

# Consequences and Remediation of Climate change with Focus on Clean Water and Sanitation in India

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(Received 2 February 2018, Revised 7 March 2018, Accepted 9 March 2018)

## Abstract

The emission of greenhouse gases mainly carbon dioxide and methane is the result of rapid industrialization to meet the demands of ever-growing population. This has resulted in an increase of global temperature which in turn is responsible for severe environmental, social, ecological and economic losses, commonly known as to as 'climate change'. This study attempts to highlight the impacts of climate change mainly focussing on water contamination, sanitation and open defecation in India. The requirement for the instantaneous employment of environment friendly technologies along with improved sanitary system has been discussed. Various other issues which are also linked to climate change that need further management like managing water resources, deterioration in human health, economic losses, modification and successful implementation of policies have been pointed out. Furthermore, stress has been made for the urgent adaptation and rethinking for making strategies along with the involvement of women in order to cop up challenges offered by climate change.

**Key words** : Climate change; Global warming; Sanitation; Open defecation.

## 1. Introduction

Intergovernmental Panel on Climate Change (IPCC AR5, 2014) predicts the rise of average global temperature which may go up by 2-4 °C by 2100.<sup>1</sup> This will restrict the availability of water resources and adversely affect the global water demand. The major consequence of global warming over water resources can be increased supply-demand gaps in tendency, which in turn adds up more challenges to already staggering water management.<sup>2</sup>

Climate change will plausibly affect groundwater and surface water resources by disturbing the water balancing components like evapotranspiration and precipitation.<sup>3,4</sup> Excessive precipitation tends to increase the rates of surface runoff along with a greater risk

of floods which indirectly affects the recharging of groundwater.<sup>5</sup> Moreover, the temperature rise will increase the rate of evapotranspiration which further causes calamities like drought and significant shift in rainfall distribution.<sup>6</sup> For water management to withstand future challenges, there is an urgent need to mitigate the contamination of water resources and usage of available water wisely. Furthermore, if precipitation got reduced along with the reduced availability of water, will constraints dilution effects and communities will be bound to use inappropriate quantity and quality of water which leads to severe waterborne diseases.<sup>7</sup>

It's a well-known fact by now that global warming being one of the major cause of climate change is greatly affecting the available surface and underground water resources. It is an urgent requirement to not to contaminate the available water recourses and management should take care of quality water

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treatment systems within their respective regions. As clean water being a precious source for healthy ecosystem, contaminated water can give rise to millions to hazardous microorganism that can be responsible for life threatening diseases.

Indian sub-continent itself can be considered as a severely affected geographical area by climate change. Many studies have revealed the ever increasing surface temperature<sup>8,9</sup> and a major shift in rainfall distribution in many states of India.<sup>10</sup> A study was conducted which includes the trends in rainfall on monthly basis over 36 climatological regions from all part of India during a period of 1901-2001. The results were evidence of the significant reduction of monsoon rainfall in some regions. However, there were some regions who suffered water-related calamities due to excessive precipitation during monsoon seasons.<sup>11</sup>

The problems in India are not restricted to only climate change. Being the second most populated country in the world, with minimal awareness of climate change and its consequences on water resources, the rate of contamination of water bodies is on ever-increasing pace. Numerous factors are involved in increasing clean water scarcity in many parts of India which may include urbanization, economic development, rapid population growth, cultures, and poor sanitation systems in rural and urban slums.<sup>12,13</sup> Variety of waterborne diseases conquers in affected regions of India where children and poorer once were targeted most.<sup>14</sup> These include diarrhoea, malaria, cholera, typhoid, filariasis etc. India also holds the burden of the single largest contributor to under-five deaths which accounts for nearly 20%.<sup>15</sup>

To conquer these issues government must take urgent steps in modifying their policies and uplift their management system. Utilization of more renewable resources especially in power sectors can provide tremendous shift towards green and sustainable approach. Installation and maintenance of improved and hygienic sanitary system are highly desirable. Finally, restrictions and increment in treatment facilities should be made for the contamination of

river water which is the major source of irrigation for agricultural production in India.

Numerous technologies, policies, and practices are going on around in India and as well as in the whole world for carbon dioxide and other greenhouse gases mitigation.<sup>16</sup> For water treatment and conservation of natural water bodies, various laws and policies are being followed. Poor Sanitation and open defecation are some of the major causes responsible for economic and health losses. The Government of India are making stringent rules and also taking immediate actions for improving the sanitation system through policies like “Swachh Bharat Abhiyan”, advertisements and by installing thousands of toilets in all parts of India.

The aim of this paper is to highlight the plausible causes and consequences of climate change in terms of deterioration of water bodies which is affecting not only humans but each and every organism. The discussion has been limited to India, covering major factors responsible for contamination of water and human health. Possible recommendations have been shared related to the adoption of carbon dioxide mitigation technology and improvement in sanitation system.

## 2. Consequences of Global Warning in India

According to the Fifth Assessment Report of the IPCC (IPCC, 2014) climate change do exist and its consequences can be seen globally. The impacts are not instantaneous but they do are long-lasting. Climate change through global warming, will increase the atmospheric temperature and will be responsible for erratic weather patterns which will affect almost all ecological depending parameters. The variability in climate can also adversely affect the psychological well-being by negatively influencing livelihoods, agricultural production, and providing insecurity among social and economic sector.<sup>17</sup>

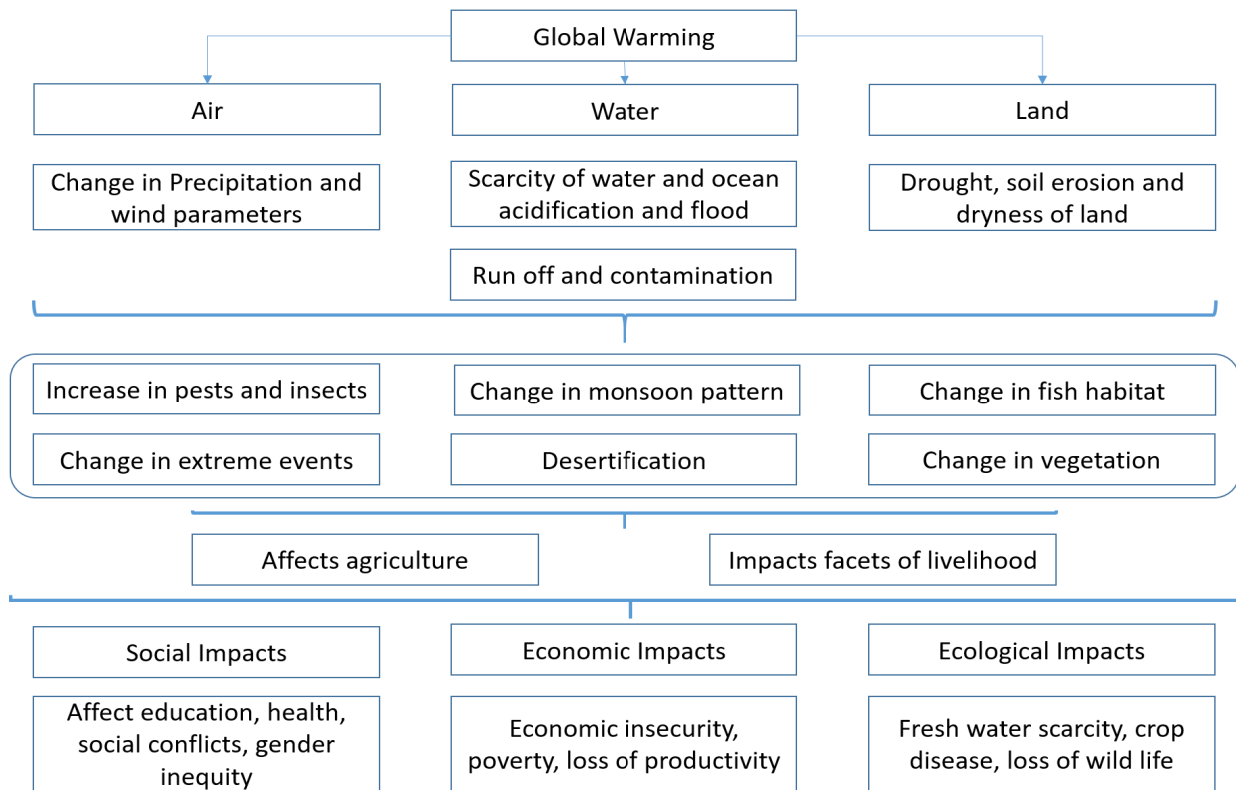
**2.1. Effect on Agriculture:**

Numerous studies have been reported regarding sensitiveness of agricultural production on climate change.<sup>18</sup> The impact in non-linear as well as complex according to IPCC categorization. For India, rice, wheat, and maize are significant as far as food security is concerned. According to Kumar et al.<sup>19</sup> and Senapati et al.<sup>20</sup> the loss in rice, wheat and maize production per degree Celsius increase in temperature will lie in the range 4% - 20%, 5% -20% and 32% - 50% respectively. These estimations include the impacts of rising temperature (like water scarcity and uneven rainfall) as well as of high carbon dioxide concentrations. From these analysis, maize is going to be affected the most in upcoming century followed by rice and wheat. A decline in percent production of approximately 72% - 90%, 12% - 52% and 15% - 52% over maize, rice and wheat respectively can be seen by 2100. It can lead to an economic loss of about 57-208 billion US\$ (0.28% - 1.02% GDP share) by 2050 and 113-367 billion

US\$ (0.26% - 0.84%) by 2100.<sup>19,20</sup> Figure 1 Depicts the patterns of affecting water availability, agriculture, rural livelihood, social and economic sectors by climate change (modified from Pradosh et al.<sup>21</sup>).

**2.2 Effect on Rivers:**

The Ganges which covers a path of about 2,525 km and draining almost quarter the area of country<sup>22</sup> has been facing a huge load of the population which is being aided by poverty. The Ganges is considered as the fifth most contaminated and polluted river in the world with the prescribed limits exceeding hundred times for faecal coliforms.<sup>23</sup> Apart from humans, as much as 140 fish species and more than 90 amphibian species are on the edge on being endangered. Various heavy metals along with other wastes discharged by industries and through run offs are playing major roles in making Ganges water hazardous causing number of diseases.<sup>24</sup> Different sources of heavy metals are presented in Table 2 (modified from (Paul et al.<sup>24</sup>)). Policies like Ganga Action Plan



**Figure 1.** Pattern representing various impacts caused by global warming.

**Table 1.** Contamination of river Ganga by heavy metals with their sources.

Sources	Heavy Metals
Pesticides	Arsenic, Cadmium, Copper, Mercury, Lead
Electroplating	Cadmium, Chromium, Copper, Nickel
Batteries	Chromium, Cadmium, Mercury, Lead
Welding	Copper, Manganese
Mining	Lead, Manganese, Copper, Zinc, Arsenic, Chromium
Paint	Manganese, Zinc, Chromium, Mercury, Lead
Textile	Mercury, Zinc, Lead, Chromium, Manganese

(GAP) which was supposed to be an initiative to clean Ganges proved to be ineffective and was considered a failure due to poor involved technologies, traditional and religious beliefs and lack of skills and technical planning.<sup>25</sup>

Even the condition of all other rivers is quite similar. According to the analysis performed by Central Pollution Control Board (CPCB),<sup>23</sup> the water in river Yamuna varied in quality and quantity with time and space. It was estimated that water flow in Yamuna is maximum in monsoon (2-3 months) while very little or negligible water can be seen in other seasons due to extensive exploitation for irrigation purposes. pH goes as high as 8.9 while dissolved oxygen reduced to as low as 0 mg/l. it shows that water is highly septic at many locations. BOD also varies in the broad range of 0.8-113 mg/l. Faecal Coliform also exceeded its limits to many folds and goes as high as  $6 \times 10^{12}$  MPN/100ml. The condition for River Brahmaputra is nothing different. Conductivity lies within range of 67-359  $\mu$ mhos/cm. The BOD values go as high as 3.6 mg/l. Faecal coliforms fall in the range of 0-910 MPN/100. Another major river in the central part of India known as Narmada has the same story. The pH varies to greatly and reaches up to 8.7. Conductivity fall in the range of 1-2130  $\mu$ mhos/cm while BOD and Faecal coliform lie within a range of 0.1-7.9 and 0-5000 MPN.100 ml respectively. Almost each and every river have similar conditions and even worse as they

cross the populated cities.

### 2.3. vals Affecting Water Resources:

Religious practices of Idol worships are becoming a serious threat to the water bodies especially rivers. These idol immersions can be considered as the major anthropogenic activity responsible for contamination of rivers throughout India.<sup>26</sup> These idols include non-degradable materials, textiles, cement, clay, plaster of Paris, varnishes, paints and dyes.<sup>27</sup> These paints and polishes contains various hazardous heavy metals like mercury, lead, chromium etc. which holds a great ability to adversely affect the water quality. These heavy metals got bio-accumulated and then transferred to food chains and can cause health hazards for humans and aquatic species.<sup>28</sup> India being an agricultural land is affected most by this practice. Contaminants originated from idols immersion ultimately affect the food crops as mostly the source of water for irrigation are these rivers, canals, and lakes. Hence, an overall food chain can be disturbed.<sup>29</sup> Moreover, plaster of Paris which can be considered as a building material of idols is basically calcium sulfate hemihydrate( $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$ ). After immersing in water it converts to gypsum which is very stable and deteriorates very slowly and can induce hardness which adversely affects aquatic life.<sup>29</sup>

Holi, “the festival of colors” is celebrated in the northern region of India. The colors used nowadays are made synthetically. Colors like purple, black, red

**Table 2:** Harmful effects and main component of chemical colours.

Colours	Chemicals	Health Effects
Green	Copper Sulphate, Lead and Cadmium Salts	Eye irritation and can cause temporary blindness
Blue	Cobalt Nitrate, Zinc Salts	Contact Dermatitis
Royal Pink	Mercury Salts	Skin irritation and itching
Black	Lead Oxide	Renal problem and can even leads to failure
Purple	Chromium Iodide	Bronchial Asthma
Red	Mercury Sulphate	Highly toxic and can cause skin cancer
Silver	Aluminium Bromide	Can cause cancer

etc. contains various heavy metals compounds as a coloring agent. These heavy metals compounds like cobalt nitrate chromium iodide lead chromate etc. are very hazardous and carcinogenic.<sup>30</sup> Heavy metals associated with colours with their harmful effects are presented in Table 2.<sup>31</sup>

#### 2.4. Sanitation and Open Defecation:

It has been estimated that around 360 million people in rural India do not have access to toilets<sup>32</sup> and 600 million people don't hesitate to defecate in open fields.<sup>33</sup> Moreover, inadequate sanitary systems estimate losses of about \$54 billion or 6.4% of India's GDP over the year 2006. More than 70% i.e. \$38.5 billion economic loss was due to health concern issues.<sup>34</sup>

Serious adverse consequences of poor sanitation or open defecation can be seen more on women than men. Women are more prone to health hazards from unsanitary environments and open defecation may lead to more victims of violence or sexual assault.<sup>35</sup>

In 1999, Total Sanitation Campaign (TSC) was launched in order to achieve universal access to sanitation by 2012. It focussed on infrastructural development and aims to provide incentives for household sanitation. However, this campaign was found to be ineffective and was able to make only modest improvement.<sup>36</sup> The Nirmal Gram Puraskar (NGP) which

offered cash prize to all villages, towns and districts was introduced in 2003. This encourages to the introduction of Nirmal Bharat Abhiyan (NBA) which believed on a community-led total sanitation.<sup>32,37</sup> NBA further modified to Swachh Bharat Mission (SBM) in 2014 and continued its interest to support the below poverty line households. Its main aim and objective is to eliminate open defecation by 2019. According to SBM, achieving this arduous task requires two significant tasks to be fulfilled: a) Increment in toilet equipped households; b) Increment in number of household family members using toilets. A separate rural policy named SBM-Gramin was also introduced in order to deal unique challenges in remote rural areas by categorizing people to whom safe sanitary systems are not accessible.<sup>38</sup> National Urban Sanitation Policy (NUSP), another step to eradicate open defecation was launched in 2008 with the aim to promote sanitation to poor urban peoples. The same story followed here as operating and management systems were seen weak with lack of financial support to implement their duties and functions. Furthermore, none of the metropolitan city have continuous supply of adequate quantity of clean water.<sup>36</sup>

Despite all these efforts across disciplines only modest success have been achieved till now. A lot more is required to make India an open defecation free country. Some social issues are also hindering and managing the gap between failure and success to

overcome sanitation problem. An array of reasons have been found for the failure of motivations or encouragements in using and building toilets. Cost of constructing toilet in household has been a major constraint<sup>39</sup> while some studies argued that people don't want to use.<sup>40</sup> Social mentality of unequal status and power like class distinction, informal, gender and communalism designation that who can or cannot forces poor to find alternate route or to defecate in open.<sup>41,42</sup>

### 2.5. Effect of Water Borne Diseases

On annual basis, Around 1.2 million children die every year and most of them are under five year of age.<sup>15</sup> Diarrhoea, being the most common and fatal disease caused by contaminated water responsible for more than 300,000 lives.<sup>43</sup> Moreover, it also results for an economic losses of \$13 billion which is almost equal to 1.5% of gross domestic product (GDP) annually.<sup>44</sup> Diarrhoea can be caused by rotavirus and non-rotavirus. Vaccines are only available for rotavirus based diarrhoea in India which aids to about 40% of all diarrhoea hospitalizations. However, non-rotavirus diarrhoea is still responsible for morbidity and mortality.<sup>45,46</sup> The United Nations Children's Fund (UNICEF) and World Health Organization (WHO) suggested a seven point to suppress and prevent the childhood diarrhoea. Three of among seven strategies revolved around sanitation ("Community wise sanitation promotion"), quality water supply ("Improved quality and quantity of water supply") and hygiene ("hand washing with soap").<sup>47</sup>

According to Kumar et al.<sup>48</sup> on an averages basis, 2 million confirmed cases of Malaria are registered annually in India. Moreover WHO, 2008<sup>49</sup> also estimates a death of about 15,000 individuals per year. It is evident that variation in rainfall and temperature change plays a significant role in the growth of disease causing vectors.<sup>50</sup> Also parasitic incidences are directly linked and can be correlated with humidity, precipitation and temperature.<sup>51</sup> Furthermore, deaths caused due to malaria are still increasing significantly and can be responsible for

the economic loss of about 20.7 billion US\$ by the year 2100.

### 3. Involvement of Eco-friendly Technologies:

Conventional energy sectors can be considered responsible for major environment degradation by emitting hazardous gases along with huge quantity of carbon dioxide especially coal fired power plants. India being dependent mainly on coal for fulfilling energy demands urgently requires to shift and adapt more renewable resources. The total installed capacity of coal fired power plants in India is around 190 GW accounting to almost 60% of total installed capacity and is expected to increase.<sup>52</sup> Moreover, the amount of carbon dioxide emitted from these power sectors was estimated over 902 Mt by 2015.<sup>53</sup> Utilization of carbon dioxide and shifting towards renewable energy resources are highly desirable as can be the only option to save this planet from climate change. Although there have been few renewable energy production plants in India but the quantity of power produced by through them is modest and is negligible when compared to total power supply needed for the sustenance of the country.

Various factors are responsible for climate change and among them the foremost factor is the emission of carbon dioxide. It is very much desirable to design and develop such technologies which can utilize carbon dioxide for production of desired products. One such technology which is based on "carbon capture and utilization" concept is accelerated carbonation. Lim et al.<sup>16</sup> encouraged and promoted various applications of accelerated carbonation technology (ACT). ACT not only can utilize carbon dioxide to make green products but also acts as a pollutant stabilizer.

Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, South Korea is evident for the successful utilization of carbon dioxide through accelerated carbonation in a number

of applications. They established a pilot plant capable of heavy metal stabilization, green concrete production, and chloride removal.<sup>16</sup> Accelerated carbonation also has the ability to treat waste water. Enick et al.<sup>54</sup> reported the treatment and recovery of metals like aluminium and zinc in wastewater with a precipitation efficiency of around 90% for both metals. Moreover, Precipitated Calcium Carbonate (PCC) produced by KIGAM via accelerated carbonation can be used successfully in recycling paper to get high quality papers, recycling diapers and as additives in polymer composites. This technology can not only provide better green products but can also utilize carbon dioxide from the atmosphere. This can be considered as a proper solution which helps in mitigating climate change from two directions i.e utilization of carbon dioxide and recycling of waste products which can directly boost the country's economic.

According to a study performed by Nandi et al.<sup>14</sup>, scaling up the quantity and quality of sanitation system along with access to clean water supply can prevent almost 43,500 diarrheal cases per 100,000 under 5 year children per year which will ultimately reduce the economic losses thus aiding the countries in country's growth. Moreover, improved sanitation system with employment of advanced technologies can be a boost for development from the baseline. An example is set by Huang et al.<sup>55</sup> by utilizing electrochemical cell for disinfection of urine and toilet waste water. The impressive point of this system includes that there is no need for water supply and drainage system as the waste generated itself got cleaned and recycled through electrochemical treatment. This process is estimated to be extremely cheap and can operate with solar cells allowing it to place at almost any part of the country. These are some of the numerous technology available now which needs to be exploited for a better sustainable world.

#### 4. Need for Adaptation

Even though evidence of climate change impacts attracted to make substantial attention, the effectiveness of the introduced strategies was found to have modest impacts against climate change mitigation. There is a strong need to adopt climate change at social, physiological and organizational scales. Moreover, these strategies should focus on specific temporal and spatial levels suitable for India.<sup>56</sup> Strategies should focus on minimization of contamination of main water bodies like rivers, canals and lakes. Stringent rules should be made and applied and heavy penalty should be imposed on point source contamination.

The government should promote the education regarding climate change to all individuals especially poorer once as the ecological sector is much more sensitive to climate change. One example of people unawareness and government inefficiency to take people into confidence can be seen as the protest against Narmada Dam Project over river Narmada, India as people were afraid that it could generate rehabilitation problem.

Moreover, the country like India needs special attention to tackle problems offered by climate change. Introduction of separate policy measures and successful implementation is required to deal with challenges like gender inequity, urbanization, open defecation, poor sanitation and biodiversity conservation. Studies have found the importance of women regarding their knowledge and responsibilities regarding management of resources and can perform a key role in community survival.<sup>57</sup> Hence, women involvement should be encouraged and is highly desirable.

Developed countries being more aware of the hazardous consequences of climate change, already developed innovative technologies. In contrast, developing and undeveloped countries are lacking in incorporating mitigation measures against climate change while designing and implementing their plans. According to Kyoto Protocol, technological

investment can be possible between underdeveloped & developing countries but not many countries can utilize this opportunity due to lack of available fund. Hence, initiatives are required from developed countries to transfer their eco-friendly technologies at affordable prices.

## 5. Conclusion:

This review highlights few consequences along with some remedies regarding climate change in India. Indeed India is among those countries that are highly vulnerable to climate change. Numerous impacts are associated with climate change and current review only point out limited initial insights. The consequences and mitigation measures for three sectors i.e. hydrological flows, agricultural production and sanitation were discussed and needs to be focused more on future. Contamination of water resources, poor sanitation and open defecation with huge population which comprise mainly poorer individuals were among the main reasons responsible for millions of death due to air and waterborne diseases per year. Traditional festivals were additional factors introducing toxic contaminants in air and water bodies. Focus has been made on utilization of carbon dioxide storage and utilization technique along with reducing carbon dioxide emission through the use of renewable resources. The need for adaptation of climate change mitigation policies and techniques along with the positivity on education for women and poorer once has been put forward.

## Acknowledgments

This research was supported by the National Strategic Project-Carbon Upcycling of the National Research Foundation of Korea(NRF) funded by the Ministry of Science and ICT(MSIT), the Ministry of Environment(ME) and the Ministry of Trade, Industry and Energy(MOTIE).( 2017M3D8A2084752)

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