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ORIGINAL ARTICLE

An estimation of greenhouse gas emission from livestock in Bangladesh

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ABSTRACT

Objectives: The study was undertaken to investigate the greenhouse gas (GHG) emission from livestock in Bangladesh.
Materials and Methods: The GHG emission inventory of livestock in Bangladesh was estimated according to the tier 1 approach of the Intergovernmental Panel on Climate Change (IPCC) using livestock population data from 2005 to 2018. It was also extrapolated for the next three decades, according to the growth of the livestock population.
Results: According to the calculation, the GHG emission from livestock was 66,586 Gg/year CO_2 equivalent (CO_2e) in 2018. This emission may rise to 69,869, 80,618, 94,638, and 113,098 Gg/year CO_2e in 2020, 2030, 2040, and 2050, respectively. The share of enteric methane, manure methane, direct nitrous oxide emission, and indirect nitrous oxide emission in the total GHG emissions represented 44.0%, 3.6%, 51.5%, and 0.9%, respectively, in 2018. It may arise at a rate of 1.54%–1.74% annually until 2050.
Conclusion: The GHG inventory may guide professionals to formulate and undertake the effective mitigation measures of GHG emissions from livestock in Bangladesh. However, this inventory can be amended following the tier 2 approach recommended by the IPCC if necessary data are available at the national level.

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Introduction

The emission of anthropogenic greenhouse gasses (GHGs) is a global concern because of their huge climate change impacts. The primary GHG emission that leads to global warming is carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and different chlorofluorocarbons. However, significant sources of different atmospheric GHGs are various. For example, agriculture is mainly responsible for the atmospheric rise of CH_4 and N_2O, whereas the burning of fossil fuel and changing land-use patterns lead to higher CO_2 in the air [1]. The estimated global anthropogenic CH_4 emission was about 6,875 × 10^6 ton CO_2 equivalent (CO_2e) with the share of enteric fermentation of ruminants and their manure management by 29% and 4%, respectively, which may rise to about 7,904 × 10^6 ton CO_{2e} by 2020 [2]. According to Van der Maas et al. [3], enteric fermentation of ruminants shares about 69% of agricultural CH_4 emission, of which 89% from cattle. The enteric fermentation is an indispensable biological phenomenon of ruminants, which may cause about 2%–12% of dietary gross energy loss as gas production, particularly CH_4 [4]. This gaseous energy loss by the enteric fermentation is significantly affected by the quality and composition of the diet of ruminants [5]. About 6.5% of dietary gross energy loss was reported when cattle were fed moderate- to high-quality diets, whereas it was only about 3% if fed high-grain diets [5].

In Bangladesh, the population of different livestock categories is vast, where the density of ruminant livestock is about 376 heads/km^2 [6]. Along with the increased livestock population, intensive farming of animals and its associated technologies also contribute to GHG emission [7]. Although GHG emission inventory from livestock and its mitigation at global, national, and local levels are reported in many studies [8–10], it is scanty in Bangladesh.

The emission of CH_4 from livestock was reported by some studies [11,12], but they did not produce a report on GHG emission, including future predictions, suitable for professionals in taking mitigation strategies to achieve

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climate-smart livestock production. Therefore, the objectives of the study were to analyze the trends of GHG from livestock over the past 13 years (2005–2018) and its predicted emissions over the next three decades (up to 2050).

Materials and Methods

The estimation of GHG emission from livestock was done by following the tier 1 method of the Intergovernmental Panel on Climate Change (IPCC) [5]. Considering the average temperature of the country over the past 25 years (1991–2015; 25.27°C) [13], all necessary emission factors reported by the IPCC [5] for the warm climatic zone were used in the estimation. The emission of CH_4 and N_2O is expressed in CO_2e by considering their global warming potential (25 and 298 times, respectively) [14]. All the estimated values were expressed in gigagram (Gg; 1 Gg = 10^3 *t* = 10^6 kg). The details of the methods are as follows.

Categorization of livestock population data

The principal livestock categories (T) in Bangladesh which contribute to GHG emission are cattle, buffalo, goat, sheep, and poultry. Data on different livestock categories were collected from Department of Livestock Services [6], and it was expressed as an annual average livestock population in a million heads (10^6) in each calendar year. The dairy cattle and other cattle population was calculated by following the ratio reported by Huque [15] and extrapolated according to their annual growth rate (AGR, %). The AGR of different livestock categories was calculated by considering their population growth from 2005 to 2018 (13 years), and it was used for calculating the predicted livestock population in 2020, 2030, 2040, and 2050 (Table 1). The average animal live weight, the emission factor for enteric fermentation and manure management, nitrogen excretion rate, manure management systems, direct and indirect N_2O-N emission factors in different manure management systems, and nitrogen volatilization of different livestock categories were taken from the IPCC [5].

Enteric methane emission

The enteric CH_4 emission of ruminants was calculated according to the following equation:

$$CH_{4\ Enteric} = \sum_T \frac{(N_{(T)} \times EF_{(E,T)})}{10^6} \times 25, \text{Gg / year } CO_2e$$

where $CH_{4\ Enteric}$ = the total CH_4 emissions for enteric fermentation of ruminants, Gg/year CO_2e

N_T = the heads of livestock species/category T in the country

$EF_{(E,\ T)}$ = emission factor for the enteric fermentation of the livestock category "T," kg CH_4/head/year. The default $EF_{(E,\ T)}$ values for different livestock categories are presented in Table 2, according to the IPCC [5].

Methane emission from the manure of animals

The manure management of different livestock species that contributes to CH_4 emission was calculated according to the following equation:

$$CH_{4\ Manure} = \sum_T \frac{(EF_{(M,T)} \times N_{(T)})}{10^6} \times 25, \text{Gg / year } CO_2e$$

where, $CH_{4\ Manure}$ – total CH_4 emissions from the different manure management systems of different livestock categories, Gg/year CO_2e; $EF_{(M,T)}$ – the emission factor of CH_4 for the manure management systems of varying livestock categories "T," kg CH_4/head/year; and N_T – heads of livestock species/category "T." The default $EF_{(M,T)}$ values [5] are presented in Table 2.

Nitrous oxide emission

The N_2O emission may occur directly or indirectly from different manure management systems. The direct N_2O emission was calculated by the following equation:

$$N_2O_{D(mm)} = \sum_S [[\sum_T (N_T \times N_{ex(T)} \times MS_{S,T})] \times EF_{3(S)}] \times \frac{44}{28} \times 298 \times \frac{1}{10^6}, \text{Gg / year } CO_2e$$

where, $N_2O_{D(mm)}$ – total direct N_2O emission for the different manure management systems of different livestock categories (kg/year); $N_{(T)}$ – heads of livestock species/category "T;" $N_{ex(T)}$ – average nitrogen excretion rate of different livestock species/categories "T," kg/head/year; $MS_{(S,T)}$ – proportion of manure managed by a manure management system "S," dimensionless; $EF_{3(S)}$ – direct N_2O-N emission factor from a manure management system "S," kg/kg N; S – manure management system; and 44/28 – conversion of N_2O-N to N_2O. The default manure management systems ($MS_{S,T}$) and their emission factors (EF_3) are presented in Table 3 [5]. The manure management systems of goat, sheep, and poultry were taken as reported by Huque et al. [16]. The default live weight of different livestock categories and N_{ex} values for Asia are given in Table 2 [5]. The average live weight of poultry was taken from Ministry of Fisheries and Livestock [17].

The indirect N_2O emission was calculated by the following equation:

$$N_2O_{G(mm)} = \sum_T \left(N_{volatalization-MMS(T)} \times EF_4 \times \frac{44}{28} \times 298 \times \frac{1}{10^6} \right), \text{Gg / year } CO_2e$$

Table 1. The livestock population of Bangladesh ($\times 10^6$ heads).

Years	Livestock species/category (T)						
	Dairy cattle	Other cattle	Total cattle	Buffalo	Goat	Sheep	Poultry
2005	9.01	13.74	22.75	1.15	19.55	2.52	216.11
2010	9.14	13.95	23.09	1.37	23.71	2.99	274.76
2011	9.17	13.99	23.16	1.42	24.63	3.04	283.69
2012	9.20	14.07	23.27	1.45	25.20	3.11	290.17
2013	9.22	14.42	23.64	1.45	25.36	3.17	299.32
2014	9.25	14.54	23.79	1.46	25.52	3.24	309.58
2015	9.27	14.44	23.71	1.47	25.68	3.30	316.46
2016	9.31	14.55	23.86	1.47	25.85	3.37	324.92
2017	9.34	14.68	24.01	1.48	26.02	3.43	333.60
2018	9.36	14.80	24.16	1.48	26.18	3.50	342.52
AGR	0.27	0.61	0.48	2.27	2.61	3.00	4.50
2020	9.40	14.81	24.21	1.67	29.71	3.82	389.94
2030	9.67	15.57	25.24	2.15	39.04	5.00	571.01
2040	9.95	16.36	26.31	2.75	51.28	6.55	836.16
2050	10.23	17.20	27.43	3.52	67.37	8.59	1,224.44

AGR = annual growth rate of livestock species (%)

Table 2. Methane emission factors, nitrogen excretion rate, and live weight of different livestock categories [2].

Parameters	Livestock species/category (T)					
	Dairy cattle	Other cattle	Buffalo	Goat	Sheep	Poultry
$EF_{(E, T)}$	58	27	55	5	5	-
$EF_{(M, T)}$	5	2	5	0.22	0.20	0.02
LW	275	110	295	30	28	1.50
N_{ex}	0.47	0.34	0.32	1.37	1.17	0.82

$EF_{(E, T)}$ = enteric methane emission factor (kg/head/year CH_4); $EF_{(M, T)}$ = methane emission factor for manure management (kg/head/year CH_4); LW = default live weight of animals (kg); N_{ex} = nitrogen excretion in manure of different livestock categories (kg/1,000 kg animal mass/day); and - = not reported.

where, $N_2O_{G(mm)}$ – total indirect N_2O emission from different manure managements of livestock, Gg/year CO_2e; $N_{volatilization\text{-}MMS(T)}$ – the loss of manure nitrogen of a livestock species/category "T," kg/year; EF_4 – N_2O emission factor for the deposition of nitrogen on soils and water surfaces, kg N_2O-N/kg NH_3-N and NO_x-N volatilized; and 44/28 – conversion of N_2O-N to N_2O emission. The $N_{volatilization\text{-}MMS(T)}$ was calculated by the following equation:

$$N_{volatilization-MMS(T)} = \sum_S \left[\left[\sum_T \left(N_T \times N_{ex(T)} \times MS_{S,T}\right) \times \left(\frac{Frac_{GasMS}}{100}\right)\right]\right], kg / year$$

where, $N_{(T)}$ – heads of livestock species/category "T;" $N_{ex(T)}$ – nitrogen excretion of a livestock species/category "T," kg/head/year; $MS_{(T, S)}$ – proportion of manure under a manure management system "S," dimensionless; and $Frac_{GasMS}$ – the proportion of manure nitrogen of a livestock category "T" that volatilizes as NH_3 and NO_x under a manure management system "S" (%). The default values of EF_4 and $Frac_{GasMS}$ [5] are presented in Tables 3 and 4, respectively.

Results

Methane emission from livestock

The CH_4 emissions from both the enteric fermentation and manure management sources of different livestock categories are presented in Table 5. The highest CH_4 emission was estimated from the enteric fermentation of dairy cattle from 2005 to 2018, followed by other cattle, goats, buffalo, and sheep. The position of the different livestock categories in terms of enteric CH_4 emission may remain the same until 2050. Regarding manure management, the

Table 3. Manure management system (%) and their N_2O-N emission factors [5,16].

Manure management system (MS, %)	Livestock species/category						EF_3	EF_4
	Dairy cattle	Other cattle	Buffalo	Sheep	Goat	Poultry		
Uncovered anaerobic lagoon	0	0	0	0	0	0	0.00	0.01
Liquid/slurry	1	1	0	0	0	0	0.00	0.01
Solid storage	0	0	0	100	100	0	0.005	0.01
Dry lot	0	4	4	0	0	0	0.02	0.01
Pasture	27	22	19	0	0	0	0.02	0.01
Daily spread	19	20	21	0	0	0	0.00	0.01
Anaerobic digester	1	1	1	0	0	25.5	0.00	0.01
Burn for fuel	51	53	55	0	0	0	0.00	0.01
Pit storage	0-	0-	0-	0	0	0	0.002	0.01
Poultry manure (without litter)	0-	0-	0-	0	0	74.4	0.001	0.01
Others	0	0	0	0	0	0	-	0.01

EF_3 = direct N_2O-N emission factor (kg/kg nitrogen excreted); EF_4 = indirect N_2O-N emission factor (kg N_2O-N/kg NH_3-N and NO_x-N volatilized); and - = not reported.

Table 4. Default values of nitrogen volatilization in different manure management system usages [5].

Manure management systems	$Frac_{GasMS}$ (%)					
	Dairy cattle	Other cattle	Buffalo	Sheep	Goat	Poultry
Uncovered anaerobic lagoon	35	-	-	-	-	40
Liquid/slurry	40	-	-	-	-	-
Solid storage	30	45	-	12	12	-
Dry lot	20	30	-	-	-	-
Daily spread	7	-	-	-	-	-
Pit storage	28	-	-	-	-	-
Poultry manure (without litter)	-	-	-	-	-	55
Poultry manure (with litter)	-	-	-	-	-	40
Deep bedding	-	30		25	25	-

$Frac_{GasMS}$ = percentage of nitrogen volatilization from managed manure of different livestock categories in different manure management systems; and - = not reported.

dairy cattle had the highest emission from 2005 to 2018, followed by other cattle, buffalo, poultry, goat, and sheep. This position of livestock categories may remain the same in 2020. However, in the next two decades (2030–2050), manure CH_4 emission from poultry may be higher than buffalo. The total emission of CH_4 from all livestock categories in 2018 was 31,741 Gg/year CO_2e, consisting of 29,313 and 2,428 Gg/year CO_2e from enteric fermentation and manure management, respectively.

Nitrous oxide emission from livestock

The N_2O emission from different livestock categories is presented in Table 6. The direct N_2O emission from the manure management of dairy cattle was the highest between 2005 and 2018, followed by the goat, other cattle, poultry, buffalo, and sheep. In 2020, the highest direct N_2O may come from goat, followed by dairy cattle, other cattle, poultry, buffalo, and sheep. In 2030 and 2040, poultry manure may produce higher direct N_2O emission than other cattle category, and it may excel the dairy cattle, reaching the second most source of emission in 2050. The highest indirect N_2O emission from 2005 to 2018 was from the poultry, followed by the goat, dairy cattle, sheep, and other cattle. The position of them may remain the same in 2020 and 2030. In 2040 and 2050, the indirect N_2O emission from sheep may excel the dairy cattle category. The total N_2O emission from all livestock categories in 2018 was 34,845 Gg/year CO_2e, consisting of 34,259 and 586 Gg/year CO_2e from the direct and indirect emissions, respectively.

Table 5. Methane emission from different livestock categories (Gg/year CO_2e).

Enteric fermentation	Estimated				Projected		
	2005	2015	2018	2020	2030	2040	2050
Dairy cattle	13,071	13,444	13,572	13,635	14,023	14,422	14,832
Other cattle	9,271	9,746	9,991	9,996	10,508	11,046	11,612
Buffalo	1,574	2,018	2,038	2,302	2,950	3,781	4,846
Goat	2,444	3,211	3,273	3,714	4,880	6,411	8,422
Sheep	315	413	438	477	625	819	1,073
Total enteric fermentation	26,676	28,831	29,313	30,124	32,986	36,479	40,785
Manure management							
Dairy cattle	1,127	1,159	1,170	1,175	1,209	1,243	1,279
Other cattle	687	722	740	740	778	818	860
Buffalo	143	183	185	209	268	344	441
Goat	108	141	144	163	215	282	371
Sheep	13	17	18	19	25	33	43
Poultry	108	158	171	195	286	418	612
Total manure management	2,185	2,380	2,428	2,503	2,781	3,138	3,605
Total methane emission	28,861	31,212	31,741	32,627	35,766	39,617	44,391

Table 6. Nitrous oxide emission from different livestock categories (Gg/year CO_2e).

Direct emission	Estimated				Projected		
	2005	2015	2018	2020	2030	2040	2050
Dairy cattle	11,238	11,559	11,669	11,723	12,056	12,399	12,752
Other cattle	5,055	5,314	5,447	5,450	5,729	6,022	6,331
Buffalo	1,053	1,350	1,363	1,540	1,973	2,529	3,242
Goat	7,828	10,284	10,485	11,898	15,631	20,535	26,979
Sheep	804	1,054	1,118	1,218	1,596	2,091	2,741
Poultry	2,635	3,859	4,177	4,755	6,963	10,196	14,931
Total direct emission	28,614	33,419	34,259	36,583	43,948	53,774	66,974
Indirect emission							
Dairy cattle	34	35	36	36	37	38	39
Other cattle	11	11	11	11	12	13	13
Goat	165	217	221	250	329	432	568
Sheep	17	22	24	26	34	44	58
Poultry	186	273	295	336	492	720	1,055
Total indirect emission	413	558	586	659	903	1,247	1,733
Total nitrous oxide emission	29,027	33,977	34,845	37,242	44,852	55,021	68,707

Total GHG emission from livestock

The GHG emissions from different livestock categories are presented in Table 7. The share of different livestock categories and greenhouse gases in total GHG emission in 2018 is presented in Figures 1 and 2, respectively. Overall, the estimated GHG emission from dairy cattle was the highest in 2005 to 2018, followed by other cattle, goats, poultry, buffalo, and sheep. According to future predictions, a similar trend will exist until 2020. In 2030 and 2040, the emission from goats may be higher than other cattle and take the second position, next to dairy cattle. In 2050, the GHG emission from goats may be the highest, followed by dairy cattle, other cattle, poultry, buffalo, and sheep. The rate of increase in annual total GHG emissions from 2005 to 2018 was 1.16% (57,887 and 66,586 Gg/year in 2005

Table 7. Greenhouse gas emission from different livestock categories (Gg/year CO_2e).

Livestock category	Estimated			Projected			
	2005	2015	2018	2020	2030	2040	2050
Dairy cattle	25,471	26,197	26,447	26,570	27,325	28,103	28,902
Other cattle	15,024	15,793	16,190	16,197	17,027	17,899	18,816
Buffalo	2,771	3,551	3,587	4,051	5,192	6,654	8,529
Goat	10,544	13,853	14,122	16,026	21,054	27,660	36,339
Sheep	1,149	1,506	1,597	1,739	2,279	2,987	3,915
Poultry	2,929	4,290	4,643	5,286	7,740	11,334	16,598
Total	57,887	65,189	66,586	69,869	80,618	94,638	11,3098
Annual increase (%)		1.16		-	1.54	1.74	1.95

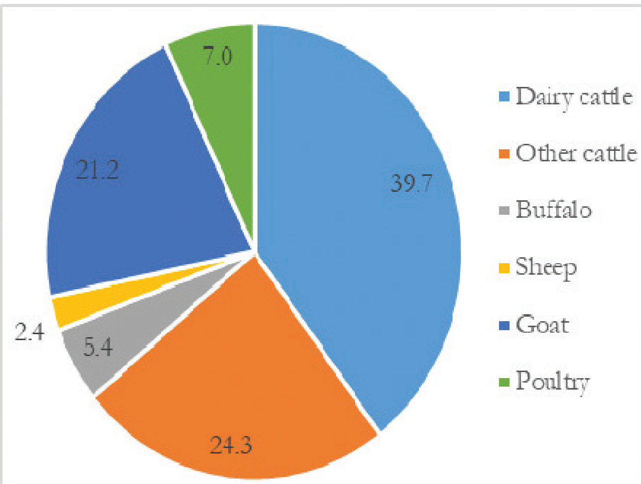

Figure 1. Share of livestock categories in greenhouse gas emission (% CO_2e) in 2018.

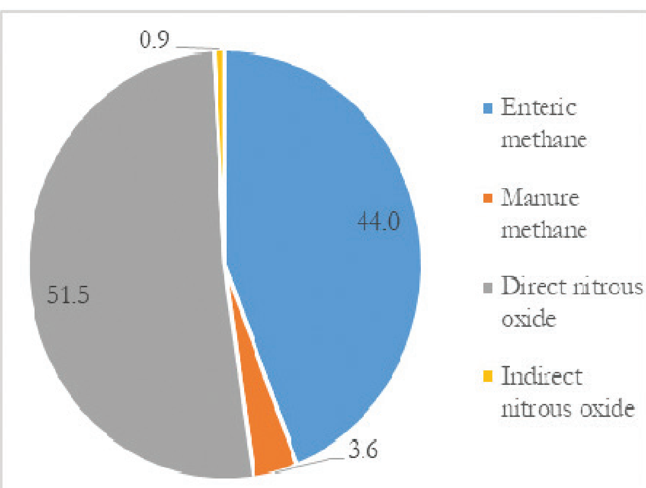

Figure 2. Share of different gases in total greenhouse gas emission (% CO_2e) in 2018.

and 2018, respectively). The rate of total GHG emission may be 1.54%, 1.74%, and 1.95% in the next three decades (2020–2050). The share of dairy cattle, other cattle, goats, poultry, buffalo, and sheep in total GHG emission in 2018 was 39.7%, 24.3%, 21.2%, 7.0%, 5.4%, and 2.4%, respectively (Fig. 1). The GHG emission in 2018 was accounted for 44.0%, 3.6%, 51.5%, and 0.9% of enteric CH_4, manure CH_4, direct N_2O emission from manure, and indirect N_2O emission from manure, respectively (Fig. 2).

Discussion

The emission of enteric CH_4 (28,831 Gg/year CO_2e, Table 5) and CH_4 and N_2O from manure in 2015 (2,380 and 558, Gg/year CO_2e, respectively, Tables 5 and 6) was equal to 9.5%, 7.7%, and 14.0%, respectively, of emission from Indian livestock, according to its livestock population in 2012 [18]. Compared to the GHG emission of 7.1 $\times 10^9$ t/year from global livestock [19], the total GHG emission from livestock of Bangladesh in 2015 (65,189 Gg/year CO_2e, Table 7) represented only 0.92%. In 2020, the GHG emission from livestock of Bangladesh (69,869 Gg/year CO_2e, Table 7) may represent about 0.88% of emissions from global livestock (7.9×10^9 t/year CO_2e) [2]. The annual increase of GHG emission from the livestock in Bangladesh (1.16%, Table 7) from 2005 to 2018 was higher than that in India and the globe from 1961 to 2010 (0.92% and 1.13%, respectively) [20]. The difference in the proportion of different livestock categories in the total livestock population results in the changes of GHG emission.

The estimated GHG emission based on the annual average livestock population and growth of different livestock categories according to the IPCC [5] provides us an assumption about the level of GHG emission from livestock in the country. Such an assumption may help in producing different country reports, taking necessary climatic policies, development activities, and projects to fight climate change issues. However, the inventory based on default nutritional and management characteristics of different livestock categories and emission factors according to the IPCC [5] may not represent the actual GHG emission from indigenous livestock. Therefore, determining the GHG emission factor, characterizing livestock population data, and studying feeds and nutrition of indigenous livestock are important. In particular, the dietary intake of energy and digestibility are the main determinant of the enteric CH_4 emission from different livestock categories. Similarly, the nitrogen excretion rate of different livestock categories, the volatile solid contents of manure management system countrywide determine the CH_4 and N_2O emission from manure. Furthermore, the growth of the livestock population many not follow a numerical trend in a country for a long period of time. Increasing productivity rather than increasing the livestock population is considered to meet the growing demand for animal-sourced foods of a country. As a result, intensive farming of improved livestock breeds/varieties is growing and may beat the necessity of rearing low-producing huge indigenous stock. The change in the livestock production system and its future prediction is of importance to study.

Conclusion

It may be concluded that total GHG emissions from the livestock in Bangladesh were 66,586 Gg/year CO_2e in 2018. The share of enteric CH_4, manure CH_4, direct N_2O emission, and indirect N_2O emission to the total GHG emissions represented 44.0%, 3.6%, 51.5%, and 0.9%, respectively. The predicted GHG emissions may raise at the rate of 1.54%–1.95% up to 2050.

Conflict of interests

The authors declare that there is no conflict of interests with any scientists or organizations.

Authors' contribution

Nani Gopal Das and Nathu Ram Sarker contributed equally in calculating the greenhouse gas (GHG) emission from livestock and preparing the manuscript. Md. Najmul Haque was involved in editing and reviewing the article.

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