is found to be consistent with the trend noticed by India Meteorological Department for the state of Gujarat. The spatial distribution of trend further needs to be analysed to correlate it with the changing pattern of land use – land cover over a period of time. The present case study for the assessment of climate change would be useful to the water resources engineers for planning and management and policy decisions for climate change adaptation in the study area. (10 Figures, 8 Tables, 56 References)

[14873]

Cole J and Desphande J. 2019

The Lancet Planetary Health 3: e494–e495

Department of Geography, Royal Holloway University of London, Surrey TW20 0EX, UK

Poultry farming, climate change, and drivers of antimicrobial resistance in India

The poultry system faces a number of interrelated stressors from climate change. A planetary health lens, through which the entire system is approached, could offer potential solutions. Local building materials and traditional practices that could mitigate heat stress and spread of disease risk being overlooked if poultry systems are approached only from the perspective of modernizing the Indian system to Global North standards. Energy policies might need to readdress how rural areas are able to use self-generated energy. (10 References)

[14874]

Deb S and Sil B S. 2019

Urban Climate 30: 100530

Department of Civil Engineering, NIT Silchar, Cachar, Assam 788010, India

Climate change study for the meteorological variables in the Barak River basin in North-East India

In this study, trend analysis is done for the meteorological variables such as minimum temperature ($T_{\min}$), maximum temperature ($T_{\max}$), precipitation (P), and potential evapotranspiration (PET) in and around of the Barak River basin in India. A total of 10 numbers of meteorological stations with 100 years of observed data are considered for trend analysis. Two non-parametric methods, Mann-Kendall (MK) test and Sen's slope estimator, are applied for detection of direction and magnitude of the trend. From the trend analysis, it is found that both the annual temperature and seasonal temperature ($T_{\max}$ and $T_{\min}$) are increasing since a couple of decades. Also, it is observed that the average rate of increase in temperature is more in $T_{\min}$ as compared to $T_{\max}$. The decreasing trend of annual and seasonal precipitation pattern is found where negative trends are significant in the monsoon P series with a confidence interval of 95%. The potential evapotranspiration showed significant increasing trend in monsoon season. Change point analysis is also done to know the shift of the trend of meteorological variables. This study gives a fair idea about the variation of meteorological parameters which may be used for climate change analysis as well as sustainable watershed management. (12 Figures, 7 Tables, 52 References)

[14875]

Falco C, Galeotti M, and Olper A. 2019

Global Environmental Change 59: 101995

Department of Environmental Science and Policy, University of Milan, Via Festa del Perdono 7 - 20122 Milano, Italy

Climate change and migration: is agriculture the main channel?

Migration and climate change are two of the most important challenges the world currently faces. They are connected as climate change

may stimulate or hinder migration. One of the sectors strongly affected by climate change is agriculture, which is the source of income for most of the world's poor. Climate change may affect agricultural productivity and hence migration because of its impact on average temperatures and rainfall and because it increases the frequency and intensity of weather shocks. In this paper, the authors use data on 108 countries from 1960 to 2010 to analyse the relationship between weather variations, changes in agricultural productivity, and international migration. The authors find that negative shocks to agricultural productivity caused by climate fluctuations significantly increase emigration from developing countries, an especially strong impact in poor countries but less so in middle income countries. These results are robust to the definitions of the poor country sample and to several checks and alternative explanations suggested by the literature. Importantly, the results point to a causal interpretation of the agricultural channel to explain the climate change–migration nexus. (4 Figures, 23 Tables, 73 References)

[14876]

Gaupp F, Hall J, Mitchell D, and Dadson S. 2019
Agricultural Systems **175**: 34–45
Environmental Change Institute, Oxford University
Centre for the Environment, South Parks Road,
Oxford, OX1 3QY, University of Oxford, UK
E-mail: enquiries@eci.ox.ac.uk

Increasing risks of multiple breadbasket failure under 1.5 and 2°C global warming

The increasingly interconnected global food system is becoming more vulnerable to production shocks owing to increasing global mean temperatures and more frequent climate extremes. Little is known, however, about the actual risks of multiple breadbasket failure due to extreme weather events. Motivated by the Paris Climate Agreement, this paper quantifies spatial risks to global agriculture in 1.5 and 2 °C

warmer worlds. This paper focuses on climate risks posed to three major crops – wheat, soybean and maize – in five major global food producing areas. Climate data from the atmosphere-only HadAM3P model as part of the ‘Half a degree Additional warming, Prognosis and Projected Impacts’ (HAPPI) experiment are used to analyse the risks of climatic extreme events. Using the copula methodology, the risks of simultaneous crop failure in multiple breadbaskets are investigated. Projected losses do not scale linearly with global warming increases between 1.5 and 2 °C global mean temperature (GMT). In general, whilst the differences in yield at 1.5 versus 2 °C are significant, they are not as large as the difference between 1.5 °C and the historical baseline, which corresponds to 0.85 °C above pre-industrial GMT. Risks of simultaneous crop failure, however, do increase disproportionately between 1.5 and 2 °C, and so surpassing the 1.5 °C threshold will represent a threat to global food security. For maize, risks of multiple breadbasket failures increase the most, from 6% to 40% at 1.5 to 54% at 2 °C warming. In relative terms, the highest simultaneous climate risk increase between the two warming scenarios was found for wheat (40%), followed by maize (35%) and soybean (23%). (3 Figures, 1 Table)

[14877]

Gerlak A K and Greene C. 2019
Climatic Change **157**(1): 99–114
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E. 1st St, Tucson, AZ 85719 USA
E-mail: agerlak@u.arizona.edu

Interrogating vulnerability in the Global Framework for Climate Services

Over the past decade, the Global Framework for Climate Services (GFCS) has emerged as a major influence on the practice of and discourse about climate services, which aim to

reduce the vulnerability of society to climate-related hazards through better provision of climate information and engagement of users of climate services. Yet, there is little research into the relations, practices, and discourses produced and institutionalized through the GFCS. The treatment of vulnerability in climate services, and by the GFCS in particular, remains understudied. To address this gap, the authors conducted a document analysis of key GFCS reports to interrogate framings of vulnerability and examine their implications for the development and practice of climate services for adaptation. To meet its own objectives, and the larger vision of climate services, the authors propose that the GFCS draw upon a rich literature on vulnerability and promote the global development of climate services that considers the coupled physical and social dimensions of vulnerability and prioritizes climate services for the most vulnerable. (1 Figure, 4 Tables, 61 References)

[14878]

Khanal U and Wilson C. 2019

Environmental Science & Policy **101**: 156–165

Queensland University of Technology, Gardens Point campus, 2 George St, Brisbane, QLD 4000, Australia

Derivation of a climate change adaptation index and assessing determinants and barriers to adaptation among farming households in Nepal

This paper attempts to fulfil the methodological gap in measuring adoption of climate change adaptation practices among smallholder farmers in less developed countries. It explains the derivation of an adaptation index taking into account the importance of adaptation practice and the scale of adoption. Based on information collected through a questionnaire survey of 720 farming households in six districts of Nepal, this study further identifies the factors influencing the adoption of climate change adaptation practices

by farmers. The multiple regression models revealed 11 variables significantly influencing the adoption of climate change adaptation practices. The variables found significant are age and education of the household head, family size, income sources, access to credit and extension services, number of plots under cultivation, past climate change experience, access to climate information, acceptance of climate change, and belief on adaptation. This indicates that policies aimed at planning and implementation of adaptation programmes should emphasize the crucial role of social, economic, and attitudinal characteristics of farming households. (2 Figures, 6 Tables, 45 References)

[14879]

Nayak S and Mandal M. 2019

Land Use Policy **89**: 104238

Center for Oceans, Rivers, Atmosphere and Land Sciences, Indian Institute of Technology Kharagpur, West Bengal 721302, India

Impact of land use and land cover changes on temperature trends over India

This study estimates the temperature trends over India and seeks to understand the contribution of land use and land cover (LULC) changes towards the change in the temperature trends (warming or cooling) during 1981–2006 by using ‘observation minus reanalysis’ (OMR) method. The authors find that India got warmer by 0.1 °C per decade during 1981–2006 and LULC changes contributed to cooling over India by 0.02 °C per decade during this period. The contribution of land use changes to the temperature trends depends on the type of LULC and their conversion from one type to another. With the exception of dense forest, all land cover conversions to agriculture lead to cooling, whereas conversion from dense forest to agriculture results in warming. The contribution of LULC changes towards cooling over India during 1981–2006 is due to the reduction of

the area under shrubs/small vegetation and the subsequent increase of the area under agricultural/fallow land. The analysis shows that even though the LULC changes contributed towards overall cooling during 1981–2006 over India, it contributed towards warming during 1991–2006. The authors find that the cooling caused by LULC changes during 1981–2006 is due to the cooling contributed during 1981–1990. The overall results have implications for future land use change strategies that can be undertaken over India in order to avoid further worsening of the Indian climate. (6 Figures, 5 Tables, 50 References)

[14880]

Paul A, Deka J, Gujre N, Rangan L, and Mitra S. 2019 *Journal of Environmental Management* **251**: 109591
Centre for Environment Science and Climate Resilient Agriculture, Indian Agricultural Research Institute (IARI), Pusa, New Delhi 110012, India

Does nature of livelihood regulate the urban community's vulnerability to climate change? Guwahati city, a case study from North East India

There is dearth of studies on climate change based vulnerabilities of the urban people. It has been a matter of widespread debate whether nature of livelihood has any role to play in regulating vulnerabilities of an individual. To find an answer, in a first ever attempt, this study tested three different approaches, namely, livelihood vulnerability index, Intergovernmental Panel on Climate Change models, and climate vulnerability index, to estimate climate change vulnerability of urban communities from various livelihoods in Guwahati city, Assam, India. Guwahati is considered to be the gateway to the seven northeastern states of India and therefore strategically very important for this region. A structured survey was conducted involving 200 stakeholders from various livelihood sectors. Data was systematically aggregated and examined using the above-mentioned composite

indices. The differential vulnerabilities were compared and results suggested that farmers were the most vulnerable community by virtue of their high sensitivity towards health and economic losses, exacerbated by their poor adaptive capacity toward unpredictable climatic variations. Doctors were the least vulnerable owing to their higher levels of awareness and adaptive capacity. These results reiterated the importance of awareness and access to resources in regulating vulnerability. (4 Figures, 6 Tables, 53 References)

[14881]

Rao C S, Kareemulla K, Krishnan P, Murthy G R K, Ramesh P, Ananthan P S, and Joshi P K. 2019 *Ecological Indicators* **105**: 621–633
ICAR-National Academy of Agricultural Research Management (NAARM), Rajendra Nagar, Hyderabad 500 030, Telangana, India

Agro-ecosystem based sustainability indicators for climate resilient agriculture in India: a conceptual framework

The impending threats of changing climate have been well documented across sectors. The climate risks are best addressed through increasing adaptive capacity and building resilience. Ever since the global call during the Rio Summit in 1992 for establishing sustainability indicators across sectors, there have been several studies across the world on developing indicators for sustainability, vulnerability, and climate resilience. Agriculture, the most vulnerable system to changing climate, depends on the resilience of both social and ecological systems. This paper focuses on integrating the variability of climate into the agricultural sustainability measurement with a broad base of indicators and bringing in the localized factors for representing the agroecosystem specificities. The paper also aims at identifying indicators for measuring climate resilient agriculture in Indian subcontinent and developing a conceptual framework for profiling the spatial resilience across various agroecosystems for appropriate location-specific

policy interventions. In the current study, 1209 indicators used in various research studies were screened, grouped for similarity and purpose, and classified based on the various dimensions, such as social, economic, and ecological. After a critical review based on their appropriateness as a measurable indicator, the extent of overlap, relevance in Indian context, and possible data availability, the authors advocate an action-oriented model called Climate Risk Management Package for Agriculture to aid in planning spatial/agroecosystem-specific interventions, which in turn could strengthen the National Action Plan for Climate Change of Government of India. (9 Figures, 5 Tables, 65 References)

[14882]

Shrestha S, Gunawardana S K, Piman T, and Babel M S. 2019

Environmental Research **181**: 108942

Water Engineering and Management, Asian Institute of Technology, P.O. Box 4, Klong Luang, Pathum Thani, 12120, Thailand

Assessment of the impact of climate change and mining activities on streamflow and selected metal's loading in the Chindwin River, Myanmar

The rapid expansion in mining activities is deteriorating the water quality in the Chindwin River of Myanmar. In addition, climate change may also aggravate this situation in future. Therefore, the aim of this study was to establish a connection between hydrology, mining area, heavy metal loading, and climate change in the Chindwin River. The hydrology of the upper Chindwin basin was modelled using SHETRAN hydrological model. Geochemical model PHREEQC was utilized to conduct speciation and saturation indexes modelling along the river in order to quantify the precipitated minerals along the river. Thereafter a regression relationship along with LOADEST model was used to quantify the heavy metal loads. The projected metal loading under future climate

conditions shows a decreasing pattern, which is similar to the projected discharge pattern. In both baseline and future climate conditions, the area between stations Naung Po Aung and Uru downstream shows the highest load effluent for both arsenic and mercury, while the area between stations Uru downstream and Mokekalae shows the highest load of iron effluent. Although future heavy metal loadings are expected to decrease, mining activities should be carefully monitored since they discharge a large amount of toxic heavy metal loadings into the Chindwin River, which is also expected to suffer a decrease streamflow in future. (5 Figures, 4 Tables, 44 References)

[14883]

Solaun K and Cerdá E. 2019

Renewable and Sustainable Energy Reviews **116**: 109415

School of Sciences, Universidad de Navarra, Campus Universitario 31009, Pamplona, Navarra, Spain
E-mail: info@unav.es

Climate change impacts on renewable energy generation. A review of quantitative projections

Research on climate change impacts on renewable energy is becoming increasingly relevant due to the vulnerability of the sector and to the continual development of methodologies and availability of data. Public and private decision-making needs specific research. However, many gaps still exist in certain geographical regions and technologies. Economic estimates with a value chain perspective are also missing in most papers. This paper addresses the most relevant studies that project quantitative estimates of climate change impacts on solar, wind, hydro, and other renewable generation technologies. Summary tables of impacts and projections are provided so that researchers, governments, and the private sector may have an accurate view of the state of the art on this topic. (2 Figures, 6 Tables, 164 References)

[14884]

Wilke A B B, Beier J C, and Benelli G. 2019

Current Opinion in Insect Science **35**: 1–9

Department of Public Health Sciences, Miller School of Medicine, University of Miami, Rosenstiel Medical Sciences Building, Suite 1128, 1600 NW 10th Avenue, Miami, Florida 33136, United States

E-mail: ogps@med.miami.edu

Complexity of the relationship between global warming and urbanization: an obscure future for predicting increases in vector-borne infectious diseases

Arthropod vectors are responsible for the transmission of many infectious diseases. Currently, more than three billion people living in endemic areas are exposed to vector-borne pathogens. Substantial differences in the biology of arthropod vectors make it extremely challenging to predict the incidence of vector-borne diseases in the future. However, global warming and urbanization both profoundly affect the ecology and distribution of arthropod vectors. Such processes often result in a biotic homogenization of species in a non-random process of biodiversity loss. The data presently available indicate a trend towards progressive increases in the presence and abundance of vectors capable of thriving in urban environments among humans, thus increasing the contact between vectors and human hosts. As a consequence, the authors expect the incidence of vector-borne diseases to increase. In our opinion, resources should be made available and directed to strategies within the Integrated Vector Management (IVM) framework, focusing on proven vector control tools. Besides, a substantial reduction in IVM costs would be achieved by observing environmental guidelines and providing basic sanitary infrastructure at early stages of its development. This could help to increase IVM effectiveness in attenuating social determinants of health and social inequities due to exposure to vectors. (4 Figures, 8 References)

[14885]

Yue Y, Zhang P, and Shang Y. 2019

Science of The Total Environment **688**: 1308–1318

Key Laboratory of Environmental Change and Natural Disaster of Ministry of Education, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China

The potential global distribution and dynamics of wheat under multiple climate change scenarios

Accurately predicting changes in the potential distribution of crops resulting from climate change has great significance for adapting to and mitigating the impacts of climate change and ensuring food security. Based on very large datasets of wheat (*Triticum aestivum* L.) occurrence points and the main environmental factors that affect wheat growth, the authors used the Maxent model to predict the future global potential distribution and land suitability for wheat cultivation under multiple global climate change scenarios. The results indicated that the suitability for wheat cultivation is primarily influenced by climatic factors and that the accumulated temperature is especially important. The RCP4.5 scenario is more favourable for wheat cultivation, whereas the RCP8.5 scenario is least favourable. Moreover, land suitability for wheat cultivation increased in Europe, Russia, the United States, Canada, China, and Pakistan, whereas a decreasing trend in suitability was found in Central and Eastern Africa, Australia, and South India. Overall, climate change is predicted to increase land suitability for wheat cultivation in middle and high latitude areas and to decrease suitability in low latitude areas. Although the global distribution of wheat will not significantly alter with climate change, the risks to wheat cultivation may be significantly higher in the future because of high temperatures, heat waves, and droughts caused by climate change. (8 Figures, 88 References)

[14886]

Zhao H, Qu S, Guo S, Zhao H, Liang S, and Xu M.

2019

Journal of Cleaner Production **230**: 1013–1026

School of Economics and Management, North China

Electric Power University, Beijing 102206, P.R. China

Virtual water scarcity risk to global trade under climate change

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has concluded that climate change will have significant impacts on global water resources. The risk of production loss due to water scarcity can be transmitted through international trade to distant economies downstream the supply chain. In this research, how climate change may affect the global economy via reducing available water resources in some regions is investigated based on a multi-regional input–output (MRIO) model that provides information on the current global economic structure. Key nation-sectors with the greatest virtual water scarcity risk (VWSR) exports are identified under two climate change scenarios, including the agriculture sectors in Syria, Pakistan, Kazakhstan, India, Uzbekistan, Iran, and China. Improving water efficiency in these sectors is essential for increasing the resilience of the global economy against climate change induced water scarcity. Nation-sectors with the largest VWSR imports are also identified under the two climate change scenarios, including food and beverages sectors, textiles and wearing apparel sectors, and petroleum, chemical and non-metallic mineral products sectors in Saudi Arabia, the United States, Russia, Germany, Italy, and China. These are the most vulnerable nation-sectors facing the reduction in foreign water resources due to climate change. The evaluation demonstrates that nations should cooperatively manage water resources and be aware of the transmission of virtual water scarcity risk through international trade under climate change. Moreover, nation-sectors with

high VWSR imports may reduce the reliance on water-intensive products and diversify importing sources, and national governments can encourage residents to change consumption patterns. (7 Figures, 2 Tables, 41 References)

GHG EMISSIONS AND MITIGATION

[14887]

Bajgai Y, Yeshey Y, De Mastro G, Ghimiray M, and

Chhogyel N. 2019

Environmental Development **32**: 100469

Agriculture Research and Development Centre,

Department of Agriculture Ministry of Agriculture and

Forests, Bajo, Wangduephodrang, Post Box 1263,

Bhutan

Influence of nitrogen application on wheat crop performance, soil properties, greenhouse gas emissions and carbon footprint in central Bhutan

In Bhutan, wheat (*Triticum aestivum* L.) is an important staple crop and its productivity is low due to poor soil fertility and inadequate external inputs. Hence, effects of four levels of nitrogen (N) (0, 50, 80, and 100 kg N per ha) on wheat crop and soil properties were examined for two consecutive years (2012 and 2013) in a rice–wheat rotation. The experiment was set up in a randomized complete block design and the treatments were replicated three times. In addition, greenhouse gas (GHG) emission was analysed for both per unit area and per kilogram of wheat grain to determine the emission-intense sources. Data were subjected to analysis of variance. The study concludes that, in Bhutan, the application of N fertilizer significantly enhanced wheat productivity and soil health at N rates of ≥ 50 kg N/ha. Further, the results indicated potentials to increase wheat yield with lower GHG emissions through improved N management. (8 Figures, 6 Tables, 75 References)

[14888]

Baumert N, Kander A, Jiborn M, Kulionis V, and Nielsen T. 2019

Environmental Science & Policy **92**: 228–236

Lund University, Department of Economic History, Box 7083, S-220 07, Lund, Sweden

Global outsourcing of carbon emissions 1995–2009: a reassessment

Increasing global production fragmentation allows for outsourcing of emissions, which may undermine national climate policies. Researchers focusing on the gap between consumption-based and production-based emissions have concluded that developed countries are systematically outsourcing emissions to developing countries. However, asymmetries in emissions embodied in trade may emerge due to differences in carbon intensity of energy and production between different countries and need not be evidence of outsourcing. This study investigates if previous results concerning emission in- and outsourcing of developed and developing countries hold when emission flows are adjusted for technological differences. Two striking results are demonstrated: first, the magnitude of outsourcing is significantly smaller than previous studies have suggested, and, second, there is no clear divide between developing and developed countries. Large developed Anglophone countries (US, UK, Canada, and Australia) were increasingly outsourcing emissions between 1995 and 2009 by shifting towards more carbon intensive goods in their imports and less carbon intensive goods in exports, whereas other developed countries (i.e., the Nordics, advanced Asia, and even the aggregate EU-27) maintained a positive emission trade balance. Among major developing countries, China is a major insourcer of emissions, while other emerging economies show no consistent pattern (e.g., India, Turkey, and Brazil) or marginal outsourcing (e.g., Indonesia and Mexico). These results contribute

to a more nuanced understanding of the impact of international trade on global carbon emissions. (8 Figures, 1 Table, 25 References)

[14889]

Dutta M K, Kumar S, Mukherjee R, Sharma N, Acharya A, Sanyal P, et al. 2019

Estuarine, Coastal and Shelf Science **229**: 106426

Geosciences Division, Physical Research Laboratory, Navrangpura, Ahmedabad 380009, Gujarat, India

Diurnal carbon dynamics in a mangrove-dominated tropical estuary (Sundarbans, India)

Based on a 24 h time-series study, the authors report the effects of a tidal cycle on carbon biogeochemistry of a mangrove dominated tropical estuary (the Sundarbans) located in the eastern part of India. Salinity, dissolved oxygen, and pH showed clear tidal variability with relatively higher values during high tide than low tide. Dissolved inorganic carbon (DIC) concentrations varied over a narrow range with relatively higher values during low tide; reverse trend, however, was noticed for $\delta^{13}\text{C}_{\text{DIC}}$ with significant variability. During low tide, along with estuarine mixing, preliminary evidences for influences of biogeochemical (e.g., organic carbon mineralization, sulphate reduction, and denitrification) and hydrological processes (porewater exchange) were found on DIC dynamics. The $\delta^{13}\text{C}_{\text{DIC}}$ relationship suggested respiration of marine plankton to be one of the possible sources for DIC. Dissolved organic carbon showed tidal influence during high tide with a signal of porewater mediated addition during low tide. Both particulate organic carbon and particulate nitrogen concentrations reached the maximum during low tide with stable isotopic compositions showing predominantly marine signature along with the possibility of biogeochemical modifications within the estuary. (7 Figures)

[14890]

Ganeshamurthy A N, Ravindra V, and Rupa T R. 2019
Current Science **117**(12): 2006–2013
 Indian Institute of Horticultural Research, ICAR-IIHR,
 Hessaraghatta Lake Post, Bengaluru 560 089,
 Karnataka, India

Carbon sequestration potential of mango orchards in India

Estimates of carbon stocks and stock changes in fruit orchards are necessary under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. In this direction, the authors estimated the carbon stocks in cultivated mango orchards in India using an exclusive allometric equation developed for estimation of tree biomass of grafted mangoes. Extensive tree, litter, weed, and soil samples were collected for estimation of carbon pools by grouping mango areas based on similarity of tree canopy, climate, and dominance of mango varieties grown in these regions. The carbon held in these pools was then compiled and national-level carbon storage in cultivated mango orchards was computed by multiplying with the area occupied by mango in these regions. The country as a whole has sequestered 285.005 mt of carbon in its mango orchards. This is, however, very low compared to polyembryonic mango trees grown from seeds in the wild. (6 Tables, 29 References)

[14891]

Hanif I, Aziz B, and Chaudhry I S. 2019
Renewable Energy **143**: 586–595
 Department of Economics, NUR International
 University, 17-KM, Raiwind Road, Model Town,
 Lahore, Punjab, Pakistan
 E-mail: Info@niu.edu.pk

Carbon emissions across the spectrum of renewable and non-renewable energy use in developing economies of Asia

The present study explores the impacts of renewable and non-renewable energy use and economic growth on carbon emissions in

the developing Asian economies. The study adopts a robust version of the two-step system generalized method of moments (GMM) on a panel of 25 upper middle and lower middle income economies for the period 1990–2015. The results show that the use of renewable energy helps in the control of carbon emissions, while the consumption of non-renewable energy contributes to the increase of carbon emissions in the developing Asian economies. Moreover, the results confirm inverted U-shaped relationship between per capita economic growth and carbon emissions in this region. Empirical results further depict that in developing countries, depletion of natural resources and growing population pressures are both contributing factors to carbon emissions. The findings spotlight that a transition from non-renewable to renewable energy sources is indispensable if Asian developing countries are to control carbon emissions and foster carbon-free economic growth. Finally, the study suggests that regional cooperation (to expedite the transition from non-renewable to renewable energy sources and to facilitate the expansion of green bond markets to developing countries) may prove helpful for mitigating carbon emissions and for increasing investment in clean energy projects. (5 Figures, 5 Tables)

[14892]

Hilaire J, Minx J C, Callaghan M W, Edmonds J,
 Luderer G, Nemet G F, et al. 2019
Climatic Change **157**: 189–219
 Potsdam Institute for Climate Impact Research (PIK),
 Telegraphenberg A 31, 14473 Potsdam, Germany

Negative emissions and international climate goals: learning from and about mitigation scenarios

For aiming to keep global warming well below 2°C and pursue efforts to limit it to 1.5°C, as set out in the Paris Agreement, a full-fledged assessment of negative emission technologies (NETs) that remove carbon dioxide from the atmosphere is crucial to inform science-based

policymaking. With the Paris Agreement in mind, the authors re-analyse available scenario evidence to understand the roles of NETs in 1.5°C and 2°C scenarios and, for the first time, link this to a systematic review of findings in the underlying literature. Most recent evidence stresses the importance of future socio-economic conditions in determining the flexibility of NET deployment and suggests opportunities for hedging technology risks by adopting portfolios of NETs. Future research needs to explore the role of climate damages on NET uptake, better understand the geophysical constraints of NET deployment (e.g., water, geological storage, climate feedbacks), and provide a more systematic assessment of NET portfolios in the context of sustainable development goals. (3 Figures, 92 References)

[14893]

Jiang L, He S, Zhong Z, Zhou H, and He L. 2019
Structural Change and Economic Dynamics 50:
245-257

School of Economics, Zhejiang University of Finance
& Economics, 18 Xueyuan Street, Jianggan District,
Hangzhou, 310018, P.R. China

Revisiting environmental Kuznets curve for carbon dioxide emissions: the role of trade

In the three decades since the environmental Kuznets curve (EKC) hypothesis was proposed, there have been a massive amount of empirical studies on the relationship between per capita income and carbon dioxide (CO₂) emissions based on the production accounting approach. International trade has played a critical role in effectively and efficiently allocating resources in the process of economic globalization. Through international trade, part of the responsibilities for CO₂ emission mitigation that should have been taken by consumers have been transferred to the producers of traded goods and resources. The focus of this research is on the re-examination of the EKC hypothesis, taking the role of international trade into account.

The findings are as follows. In the first stage, the authors calculated the CO₂ emissions of 39 countries using the input-output analysis approach based on production accounting and consumption accounting. Currently, China is the largest CO₂ emitter, surpassing the United States. However, the per capita CO₂ emissions of China lag behind those of the United States. In the second stage, although both an inverted U-shaped curve and an N-shaped curve were obtained, the cubic functional form model is better fitted. In addition, the turning point occurs earlier when adopting the production-based accounting rather than adopting the consumption-based accounting, implying that international trade postpones the peak time of global CO₂ emissions. From the above analysis, it follows that when testing for the validity of the EKC for global CO₂ emissions, the role of trade cannot be overstated. (5 Figures, 8 Tables, 36 References)

[14894]

Kang S H, Islam F, and Tiwari A K. 2019
Structural Change and Economic Dynamics 50:
90-101

Department of Business Administration, Pusan
National University, Busan 609-735, Republic of
Korea

The dynamic relationships among CO₂ emissions, renewable and non-renewable energy sources, and economic growth in India: evidence from time-varying Bayesian VAR model

The authors apply a three-variable VAR model with probabilistic variability using a time-varying parametric approach to determine the dynamic interactions among GDP growth, energy use by renewable energy sources and non-renewable energy sources, and CO₂ emission. Further, the authors characterize and quantify the impact of the nexus on the CO₂ emissions and energy sources vis-à-vis India's economic growth and fluctuations during 1965Q1–2015Q4. The authors contribute to the literature by finding

that stochastic volatility for renewable and non-renewable energy sources appears to be U-shaped besides using TVP-VAR model to the Indian context. This U-shaped pattern seems to be related to economic growth. The authors also observe the time-varying patterns of the impact transmission mechanisms among energy sources, CO₂ emissions, and GDP. In addition, the impulse response of GDP from a positive shock to CO₂ varies with the type of energy use in different time horizons. (11 Figures, 3 Tables)

[14895]

Mohammed A, Li Z, Arowolo A O, Su H, Deng X, Najmuddin O, *et al.* 2019

Resources, Conservation and Recycling **148**: 157–169

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, 11A, Datun Road, Chaoyang District, Beijing, 100101, P.R. China

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Driving factors of CO₂ emissions and nexus with economic growth, development and human health in the top ten emitting countries

This study explored the drivers of carbon dioxide (CO₂) emission (million metric tons) in the top 10 emitting countries (China, United States, India, Russian Federation, Japan, Germany, South Korea, Iran, Canada, and Saudi Arabia). The logarithmic mean Divisia index method was used to analyse the drive of CO₂ emission change pertinent to population (1000 people), per capita income, energy intensity (metric ton energy/\$GDP), and carbon intensity effects (metric ton CO₂/ton energy) from 1991 to 2014. Further, analysis was carried out for the impact of CO₂ emitted by different sectors (agriculture, energy, fugitive, industrial, manufacturing, transportation, and waste), the corresponding human development index, and economic growth using the panel model. This was done along with predictions for the

total CO₂ emissions over the next 16 years. The general results showed that the CO₂ emission change has a significant effect by population and income, especially in China and the United States. Also, there is a strong relationship between human development index, economic growth, and healthy life expectancy with sector CO₂ emission for most of the investigated countries. The forecast of sector CO₂ emission for the year 2030 showed an increase of CO₂ for all the countries, which requires a policy plan aimed at decreasing their CO₂ emission for a safer environment. (6 Figures, 1 Table, 68 References)

[14896]

Mohsin M, Rasheed A K, Sun H, Zhang J, Iram R, Iqbal N, and Abbas Q. 2019

Sustainable Energy Technologies and Assessments **35**: 365–374

School of Finance and Economics, Jiangsu University, Zhenjiang 212013, P.R. China

Developing low carbon economies: an aggregated composite index based on carbon emissions

Energy indices provide a clear summary to measure the energy performance of the country, which is a prerequisite for policymaking. Increasing rate of emissions of greenhouse gases (GHGs) is causing dangerous climate changes that seem irreversible. Therefore, it is vital to rank countries with the highest GHGs and carbon emissions in order to develop low-carbon economies. This requires a comprehensive statistical analysis. In this study, the authors develop an aggregated composite index (ACI) of energy security and environmental sustainability for each of the world's highest GHGs and CO₂ emitting countries. The index is based on a comprehensive set of indicators, including carbon emission and energy metrics. Composite indicator has been used to combine all the indicators in a holistic way. Higher values show a better efficiency and vice versa. The analysis

reveals that there are considerable differences in performances of top and low ranked countries. The study ranks the countries based on their efficiency score from top to down. (2 Figures, 4 Tables, 56 References)

[14897]

Pan W, Wang H, Wang Z, Lin L, Zhang Q, Zheng X, and Chen W. 2019

Journal of Cleaner Production **241**: 118418

Academy of Chinese Energy Strategy, China University of Petroleum, Beijing 102249, P.R. China

Carbon Palma Ratio: a new indicator for measuring the distribution inequality of carbon emissions among individuals

A new indicator – the carbon Palma ratio, extended from the income Palma ratio and defined as the ratio of the total emissions of the top 10% emitters to those of the bottom 40% – is proposed. It provides a new perspective to inform the international community and the public of the distribution inequality of carbon emissions among individuals. The ratio is quantified within and across countries by applying an elastic relationship between individual emissions and income. Results show that the carbon Palma ratios within most developing countries are overall high, suggesting them to focus more on coordinating regional and income differences and mainly guide high emitters to mitigate so as to improve emissions and income equity simultaneously. The carbon Palma ratios within developed countries are comparatively smaller; however, the greater historical responsibilities to warming suggest them to substantially reduce emissions of all citizens so as to enhance national mitigation contributions systematically. At a global scope, the current carbon Palma ratio is observably higher than within any country, reflecting an extremely severe inequality when looking at individual emissions beyond territorial limitations. The regional decomposition of emitters further suggests developed countries to take the lead in the post-Paris era in ratcheting

up mitigation and climate finance ambition. (8 Figures, 3 Tables, 43 References)

[14898]

Sinha R K and Chaturvedi N D. 2019

Renewable and Sustainable Energy Reviews **114**: 109304

Department of Chemical and Biochemical Engineering, Indian Institute of Technology Patna, Bihta, Patna 801106, Bihar, India

A review on carbon emission reduction in industries and planning emission limits

Carbon emission is a prime reason for global warming. There are various industrial processes that discharge a significant amount of carbon dioxide to the atmosphere. Carbon emission from industrial process can be controlled by the application of technologies at different stages in industries. This paper reviews the research works carried out for executing energy-efficient and low-carbon technologies for industries at different stages and classifies these works into inward and outward process stages. The review outlines a few major approaches that are followed in majority of the research works. Process integration technique and improving energy and matter efficiency are key approaches of the inward process stage. Retrofitting of existing industries with the best available technique and utilizing energy model tools for predicting energy consumption and carbon emission are key approaches of inward process stage. Incorporating CCUS technology and targeting of CCUS via the process integration technique are key approaches of the outward process stage. The research works carried out for planning of carbon emission limits are also studied. Further, a methodology based on pinch analysis is developed for determining restrictions on the carbon emission on tenure track basis. The emission limits can guide policymakers about the future course of action with respect to process modifications and technological innovations. (9 Figures, 10 Tables, 1 Reference)

[14899]

Tanwar S P S, Kumar P, Verma A, Bhatt R K, Singh A, Lal K, et al. 2019

Current Science **117**(12): 2014–2022

ICAR-Central Arid Zone Research Institute,
Jodhpur 342 003, Rajasthan, India

Carbon sequestration potential of agroforestry systems in the Indian arid zone

Carbon sequestration potential of eight recommended land-use systems of arid western Rajasthan was compared. This study indicated the carbon sequestration potential of arid regions by adopting agroforestry systems. The authors conclude that trees in different LUS significantly increased CO₂ assimilation, which is partly harvested as the economic product and partly accumulated as standing biomass and in soil. It was found that 50–75% improvement in total soil carbon stock was due to change in soil inorganic carbon stock, thus underlying the importance of soil inorganic carbon while estimating carbon sequestration potential in the arid regions. (2 Figures, 6 Tables, 42 References)

[14900]

Zerbo E and Darné O. 2019

Energy Economics **83**: 319–332

EconomiX, University of Paris Nanterre, 200 avenue de la République, 92001 Nanterre Cedex, France

On the stationarity of CO₂ emissions in OECD and BRICS countries: a sequential testing approach

This study examines the (non)-stationary properties of the per capita carbon dioxide emissions of 29 selected OECD countries plus Brazil, China, India, and South Africa over the period 1960–2014. Following a sequential testing procedure, the authors analyse the historical path of the variable regarding the possible presence of abrupt ruptures and then carry out appropriate unit root tests. The results show that the CO₂ emissions per capita are better characterized by a random walk for all

the different countries. Furthermore, the break dates and the growth rate were estimated as well for each country under study. Finally, the authors divide the carbon emissions into a secular (or trend) component and a cyclical component and propose a chronology of cycles in growth rates. (2 Figures, 7 Tables, 24 References)

[14901]

Zheng X, Streimikiene D, Balezentis T, Mardani A, Cavallaro F, and Liao H. 2019

Journal of Cleaner Production **234**: 1113–1133

SHU-UTS SILC Business School, Shanghai University,
20 Cheng Zhong Road, 201899, Shanghai, P.R. China

A review of greenhouse gas emission profiles, dynamics, and climate change mitigation efforts across the key climate change players

The major objective of the study is to analyse and compare greenhouse gas emission profiles, dynamics thereof, and the climate change mitigation efforts of the major players in the global climate change arena, namely, the G7 and BRICS countries that are accounting for more than 60% of the world greenhouse gas emissions as in 2017. The framework of sustainable energy development indicators was applied to the comparative analysis. Greenhouse gas emissions per capita has decreased in G7 countries and increased in BRICS countries. Energy intensity, economic growth, and carbon factor are the main drivers of greenhouse gas emissions per capita growth in both groups of countries. Carbon factor represents carbon intensity of a country's energy sector and is measured by greenhouse gas emissions per unit of total primary energy supply. The impact of carbon factor was least significant among the main drivers in both groups. Energy intensity was the major driver of decrease in greenhouse gas emissions per capita for both groups; however, the economic growth exceeded the contribution of energy intensity in BRICS countries and greenhouse gas emissions have increased in this group during the

investigated period. The comparative analysis of greenhouse gas emission profiles development trends and the main drivers of these trends in both groups of countries provides important insights in shaping future climate change mitigation policies and developing greenhouse gas emission reduction targets. The policies implemented in high ranked countries, like Integrated Resource Planning in South Africa, or measures under energy efficiency directive in EU can be applied in low ranked countries by providing the substantial contribution to the country's climate targets. (16 Figures, 6 Tables, 70 References)

BIODIVERSITY AND NATURAL RESOURCES

[14902]

Banerjee A K, Mukherjee A, Guo W, Ng W L, and Huang Y. 2019

Global Ecology and Conservation **20**: e00800

State Key Laboratory of Biocontrol and Guangdong Provincial Key Laboratory of Plant Resources, School of Life Sciences, Sun Yat-sen University, Guangzhou, Guangdong, 510275, P.R. China

Combining ecological niche modeling with genetic lineage information to predict potential distribution of *Mikania micrantha* Kunth in South and Southeast Asia under predicted climate change

In this study, the authors have incorporated genetic information with ecological niche models to generate projected distribution of the invasive species *Mikania micrantha* for which two genetic clusters were identified in South and Southeast Asia. Climatic niches were compared between native and invasive ranges as well as between invasive ranges of two lineages by using multivariate and univariate analyses. Ecological niche models were built with MaxEnt using occurrence data of two lineages separately, together, and also using native range data. Predictive abilities of the models were compared

and potential distributions of the two lineages were predicted under present and future climate scenarios. The models were projected on the native range to identify climatically suitable areas for each lineage. Significant differences between climatic niches of the two invasive lineages were found and unique climatically suitable areas for each lineage were identified. A large area of South and Southeast Asia was found to be climatically suitable for both lineages. Under climate change scenarios, pole-ward range expansion for one lineage and decrease in range size along marginal areas for another lineage were predicted. However, high amounts of niche unfilling for both the lineages indicated that, if introduced, the lineages can establish in cold and dry areas of the invasive range. The evidence of niche abandonment between native and invasive ranges indicated the presence of other lineages in its native range that are not yet introduced in this region. These findings provided baseline data for implementing management strategies at early stage of invasion and quarantine measures to protect this region from future invasions. Climatically suitable areas in the native range were identified for both lineages, which can be prioritized for conducting surveys for identification of source populations and biological control agents. (8 Figures, 4 Tables, 77 References)

[14903]

Priyadarshini P and Abhilash P C. 2019

Environmental Development **32**: 100459

Institute of Environment & Sustainable Development, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India

Promoting tribal communities and indigenous knowledge as potential solutions for the sustainable development of India

Anthropogenic alternations in the planetary biophysical systems lead to climate change

and environmental degradation at the global, regional, and national strata. Nations worldwide recognize that learning from the indigenous knowledge of communities residing in harmony with nature can provide immense impetus to national conservation strategies and help research dedicated towards mitigation of climate change impacts. India, comprising 8.6% tribal population, has access to an enormous aggregate of indigenous knowledge that through proper recognition, adoption, and mainstreaming has the potential to provide sustainable solutions to concerns related to falling agricultural productivity and soil quality, biodiversity loss, water scarcity, pollution, and many other social challenges. The present work, therefore, attempts to collate the traditional practices of Indian tribes in these sectors as well as their socio-economic status with specific Sustainable Development Goals (SDG), targets, and national

indicators. For this, an in-depth analysis of available datasets related to the scheduled tribes of India was conducted and interpretations and extrapolations were done accordingly. Bubble plot analysis was performed to understand the relationship between poverty and education among the tribal communities of various Indian states. The results indicate that establishment of functional links between traditional practices and SDG 2, 6, and 15 in particular would significantly aid the climate action policy of India. Simultaneously, improvement in the income, women and child health, and education of these communities through dedicated interventions would directly have a positive effect on national indicators of SDG 1, 2, 3, and 4. Effectual policy interventions directed towards tribal welfare would greatly reduce the damaging effects of climate change in the long term. (2 Figures, 3 Tables, 79 References)

INTERNET RESOURCES

UPDATE ON WEBSITE FROM THE INTERNET ON ENERGY AND ENVIRONMENTAL ISSUES

Alliance to Save Energy

<https://www.ase.org/>

Founded in 1977 by a pair of U.S. senators who recognized the enormous opportunity of energy efficiency, the Alliance to Save Energy is a nonprofit, bipartisan alliance of business, government, environmental, and consumer leaders advocating for enhanced energy productivity to achieve economic growth, a cleaner environment, and greater energy security, affordability and reliability. Its vision is to create a nation that uses energy more productively to achieve economic growth, a cleaner environment, and greater energy security, affordability and reliability.

American Solar Energy Society

<https://www.ases.org/>

Established in 1954, ASES is a 501(c)(3) nonprofit that advocates for sustainable living and 100% renewable energy by sharing information, events, and resources to cultivate community and power progress. It integrates the perspectives of science, industry, policy, and citizens. Through the programmes such as Solar Today magazine, ASES Solar Conferences, ASES National Solar Tour, and TinyWatts, they engage individuals, businesses, and partnering groups to advance these possibilities.

Carbon Pricing Leadership Coalition

<https://www.carbonpricingleadership.org/>

The Carbon Pricing Leadership Coalition (CPLC) is a voluntary initiative that catalyzes action towards the successful implementation

of carbon pricing around the world. The CPLC brings together leaders from government, business, civil society, and academia to support carbon pricing, share experiences, and enhance the global, regional, national, and sub-national understanding of carbon pricing implementation.

Climate Action Peer Exchange

<https://www.cape4financeministry.org/>

The mission Climate Action Peer Exchange (CAPE) is to facilitate dialogue with finance ministries about leveraging fiscal policy for realizing NDC commitments. CAPE activities include making available an online platform where users can access information and virtual communication systems to connect participants with each other and with technical experts. CAPE is a forum for peer-to-peer knowledge sharing and for discussing common challenges and best practices for developing NDC aligned climate and fiscal policies.

Climate Change Knowledge Portal

<https://climateknowledgeportal.worldbank.org/>

Climate Change Knowledge Portal provides an online platform for access to comprehensive global, regional, and country data related to climate change and development. The integration of scientific information in decision-making often depends on the use of flexible frameworks, data, and tools that can provide comprehensive information to a wide range of users, allowing them to evaluate how to apply

the scientific information to the design of a project or policy.

Climate Data Guide

<https://climatedataguide.ucar.edu/climate-data>

The Climate Data Guide provides concise and reliable information on the strengths and limitations of the key observational data sets, tools, and methods used to evaluate Earth system models and to understand the climate system. Citable expert commentaries are authored by experienced data users and developers, enabling scientists to multiply the impacts of their work and the diverse user community to access and understand the essential data.

Connect4Climate

<https://www.connect4climate.org/>

Connect4Climate is a global partnership programme launched by the World Bank Group and the Italian Ministry of Environment, Land and Sea, together with the German Federal Ministry for Economic Cooperation and Development, that takes on climate change by supporting ambitious leadership, promoting transformative solutions, and empowering collective action. The Connect4Climate community connects about 500 partners around the world, including civil society groups, media networks, international organizations, academic institutions, youth groups, and the private sector.

Energy & Environmental Research Center

<https://undeerc.org/>

The Energy & Environmental Research Center (EERC) is recognized as one of the world's leading developers of cleaner, more efficient energy to power the world and environmental technologies to protect and clean our air, water, and soil. It provides solutions to today's most critical energy and environmental challenges through innovative science and engineering.

ENERGYDATA.INFO

<https://energydata.info/>

ENERGYDATA.INFO is an open data platform providing access to datasets and data analytics that are relevant to the energy sector. ENERGYDATA.INFO has been developed as a public good available to governments, development organizations, private sector, non-governmental organizations, academia, civil society, and individuals to share data and analytics that can help in achieving the United Nations' Sustainable Development Goal 7 of ensuring access to affordable, reliable, sustainable and modern energy for all.

Energy Information Administration (EIA)

<https://www.eia.gov/analysis/>

In this website, a researcher can find energy information on sound policy, efficient markets, and public understanding of energy and its interaction with the economy and the environment. It provides a wide range of information and data products covering energy production, stocks, demand, imports, exports, and prices and prepares analyses and special reports on topics of current interest.

Environmental News Network

<https://www.enn.com>

ENN brings attention to the present and future environmental issues facing the health of our planet and the people it supports. Its mission is to inform, educate, enable, and create a platform for global environmental action. ENN maintains sections on Sustainability, ENN Original News, Environmental Policy, Climate, Energy, Green Building, Pollution, Ecosystems, Wildlife, Agriculture, Sci/Tech, and Health.

MIT Energy Initiative

<http://energy.mit.edu>

This website is a hub of energy research, education, and outreach—connecting faculty, students, and staff to

develop the knowledge, technologies, and solutions that will deliver clean, affordable, and plentiful sources of energy. MITEI's research programme, the Low-Carbon Energy Centers, provides platforms for members to work with them to advance research and development in key technology areas and energy systems for addressing climate change, from solar energy to electric power systems, energy storage, and mobility, to name a few. Additional research is being conducted through the Energy at Scale Center, a collaboration with the MIT Joint Program, and the MIT Laboratory for Innovation in Fusion Technologies (LIFT).

Power & Energy

<https://www.india.gov.in/topics/power-energy>

Power and energy are two essential inputs for economic development and improving the quality of life in India. Development of conventional forms of energy for meeting the growing energy needs of society at a reasonable cost is the responsibility of the government. This section focuses on the growth of both conventional and non-conventional forms of energy in the country. Details of the schemes, policies, reports, and statistics related to the sector are available. Special initiatives by the union and state governments to promote the non-conventional/alternate/new and renewable sources of energy such as solar, wind and bioenergy, and so on are also mentioned.

Save Our Environment

<https://saveoureenvironment.org>

The Save Our Environment Action Center is a collaborative effort of the nation's most

influential environmental advocacy organizations harnessing the power of the internet to increase public awareness and activism on today's most important environmental issues.

International Union for Conservation of Nature (IUCN)

<https://www.iucn.org>

IUCN is a membership union composed of both government and civil society organizations. It harnesses the experience, resources, and reach of its more than 1300 member organizations and the input of more than 15,000 experts. This diversity and vast expertise makes IUCN the global authority on the status of the natural world and the measures needed to safeguard it.

UNFCCC NAP Central

<https://www4.unfccc.int/sites/NAPC/Pages/Home.aspx>

The objective of NAP Central is to facilitate access to data, information, and knowledge on adaptation assessment, planning, and implementation to all relevant stakeholders in LDCs and other countries that are developing national adaptation plans (NAP). The website offers a platform to showcase samples of processes and outputs of adaptation planning and implementation from other countries to offer lessons to those developing adaptation plans in developing country settings.

OCCASIONAL PUBLICATIONS

FROM STANDARDS, PATENTS, NEWSLETTERS, GOVERNMENT DOCUMENTS AND NOTIFICATIONS, ANNUAL REPORTS, AND SO ON

PATENTS

United States Patent US 10,493,375

Invented and filed by Lee, Sung Kyu (Daejeon, KR);

Shin, Joon Ho (Daejeon, KR)

Distillation device

The present application relates to a distillation device and a distillation method, and according to the distillation device of the present application, it is possible to minimize the *energy* losses that occur in the refining process of the raw material containing the monomer and the solvent used in the polymerization process of the thermoplastic elastomer and to reduce the installation cost of the distillation device more than the case of refinement with two distillation columns, and thus the process economics may be improved.

Source: [https://patentimages.storage.](https://patentimages.storage)

googleapis.com/2b/ac/ed/ece2825437aab0/US20160158667A1.pdf, accessed on June 9, 2016

United States Patent US 10,601,006

Granted on October 10, 2019

Invented by Maguire Patrick Daniel, et al.

Assigned to Ford Global Technologies, LLC, Dearborn, MI, USA

Filed on April 5, 2018

Method and battery assembly for electrified vehicle

A method according to an exemplary aspect of the present disclosure includes, among other things, compressing a cell stack, which itself includes at least one battery cell and a support plate spaced apart from an upper surface of the cell(s). The method further includes inserting the cell stack into a pocket of a structural

assembly by applying a force to the support plate. A battery assembly is also disclosed.

Source: <http://patft.uspto.gov>, accessed on October 20, 2019

United States Patent US 10,602,327

Granted on November 7, 2019

Invented by Baroudi Uthman, Albaseer Abdullatif, and Selim Shokri

Assigned to King Fahd University of Petroleum and Minerals, Dhahran, SA

Filed on July 19, 2019

Method for power consumption reduction in a wireless linear network

The present disclosure relates to a clustering approach for sensor nodes of a wireless sensor network. This clustering approach, equal distance different members, balances the power burden among sensor nodes by deriving an optimal number of sensor nodes at each segment of a length. To this end, the present disclosure describes a linear wireless sensor network wherein the distance between adjacent cluster heads is equal while the number of and distance between sensor nodes in each cluster is different. A power consumption model is derived to aid in the determination of the optimal number of sensor nodes within each cluster. Following evaluation of the cluster approach in comparison with previously described approaches, the present disclosure is observed to improve network longevity and reduce power consumption by deliberately increasing the density of sensor nodes nearest to a base station.

Source: <http://patft.uspto.gov>, accessed on November 15, 2019

United States Patent US 10,601,079

Granted on December 5, 2019

Invented by Myers Eric

Assigned to Ford Global Technologies, LLC, Dearborn, MI, USA

Filed on June 5, 2018

Battery assembly including cell strip array and method

This disclosure relates to a battery assembly, such as a battery assembly for an electrified vehicle, and a corresponding method. An example battery assembly includes a layer of electrolyte, a plurality of first electrodes arranged on a first side of the layer of electrolyte, a plurality of second electrodes arranged on a second side of the layer of electrolyte, and a plurality of battery cells. Further, each of the battery cells includes a portion of the layer of electrolyte, one of the first electrodes, and one of the second electrodes.

Source: <http://patft.uspto.gov>, accessed on December 13, 2019

STANDARDS

ASTM F2756 – 11(2016)

Standard Test Method for Determining Energy Consumption of Vacuum Cleaners

Significance and Use

- 4.1 This test method provides an indication of the amount of energy usage of the vacuum cleaner while operating over a specified cleaning area at a specified stroke speed and the total number of cleaning strokes.
 - 4.1.1 The test area is divided into a number of strips, the strip being defined as the width of the power head or nozzle. For the purpose of this procedure, the cleaning area is specified as 10 m² (15,500 in.²), the stroke speed is defined as 0.5 ± 0.03 m/s (1.7 ± 0.1 ft/s), with a total of 10 strokes per strip.

- 4.2 In order to provide a uniform basis for measuring the performance described in 1.1, standardized test carpets are employed in this procedure.

1. Scope

- 1.1 This test method covers only a laboratory test for determining the energy usage of household and commercial upright, canister, stick, and wet/dry vacuum cleaners operating on carpet when tested under specified conditions.
 - 1.1.1 This procedure may be used in conjunction with other performance criteria, such as cleaning effectiveness.
 - 1.1.2 Vacuum cleaners, other than upright vacuum cleaners, that provide a carpet-cleaning function are tested in accordance with the carpet-cleaning instructions provided in the manufacturer's instruction manual. If the manufacturer's instruction manual does not contain instructions for a carpet-cleaning function, the vacuum cleaner is not within the scope of this procedure.
- 1.2 This test method is applicable to household and commercial types of vacuum cleaners.
- 1.3 The values stated in SI units are to be regarded as standard. The inch-pound units given in parentheses are mathematical conversions that are provided for information only and are not considered standard.

ASTM E3066 – 16a

Standard Practice for Evaluating Relative Sustainability Involving Energy or Chemicals from Biomass

1. SCOPE

- 1.1 This standard practice provides a science-

based methodology for evaluating the relative sustainability of options involving energy or chemicals derived from biomass. Options may involve products, processes, or projects.

- 1.2 The methodology includes setting goals and objectives, identifying stakeholders, selecting appropriate indicators, and evaluating the relative sustainability of options where at least one option is available from biomass.
- 1.3 The objectives are to facilitate fair comparison of options, focus efforts on practical indicators reflecting stakeholder priorities, and support continual improvement for more sustainable outcomes.
- 1.4 The purpose of this standard practice is not to declare something as sustainable or not sustainable but to help users assess, compare, and rank options based on specific goals and objectives.

ASTM D6286 – 19

Standard Guide for Selection of Drilling and Direct Push Methods for Geotechnical and Environmental Subsurface Site Characterization

1. SCOPE

- 1.1 This guide provides descriptions of various methods for site characterization along with advantages and disadvantages associated with each method discussed. This guide is intended to aid in the selection of drilling method(s) for geotechnical and environmental soil and rock borings for sampling, testing, and installation of wells or other instrumentation.
- 1.2 This guide cannot address all possible subsurface conditions that may occur, such as geologic, topographic, climatic, or anthropogenic.

- 1.3 The values stated in either SI units or inch-pound units (given in brackets) are to be regarded separately as standard.
- 1.4 This guide does not purport to comprehensively address all methods and the issues associated with drilling for geotechnical and environmental purposes.
- 1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

ASTM F3218 – 19

Standard Practice for Documenting Environmental Conditions for Utilization With A-UGV Test Methods

1. Scope

- 1.1 When conducting test methods, it is important to consider the role that the environmental conditions play in the Automatic through Autonomous–Unmanned Ground Vehicle (A-UGV) performance.
- 1.2 Various A-UGVs are designed to be operated both indoors and outdoors under conditions specified by the manufacturer. Likewise, end users of the A-UGV will be operating these vehicles in a variety of environmental conditions.
- 1.3 It is also important to consider changes in environmental conditions during the course of operations (e.g., transitions between conditions).
- 1.4 This practice provides brief introduction to the following list of environmental conditions that can affect performance of the A-UGV: Lighting, External sensor emission, Temperature, Humidity, Electrical Interference, Air quality, Ground Surface, and Boundaries.

ASTM F1231 – 19**Standard Guide for Ecological Considerations for the Use of Oil Spill Dispersants in Freshwater and Other Inland Environments, Rivers and Creeks****1. Scope**

- 1.1 This guide covers the use of oil spill dispersants to assist in the control of oil spills. This guide is written with the goal of minimizing the environmental impacts of oil spills; this goal is the basis on which the recommendations are made
- 1.2 Spill responders have available several means to control or clean up spilled oil. In this guide, the use of dispersants is given equal consideration with other spill countermeasures.
- 1.3 This is a general guide only. Oil, as used in this guide, includes crude oils and refined petroleum products.
- 1.4 This guide is organized by habitat type, for example, small ponds and lakes, rivers and streams, and land. It considers the use of dispersants primarily to protect habitats from impact (or to minimize impacts).
- 1.5 This guide applies only to freshwater and other inland environments. It does not consider the direct application of dispersants to subsurface waters.
- 1.6 In making dispersant use decisions, appropriate government authorities should be consulted as required by law.
- 1.7 This guide does not address getting regulatory approval.
- 1.8 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

GOVERNMENT NOTIFICATIONS/POLICIES**India to miss 2022 renewable energy target by 42%***Bloomberg Quint, October 6, 2019*

India is unlikely to produce 175 GW of renewable energy by 2022. In fact, it will miss the target by 42%. That is according to a note by CRISIL Ltd, which cites regulatory challenges and policy flip-flops, amid record low renewable power tariffs, as reasons for the shortfall. The industry is also witnessing waning interest from developers for over a fiscal now. Recently, at the UNGA global climate summit in New York on September 23, Indian Prime Minister made a pledge to more than double India's renewable energy target to 450 GW. Indian Union Minister said India is on track to achieve its renewable energy target by 2022 as set by the Modi government.

Bihar to ban govt vehicles older than 15 years to check pollution*Mint, November 6, 2019*

Even as northern India grapples with the problem of air pollution, Bihar is proposing to ban all state-owned vehicles that are older than 15 years. News agency *Press Trust of India* reported that the Bihar government has proposed a ban on the movement of state-owned vehicles that are more than 15 years old across the state. The restriction has also been extended to commercial vehicles, but only for the Patna metropolitan area, which would make it the first non-metro city to come under such a ban. Along with northern India, Bihar too has been engulfed by toxic air post festivals, such as Diwali and Chhath, coupled with vehicular and construction-related pollution. While private vehicles have been exempted from the ban, vehicle owners will have to get fresh pollution tests done and obtain certificates.

**As told to Parliament (November 19, 2019):
40,922 MW of renewable energy capacity
installed in India in last 5 years**

Down to Earth, November 20, 2019

A total of 40,922 MW of renewable energy capacity had been installed in India during the last 5 years through solar, wind, and small hydropower projects. This was according to information provided by the Central Electricity Authority (CEA), which was presented in the Rajya Sabha by Union Minister of State (Independent Charge) for New and Renewable Energy.

**CPCB guidelines for use of treated waste in
agriculture**

The Pioneer, November 29, 2019

The Central Pollution Control Board (CPCB) has cautioned the industry against diverting treated effluents for agricultural purpose saying that it can contain harmful toxins and damage the health of both humans and soil quality. According to agriculturists, using industrial wastewater for agricultural irrigation involves changes to physicochemical and microbiological properties of soils that impact crop growth and water retention capacity of the soil, which in turn could be harmful to health. As per the guidelines, the industry should engage an agricultural scientist or tie up with an agricultural university or institute for advice on the utilization or the rate of application of the effluent for irrigation, considering the agroclimatic conditions.

While the guidelines advocated the use of treated wastewater from the industry for

irrigation as a way to conserve water resources, given the irregular availability of water, it highlighted the risk of untreated or inadequately treated water.

It is necessary to ensure the beneficial aspects of this practice before application of treated wastewater in irrigation, the guidelines cautioned.

India will have 60 GW of wind power in 2022

EVWind, December 31, 2019

The government has set the goal of installing 175 GW of renewable energy capacity by 2022, which includes 100 GW of solar energy, 60 GW of wind power, 10 GW of biomass, and 5 GW of small hydroelectric projects. India's renewable energy (RE) capacity had crossed 84 GW mark by the end of November 2019, fresh data released by the Ministry of New and Renewable Energy (MNRE) showed. "A total of 6083.48 MW of renewable energy capacity has been added during the year 2019-2020, taking the cumulative installed RE capacity to 84.39 GW as on November 2019," said the monthly report released by MNRE. The installed RE capacity of 84.39 GW includes 37.28 GW from wind energy, 32.52 GW from solar, 9.94 GW from bio-power, and 4.65 GW from small hydro plants. At present, 31.68 GW capacity projects are at various stages of implementation and 18.68 GW capacity projects are under various stages of bidding. The Ministry has so far spent around 53% or ₹2788.44 crore of its total budget allocation for the current financial year.

BOOK ALERT

UPDATE ON LATEST BOOKS ON ENERGY AND ENVIRONMENTAL ISSUES

Bent Sørensen. 2017

Academic Press; 5th edition (June 20, 2017), 1056p

Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning

This volume is a problem-solving tool for engineers, researchers, students, consultants, and planners currently working in the field, as well as a detailed map of the renewables universe for those looking to expand into new technological specialties, offering the most comprehensive coverage of the subject available. The book has been structured in three parts in order to assist readers in focusing on the issues that impact them the most for a given project or question. PART I covers the basic scientific principles behind all major renewable energy resources, such as solar, wind, and biomass. PART II provides in-depth information about how these raw renewable sources can actually be converted into useful forms, transmitted into the grid, and stored for future utilization. Finally, PART III undertakes the aspects of energy planning, environmental impacts, and socio-economic issues on regional and global levels.

Ozan Erdinc. 2017

Butterworth-Heinemann; 1st edition (March 20, 2017), 326p

Optimization in Renewable Energy Systems: Recent Perspectives

It covers all major areas where optimization techniques have been applied to reduce uncertainty or improve results in renewable energy systems (RES). Production of power with RES is highly variable and unpredictable,

leading to the need for optimization-based planning and operation in order to maximize economies while sustaining performance. This self-contained book begins with an introduction to optimization and then covers a wide range of applications in both large- and small-scale operations, including optimum operation of electric power systems with large penetration of RES, power forecasting, transmission system planning, and DG sizing and siting for distribution and end-user premises. This book is an excellent choice for energy engineers, researchers, system operators, system regulators, and graduate students.

Vikas Khare, Cheshta Khare, Savita Nema, and Prashant Baredar. 2018

Elsevier; 1st edition (October 30, 2018), 416p

Tidal Energy Systems: Design, Optimization and Control

This book provides a comprehensive overview of concepts, technologies, management, and the control of tidal energy systems and tidal power plants. It presents the fundamentals of tidal energy, including the structure of tidal currents and turbulence. Technology, principles, components, operation, and a performance assessment of each component are also covered. Other sections consider pre-feasibility analysis methods, plant operation, maintenance and power generation, reliability assessment in terms of failure distribution, constant failure rate, and the time-dependent failure model. Finally, the most recent research advances and future trends are reviewed. In addition, applicable real-life examples and a case study of India's tidal energy scenario are included. The book provides ocean energy researchers, practitioners, and graduate

students with all the information needed to design, deploy, manage, and operate tidal energy systems. Senior undergraduate students will also find this to be a useful resource on the fundamentals of tidal energy systems and their components.

David Satterthwaite, Victoria A. Beard, Diana Mitlin, and Jillian Du. 2019

Washington, DC, USA: World Resources Institute; 68p

Untreated and Unsafe: Solving the Urban Sanitation Crisis in the Global South

The report presents new sanitation data from 15 cities in the global south that shows almost two-thirds of sewage and human waste is unsafely managed, with access to safe sanitation lowest in South Asia and sub-Saharan Africa. The report argues that global monitoring efforts have resulted in an underestimation of the urban sanitation crisis. They do not adequately consider urban density and affordability from the perspective of low-income households. The new analysis confirms that the provision of sanitation infrastructure has inflexible, high, one-time costs, disincentivizing households to use safe practices.

Elias T. Ayuk, Antonio M. Pedro, Paul Ekins, et al. 2019

Nairobi, Kenya: United Nations Environment Programme; 374p

Mineral Resource Governance in the 21st Century: Gearing Extractive Industries towards Sustainable Development

The report maps existing international governance frameworks and initiatives that have overlapping subsets that focus on delivering the 2030 Global Agenda for Sustainable Development. It presents the practical actions required to improve the international governance architecture for mining to enhance its contribution towards sustainable development. It calls for a new governance framework for the

extractive sector referred to as the 'Sustainable Development Licence to Operate' that includes consensus-based principles, policy options, and best practices that are compatible with the Sustainable Development Goals and other international policy commitments.

IEA. 2019

Paris, France: IEA

Renewables 2019: Market analysis and forecast from 2019 to 2024

The report provides global trends and developments for renewable energy in the electricity, heat, and transport sectors. The analysis this year contains an in-depth look at distributed solar PV, which is set to more than double in capacity in the next 5 years, accounting for almost half of all solar PV growth. The report assesses the current state of play of distributed solar PV and maps out its huge growth potential in the coming years.

P. R. Shukla, J. Skea, R. Slade, R. van Diemen, E. Haughey, J. Malley, M. Pathak, and J. Portugal Pereira (eds). 2019

Geneva, Switzerland: Intergovernmental Panel on Climate Change. 906p

Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems

The IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems builds upon the IPCC's Fifth Assessment Report (AR5) in 2013–2014 and on relevant research subsequently published in the scientific, technical, and socio-economic literature. It was prepared following IPCC principles and procedures. This Special Report is the second of three cross-Working Group Special Reports to be published in the

AR6, accompanying the three main Working Group Reports, the Synthesis Report, and a Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Robert Brinkmann. 2019

Palgrave Macmillan; 1st edition, 325p

Environmental Sustainability in a Time of Change (Palgrave Studies in Environmental Sustainability)

This book takes a fresh look at the dynamic field of environmental sustainability by exploring the interconnections between climate change, water, energy, waste, land use, ecosystems, food, and transportation. It questions traditional approaches to sustainability that highlight the need for an equal balance of economic development, environmental protection, and social equality to achieve sustainability. This book focuses on a new line of thinking that places environmental sustainability as the key foundation in how to manage sustainability in a time of change.

J. Sachs, G. Schmidt-Traub, C. Kroll, G. Lafortune, and G. Fuller. 2019

New York, USA: Bertelsmann Stiftung and Sustainable Development Solutions Network; 478p

Sustainable Development Report 2019: Transformations to Achieve the Sustainable Development Goals

The Sustainable Development Report 2019 presents the SDG Index and Dashboards for all UN member states and frames the implementation of the Sustainable Development Goals (SDGs) in terms of six broad transformations. Sustainable Development Report 2019 calculates trend indications for a selected set of indicators using 2015–2018 data. These indicators demonstrate how the situation in the country has changed since the adoption

of the SDGs. These indicators are particularly insightful for understanding how policy implementation efforts have corresponded to changing outcomes.

Tim Searchinger, Richard Waite, Craig Hanson, Janet Ranganathan, and Patrice Dumas. 2019

Washington, DC, USA: World Resources Institute; 564p

World Resources Report: Creating a Sustainable Food Future

The synthesis report proposes a menu of options that could allow the world to achieve a sustainable food future by meeting growing demands for food, avoiding deforestation, and reforesting or restoring abandoned and unproductive land—in ways that help stabilize the climate, promote economic development, and reduce poverty. The report offers a five-course menu of solutions to ensure we can feed 10 billion people by 2050 without increasing emissions, fuelling deforestation, or exacerbating poverty. Intensive research and modeling examining the nexus of the food system, economic development, and the environment show why each of the 22 items on the menu is important and quantifies how far each solution can get us.

UN Environment Programme. 2019

Nairobi, Kenya: United Nations Environment Programme; 108p

Emissions Gap Report 2019

The report presents the latest data on the expected gap in 2030 for the 1.5 °C and 2 °C temperature targets of the Paris Agreement. It considers different scenarios, from no new climate policies since 2005 to full implementation of all national commitments under the Paris Agreement. For the first time, it looks at how large annual cuts would need to be from 2020 to 2030 to stay on track to meeting the Paris goals.

United Nations Environment Programme. 2019
UNEP's Principles for Sustainable Insurance Initiative; 58p

Unwrapping the Risks of Plastic Pollution to the Insurance Industry: The First Global Insurance Industry Study on Managing the Risks Associated with Plastic Pollution, Marine Plastic Litter and Microplastics

This study identifies how risks related to plastic pollution play out across insurance lines and

asset classes in which insurers invest. It argues that insurers should take an active role in addressing the risks related to plastic pollution and in contributing to global efforts to reduce it.

CALENDAR OF EVENTS

CONFERENCES, CONGRESSES, SEMINARS, SYMPOSIA, AND WORKSHOPS

- Berlin, Germany
September 26-28, 2019
2nd World Congress on Climate Change
Email climatechange@innovinc.org.
Website <https://wccc-2019.com/>
- London, United Kingdom
October 01-03, 2019
Smart Grid Flexibility 2019
Tel. 44 (0)20 3691 1700
Email registration@smartgrid-forums.com
Website <https://www.smartgrid-forums.com/forums/smart-grid-flexibility/>
- Bangkok, Thailand
October 3-4, 2019
2nd International Conference on Global Warming and Climate Change 2019 (GlobeWarm '19)
Tel. +94 112044480/ Ext.6102
Fax. +94 112 873 371
Email secretariat@globalclimateconference.com
Website <https://globalclimateconference.com/>
- Rabat, Morocco
October 14-16, 2019
2nd International Conference on Power and Energy Technology (ICPET 2019)
Gina Chen
Email icpet@academic.net
Tel. +86-1348-2222-225
Website <http://www.icpet.org>
- Amsterdam, Netherlands
October 20-21, 2019
6th Global summit on Climate Change
Theme: Climatology, The Science of Global Weather Systems over the Long Term
Email greenenergy@europemeet.com
- Sydney, Australia
October 21-22, 2019
10th World Convention on Recycling and Waste Management
Theme: Reduce and Recycle Waste for Sustainable Waste Management
Email wasterecycling@asiapacificmeets.com
Website <https://wastemanagement.conferenceseries.com//registration.php>
- Shandong University, Qingdao, China
October 25-27, 2019
International Symposium on Energy, Water and Environment (SEWE 2019)
Email sewe@cbees.net
Website <http://www.isewe.org/>
- Toronto, Canada
November 2-4, 2019
2019 IEEE 2nd International Conference on Renewable Energy and Power Engineering (REPE 2019)
Contact person: Ms. Teri Zhang
Tel. 86-28-83207566
Email repe@zhconf.ac.cn
Website <http://www.repe.net/>
- New York City, NY, USA
November 13-14, 2019
6th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation
Website <http://buildsys.acm.org/2019>
- Delhi, India
November 28-29, 2019
Empowering a Gas Based Economy for India
Siddharth Ranga
Tel. +91 11 6676 2378
Mobile +91 99103 86143
Email siddharth.ranga@india.messefrankfurt.com
Website http://www.lngindiasummit.com/?utm_source=NGV&utm_medium=banner
- Paris, France
December 02-03, 2019
7th Global Summit and Expo on Pollution Control
Website <https://pollutioncontrol.global-summit.com//registration.php>

- Perth, Australia
December 10–12, 2019 **Towards Green and Sustainable Future**
Contact person: Dr Farhad Shahnia
Email icpes2019@gmail.com
Website <http://www.icpes.org/>
- Perth, Australia
December 10–12, 2019 **9th International Conference on Power and Energy Systems (ICPES 2019)**
ICPES 2019 Secretary, Mr Muhammad Adnan Hayat, Engineering and Energy Discipline
Murdoch University, 90 South Street, Murdoch, Western Australia 6150, Australia
Phone: +61 (8) 9360 7429
Email icpes2019@gmail.com
Website <http://www.icpes.org>
- Munnar, India
December 11, 2019 **ISSRD – Eurasia Conference On Oil Gas And Chemical Sciences (ECOC)**
Email papers.issrd@gmail.com
Tel. +918280862844, *WhatsApp*: +919040697662
Website <http://issrd.org/Conference2019/12/Munnar/ECOC/>
- Spanish Town, Jamaica
December 11–12, 2019 **The World Congress on Pollution Control (WCPC-19)**
Conference Coordinator
Mobile +91 8870915303
Email info@itar.in
Website <https://itar.in/conf/registration.php?id=1017645>
- Melbourne, Australia
December 18–20, 2019 **2019 7th International Conference on Environment Pollution and Prevention (ICEPP 2019)**
Email icepp@cbees.net
Website <http://www.icepp.org/>
- Auckland, New Zealand
December 19–21, 2019 **2019 8th International Conference on Transportation and Traffic Engineering (ICTTE 2019)**
Contact person: Ms. Teri Zhang
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Tel. +86-130-9633-3337
Website <http://www.ictte.org/>
- Penang, Malaysia
December 28–30, 2019 **2019 International Forum on Clean Energy Engineering (FCEE 2019)**
Email fcee@iap.org
Website <http://www.fcee.net/>
- Cochin, Kerala, India
January 2–4, 2020 **PESGRE – 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy**
Prof. K Biju, Finance Chair, PESGRE 2020
Tel. +91 884 878 9090
Email bijuk@ieee.org
Website <http://pesgre2020.org/>
- Bali, Indonesia
January 13–15, 2020 **2nd International Conference on Smart Grid and Green Energy (SGGE 2020)**
Emma Chen
Tel. +852-3500-0137
Email sgge@cbees.net
Website <http://www.sgge.org/>
- Barcelona, Spain
February 10–12, 2020 **2020 9th International Conference on Clean and Green Energy (ICCGE 2020)**
Shell Xiao, Hong Kong Chemical, Biological & Environmental Engineering Society (HKCBEES)
Email iccge@cbees.org
Website <http://www.iccge.org>
- Houston, Texas, USA
February 17–20, 2020 **Fourth International Conference on Fossil and Renewable Energy**
Website <https://energy-conferences.com>
- Houston, Texas, USA
February 17–20, 2020 **International Conference on Air Quality – Science and Application: 12th International Conference on Air Quality**
Email airquality@herts.ac.uk
Website <https://www.herts.ac.uk/airqualityconference/international-conference-on-air-quality-science-and-application>

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