Is Ground Water Depletion Becoming Hazardous for Public Health in India

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***Abstract*—India's groundwater problem is becoming severe. Unregulated over-extraction for agriculture, unsustainable agricultural practices, urbanization, climate change and the absence of a sound water management mechanism is one of the reasons why India's aquifers are depleting faster than they can recharge. This has resulted in declining water tables, reduced water quality, and increased water stress, impacting food and water security. Amid all this, the one factor that is often not spoken about enough is the impact that this is having on public health in India. This paper examines how depleting water tables are hazardous for public health and warrant serious policy intervention.**

***Index Terms*—Aquifers, over extraction, agriculture, sustainability, climate change, groundwater, water table, public health, water management, urbanisation**

I. INTRODUCTION

Groundwater plays a vital role in food security, water availability, and economic growth of more than 1.3 billion people in India and cannot be left compromised. India's ground water problem can be traced back to the the 'Green Revolution' that started in the 1960s. While the revolution transformed the face of Indian agriculture and made India self-sufficient as well as one of the largest exporters of foodgrain in the world, it had a huge environmental impact. One of the most prominent fallouts was the depletion of India's ground water reserves. the green revolution encouraged the cultivation of high yielding varieties of crops which in turn multiplied the irrigation demand. Over the years this has resulted in 80% of India's water resources being diverted for irrigation (1). The absence of a well-structured canal irrigation networks led to large-scale dependence on groundwater instead. Today more than 50% of the irrigated area depends on groundwater and in several districts, it is more than 80%. According to Central Groundwater Board (CGWB), about 92% of the country's ground water draft is used for irrigation. This has led to a situation where over 28% of the groundwater assessment units in the country have groundwater use substantially greater than the rate of recharge which is causing scarcity of water for drinking and other essential needs in the affected areas. The dependence of Indian agriculture on groundwater is very high, leading to an annual groundwater usage that is more than the combined usage by the United States and China (2). Tubewells are a highly significant source of irrigation in India, with the Department of Agriculture & Farmers Welfare reporting 47.3% of net irrigated area covered by tube wells in 2021-22 (3). This over exploitation of water has resulted in declining water tables across most of the agricultural intensive states in the north and central India.

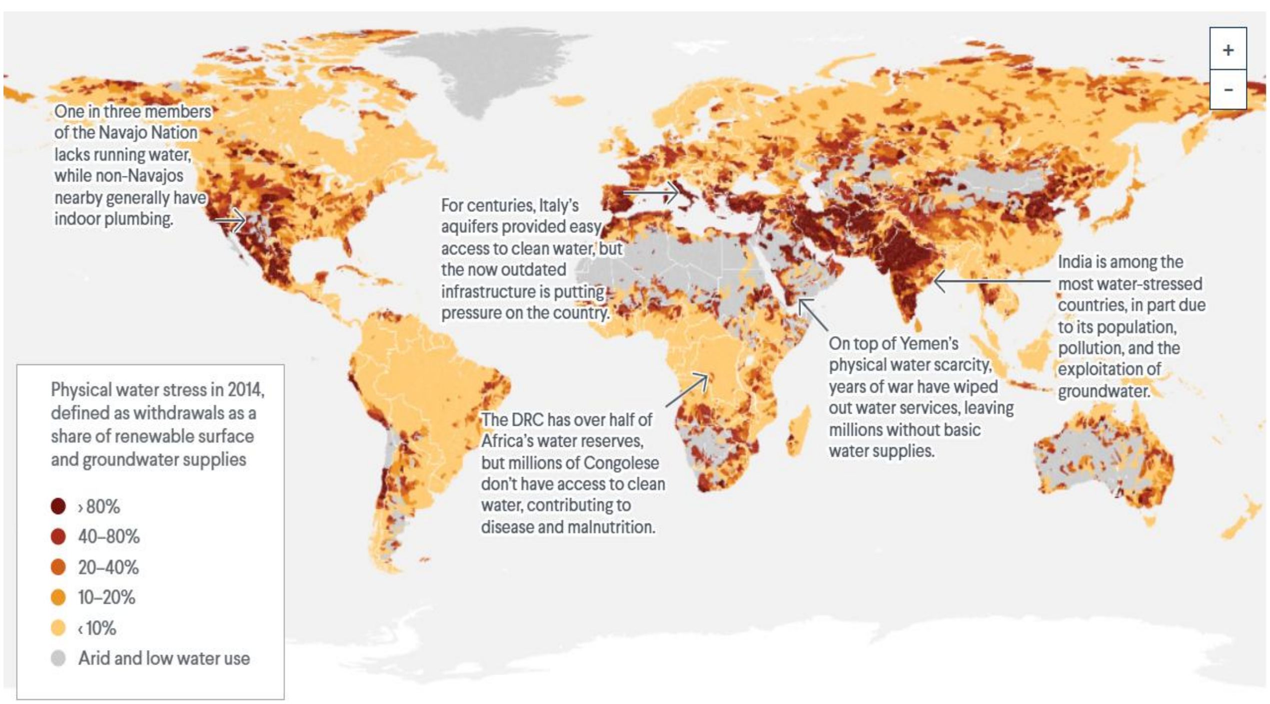
According to the World Bank, groundwater is being abstracted much faster than it is being replenished, so that 60 per cent of India's districts are likely to reach critical levels of groundwater depletion within two decades. Another study of Indian districts shows that in 60 per cent of them, groundwater is already depleted, contaminated or both (4,5,6). This not only creates acute water shortage and spells serious trouble for the country's farmers, most of whom rely on groundwater, but it also has huge implications on public health which cannot be left ignored. Depleting water tables without freshwater replenishment increases concentration of natural contaminants like arsenic and fluoride in the groundwater. Moreover, intensive use of chemical fertilizers, pesticides and herbicides for agriculture percolate into the water degrading the water quality even further. This is hazardous as millions of Indians rely on groundwater for their daily consumption and usage. This paper examines the hazardous consequences of depleting ground water tables and their impact on the health of millions of Indians to highlight an issue which needs urgent intervention.

II. CONSEQUENCES OF DEPLETING WATER TABLES AND THEIR IMPACT ON HUMAN HEALTH:

4.a Scarcity of Water

India has 18 percent of the world's population, but only 4 percent of its water resources, making it among the most water-stressed in the world (7). As many as one billion people in India live in areas of physical water scarcity, of which 600 million are in areas of high to extreme water stress, according to 'Beneath the Surface: The State of the World's Water 2019' report. what is significant is the fact that India is becoming an increasingly groundwater-dependent nation. Even at conservative estimates, recent analyses from sources like the Comptroller and Auditor General of India (2021) and the NITI Aayog (2023) confirm that approximately 85% of rural drinking water in India is sourced from groundwater, largely via wells and tube wells (8,9). The urban situation is no better. As high as 48 percent of India's urban water supply comes from groundwater, and in seven of India's 10 most populous cities, groundwater levels have dropped dangerously over the past two decades (10). Most Indian cities cannot even meet the per capita water supply requirements of 135 litres per day as specified by the Central Public Health and Environmental Engineering Organisation (CPHEEO), the technical wing of the Ministry of Housing and Urban Affairs, Government of India, that sets norms, standards and technical guidelines and prepares manuals for urban water supply and sanitation in India (11). This situation is only worsening due to the depletion of water tables, as is evident from the figure below.

The World Bank and the government think tank NITI Aayog point to several trends that could exacerbate the current crisis. For starters, the number of Indians could rise to 1.7 billion by 2050. With that comes growing demand for water, food, and consumer goods, as well as an increase in pollution and wastewater. The United Nations also estimates that over 400 million Indians will have moved to cities by 2050. In the same time period, climate change will make India much more susceptible to extreme weather events and unpredictable monsoons (12).



Sources: *National Geographic*; Navajo Water Project; UNICEF; World Resources Institute; WRI Aqueduct.

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The above figure exhibits the problem with greater clarity. Shortage of safe water has far-reaching impact on public health. Water scarcity limits access to safe water for drinking and for practising basic hygiene at home, in schools and in health-care facilities. When water is scarce, sewage systems can fail and the threat of contracting diseases like cholera surges. Scarce water also becomes more expensive (13) Drying wells push rural households to use polluted ponds/rivers leading to cholera, typhoid, hepatitis. While exact up-to-date figures vary, past estimates suggest a severe impact on children in India, with sources indicating that around 1.5 million children die from diarrhoea annually, a major waterborne disease. UNICEF also reported that in 2015, 117,300 children under five died from diarrheal disease annually. Waterborne diseases pose a significant threat to public health in India, particularly for young children, due to factors like poor access to clean water and inadequate sanitation (14,15).

Intermittent or low pressure supply due to acute water scarcity also poses a problem of breeding E. coli and Rotavirus leading to disease outbreaks. Low or negative pressures and transient pressure events can allow contaminants to enter piped drinking water through cracks, leaks, and faulty fittings, and backflow of contaminated water into the distribution system. Such pressure events can also mobilize biofilms or other contaminants attached to pipe walls, releasing them into the bulk-distributed water causing infections (16).

4.b Concentration of natural contaminants:

A depleted water table reduces the volume of water in a given surface area which then leads to greater concentration of contaminants in the same area making it unfit for human consumption and use. Lowered water tables also increase exposure of water to the previously submerged soil and sediment which can lead to greater mixing of contaminants like arsenic, fluoride, and nitrates, which were previously trapped in the soil which was more tightly compressed due to larger volume of water exerting pressure on the soil (17). The increased concentration of contaminants in this water poses a greater risk of exposure and potential health problems for humans and ecosystems. Groundwater pollution is also exacerbated by activities such as wastewater discharge from treatment facilities, landfilling, and the excessive use of pesticides and fertilizers in agricultural practices (18,19,20), leading to alterations in the regional groundwater chemical composition and quality (21,22). Deteriorating groundwater quality can trigger a series of ecological and environmental issues while posing health risks to humans, which can, in turn, lead to various social problems (23,24).

Example of some of the contaminants, their source and their health risks are as follows:

- Arsenic

Naturally occurring arsenic in rocks and soil can leach into groundwater as the water table drops. Human activities, such as mining, industrial processes (like coal-fired power plants and some manufacturing), and agricultural practices (use of arsenic-containing pesticides), and industrial waste, smelting of copper, lead, and zinc ore can introduce arsenic into the water supply. This has serious health implications like Liver, kidney and skin damage, decrease in blood haemoglobin, chronic and acute toxicity and even cancer. It can also hinder children's development (25,26,27,28)

- Barium:

This is naturally found in some kind of soils such as limestones and sandstones and also comes from fertilizers and pesticides. It can enter he ground water through leaching and natural weathering. It is known to cause cardiovascular, kidney, gastrointestinal, and neuromuscular diseases, Mental disorders and metabolic syndrome. It is also associated with hypertension and cardiotoxicity in animals (29)

- Cadmium:

Cadmium is found in rocks, coal, and petroleum. May enter the environment from Phosphate fertilizers, industrial discharge, mining waste, metal plating, water pipes, batteries, paints and pigments, plastic stabilizers, and landfill leachate. It is known to cause High blood pressure, replaces zinc biochemically in the body, causes liver and kidney damage, and anaemia. It also destroys testicular tissue and red blood cells (30,31)

- Chloride:

May be associated with the presence of high concentrations of sodium in drinking water that comes from saltwater intrusion, mineral dissolution, industrial and domestic waste. Excessive chloride consumption can lead to Hyperchloremia, an electrolyte imbalance that occurs when there's too much chloride in the blood (30,31).

- Beryllium:

This occurs naturally in soils, groundwater, and surface water. It can also be released into the ground water through mining operations, processing plants, and improper waste disposal and through ground leaching from rocks, coal, and petroleum. This is known to be carcinogenic and causes acute and chronic toxicity and damage the lungs and bones.

- Copper:

Copper enters the ground water from metal plating, industrial and domestic waste, mining, and mineral leaching. Copper is a crucial mineral to stay healthy. However, excessive consumption on a regular basis can cause liver damage, abdominal pain, cramps, nausea, diarrhoea, and vomiting (32,33).

- Chromium:

it seeps into the groundwater from old mining operations runoff and leaching into groundwater, fossil-fuel combustion, cement-plant emissions, mineral leaching, from metals plating and waste ignition. While Chromium III is a nutritionally essential element, Chromium VI is extremely toxic and causes liver and kidney damage, internal hemorrhaging, respiratory damage, dermatitis, and ulcers on the skin at high concentrations (34,35).

- Cyanide:

this is the waste that comes from electroplating, steel processing, plastics, synthetic fabrics, and fertilizer production and, from improper waste disposal and gradually makes its way to the ground water. Even small doses of cyanide poisoning damages the spleen, brain, and liver. Cyanide may lower vitamin B12 levels and hence exacerbate vitamin B12 deficiency. It has also been linked to an increased incidence of goitre (cretinism) in Zaire through effects on iodine uptake by the thyroid. Those with nutritional inadequacy or inborn metabolic errors are particularly vulnerable. Chronic effects on the thyroid and particularly on the nervous system were observed in some populations (37,38,39,40).

- Fluoride:

fluoride is added to our water and over the years has passively protected the oral health of the people. So much so, that the CDC: Center for Disease Control and Prevention in the US declared community water fluoridation one of the 20th century's greatest public health achievements. However, when the water table shrinks the high-level concentrations may cause harm causing crippling bone disorder (calcification of the bones and joints) (41,42).

- Lead:

Lead and cadmium found in water may come from both natural (weathering of bedrock) and anthropogenic (mining, industry and agriculture) sources (Krishna and Mohan, 2014). Metal leaching is a naturally occurring process; however, if the concentrations of trace elements are anomalously high, they may have a negative impact on the environment (Perkins et al., 1995). It can also percolate into the ground water from unchecked industrial discharges, corrosion of lead service lines and lead plumbing fixtures in homes, particularly when water is acidic or has low mineral content. It can also enter the environment through industrial activities, such as mining and battery production, leading to contamination of soil and water sources. Lead is widely distributed in the body and interferes with several biochemical processes by its binding to sulfhydryl and other nucleophilic functional groups and contributing to oxidative stress. Lead may disturb physiological functions and induce numerous adverse effects in respiratory system such as Chronic obstructive pulmonary disease (COPD) like changes in the lung causing asthma, lung cancer and impacting the nervous, cardiovascular and digestive system and kidney disorders. It also causes developmental delays in children, anaemia, immune system issues, and neurological damage (43,44,45,46,47,48,49)

- Mercury:

this is one of the most toxic global pollutants posing a severe threat to human health and wildlife. Due to its mobility, Hg is easily transported through the atmosphere and directly deposited onto water, sediments and soils. In groundwater, Hg concentrations can be influenced by either geogenic or anthropogenic sources, causing critical health effects such as damage to the respiratory and nervous systems and can cause acute and chronic toxicity. It harms the kidneys and can cause nervous system disorders. The geogenic sources of Hg include rocks and minerals containing Hg (cinnabar, organic-rich shales, and sulfide-rich volcanic) and geothermal fluids. The anthropogenic Hg sources include the combustion of fossil fuels, gold mining, chemical discharges from dental preparation, laboratory activities and legacy sites (50,51)

- Aluminium:

Aluminium is an extremely abundant metal in the earth's crust and is often found in the form of silicates such as feldspar. Aluminium can be selectively leached from rock and soil to enter any water source. It can also be present as aluminium hydroxide, a residual from the municipal feeding of alum (aluminium sulphate) or as sodium aluminate from clarification or precipitation softening. High concentrations of aluminium also percolate from industrial waste, mining, pesticides, coal, electrical equipment (batteries, lamps, switches), smelting, and fossil-fuel combustion.

Chronic toxicity of aluminium in drinking water is associated with severe diseases of the nervous system such as Parkinson's dementia, amyotrophic lateral sclerosis and Alzheimer's disease. Alzheimer's disease is a progressive mental deterioration manifested by memory loss, inability to calculate, visual spatial disturbances, confusion and disorientation. A study by Rondeau found that high aluminium levels in drinking water (≥0.1 mg/L) were associated with an elevated risk of dementia and Alzheimer's disease (52,53,54,55).

- Iron:

Iron is the most abundant chemical element of the Earth's core and makes up more than 85 wt % of its mass. Human-caused, geological, environmental, climatic, biological, and other processes can change the amount of iron in groundwater. Both natural and human-caused sources can induce an increase in groundwater iron levels. Rock formation, soil type, vegetation, wetlands, and human activities, including farming, housing, industrialization, market expansion, landfilling, etc., are the main drivers of iron contamination in groundwater. Iron is naturally added to groundwater through the weathering of iron-bearing minerals and rocks. It can also percolate into the ground water through mining and industrial waste (56,57).

The World Health Organization (WHO) has established secondary or aesthetic based water guideline of iron as 0.3 mg/L. groundwater. However, overexposure to iron can cause adverse health risks including, Parkinson disease, Huntington disease, cardiovascular disease, hyperkeratosis, diabetes mellitus, pigmentation changes, Alzheimer disease, kidney, liver, respiratory and neurological disorders (58,59,60,61).

- Manganese:

Furthermore, both deficiency and excessof Mn have detrimental health effects. Importantly, excessive intake of Mn, most commonly via inhalation or ingestion, may result in central nervous system (CNS)pathology. Mn deficiency may result in several disorders including skeletal defects, infertility, heart disease, hyper-tension, and altered lipid and carbohydrate metabolism

Manganese (Mn) is one of the most abundant metals in Earth's crust, usually occurring with iron (Fe). It is a transition metal widespread in geological reservoirs and links to various biogeochemical processes in marine and terrestrial environments. It percolates in the ground water and increases in concentration as the ground water levels deplete. Consumption of elevated Mn concentrations in drinking water could lead to neurotoxic effects, especially harmful to intellectual function in children. Excess of Mn have detrimental health effects which result in central nervous system (CNS)pathology and is also known to cause toxicity and cancer. It can also cause neurotoxicity, leading to symptoms resembling Parkinson's disease like tremors, muscle spasms, and motor dysfunction. High exposure, often through occupational inhalation or contaminated drinking water, can also cause mood changes, memory loss, and respiratory issues like bronchitis. While manganese is essential in small amounts for enzyme function and bone health, excessive intake from environmental sources can lead to severe, potentially permanent, health problems, especially in developing children and infants (62,63,64,65,66,67).

- Nickel

Nickel occurs naturally in soils, groundwater, and surface water. It may also be present in some groundwaters as a consequence of dissolution from nickel ore-bearing rocks.Often used in electroplating, stainless steel and alloy products, mining, and refining, it can also make its way into the ground water through industrial and mining waste. The primary source of nickel in drinking-water is leaching from metals in contact with drinking-water, such as pipes and fittings. Nickel can cause a variety of health effects, such as contact dermatitis, cardiovascular disease, asthma, lung fibrosis, and respiratory tract cancer (68,69,70).

- Nitrate (As Nitrogen):

Overapplication of nitrogen fertilizers is the key cause of degradation of groundwater quality and contamination of drinking water supplies, which can pose immediate risks to human health (71, 72). Increased nitrate levels (as nitrogen) are also caused by animal waste, domestic sewage and septic tank leakage in urban areas. High nitrate levels pose significant health risks, particularly blue-baby syndrome (methemoglobinemia) in infants and potential harm to children and adults' respiratory and reproductive systems. Potential health impacts include thyroid dysfunction, gastrointestinal disorders, adverse pregnancy outcomes and heightened cancer risks. At-risk populations, like newborns and pregnant women, are especially vulnerable (73,74,75).

- Selenium:

Sources of Se contamination in groundwater can either be of anthropogenic or geogenic origin. Selenium released through weathering of Se-rich rocks and soils may enter groundwater via leaching along with excess water from irrigation and rainfall. Atmospheric Se inputs via precipitation could also play an important role in increasing levels of the trace element. Chemical processes such as carbonate/phosphate dissolution, oxidation/reduction, and agricultural practices involving fertilizers, irrigation and anthropogenic activities may primarily be responsible for Se-contamination of groundwater. While small amounts of selenium are beneficial, excessive levels can be toxic. When the concentration of selenium in the body is too high, hair loss, body pain, muscle damage, liver and kidney failure, cancer, and even death can occur, which makes increase in Selenium concentration in ground water, which is the principal source of water supply in most Indian homes extremely worrisome (76,77,78,79).

- Suphates:

Sulphates are discharged into water from mines and smelters and from kraft pulp and paper mills, textile mills and tanneries. Sodium, potassium and magnesium sulphates are all highly soluble in water, whereas calcium and barium sulphates and many heavy metal sulphates are less soluble. Atmospheric sulphur dioxide, formed by the combustion of fossil fuels and in metallurgical roasting processes, may contribute to the sulphate content of surface waters. Sulphur trioxide, produced by the photolytic or catalytic oxidation of sulphur dioxide, combines with water vapour to form dilute sulfuric acid, which falls as “acid rain” percolates into the ground water slowly. Sources of sulphate in groundwater include mineral dissolution, atmospheric deposition and other anthropogenic sources (mining, fertilizer, etc.). Gypsum is an important contributor to the high levels of sulphate in many aquifers of the world. Sulphate is not as much as toxic, but it can cause catharsis, dehydration and diarrhoea, and when ingested in higher amount through dietary absorption, the levels of methaemoglobin and sulphaemoglobin are changed in human and animal body (80,81,82,83).

- Thallium

Emissions, which lead to increased concentrations of thallium in the environment, may be natural or associated with anthropogenic activity. The resulting air pollution (thallium ash) allows thallium contaminations to spread across wide distances and to enter other environmental niches. In the terrestrial environment, thallium is usually bound with the soil matrix, which considerably limits its transport, although dissolved thallium (soluble thallium salts) is susceptible to flushing and may be introduced to the aquatic environment. Such compounds may also leak into underground water streams and increase the risks of chronic exposure. Thallium enters the water environment mainly through the exploitation of mines containing thallium, dust deposition in ore smelting, waste discharge from sulphur mineral areas, and waste discharge from the printing and dyeing industry. It can also pollute the environment to varying degrees through the combustion of coal and sulphurous iron ore ash (84,85,86,87).

The toxicity of this element is higher compared to mercury, cadmium and lead (maximum admissible concentration at 0.1 mg mL^{-1}). The toxicity of thallium-based compounds is mainly caused by the similarity between thallium (I) ions and potassium ions, which results in the disorder of potassium-associated metabolic processes due to thallium interference. Human exposure to thallium is mainly associated with the consumption of contaminated food or drinking water. Thallium rapidly enters the bloodstream and is transported across the whole organism, which leads to accumulation in bones, kidneys and the nervous system. In consequence, the functioning of several relevant enzymes is disrupted. Stomach and intestinal ulcers, alopecia and polyneuropathy are considered as classic syndromes of thallium poisoning. Other symptoms include astral disorders, insomnia, paralysis, loss of body mass, internal bleeding, myocardial injury and, in consequence, death. Ingestion of more than 1.5 mg of thallium per 1 kg of body mass may be fatal. Recent studies also indicate that high levels of Tl may be associated with an increased risk of low birth weight (88,89,90,91,92).

- Zinc:

Zn is also found in surface and groundwater, and enters the environment from several sources including mine drainage, industrial and municipal wastes, urban runoff, and mainly from the erosion of soil particles containing Zn. According to Food and Agricultural Organization (FAO) and to World Health Organization (WHO) drinking water containing Zn > 3 mg/L tends to be opalescent, develops a greasy film when boiled, and has an undesirable astringent taste The recommended maximum content in irrigation water was set at 2 mg/L, since higher contents can be toxic to many plants and humans] and can pollute water aquifers. Although zinc occurs naturally, most zinc finds its way into the environment because of human activities. Mining, smelting metals (like zinc, lead and cadmium) and steel production, as well as burning coal and certain wastes can release zinc into the environment. A common use for zinc is to coat steel and iron as well as other metals to prevent rust and corrosion; this process is called galvanization. High levels of zinc in soil may result from the improper disposal of zinc-containing wastes from metal manufacturing industries and electric utilities. In soil, most of the zinc stays bound to the solid particles. When high levels of zinc are present in soils, such as at a hazardous waste site, the metal can seep into the groundwater. Zinc enters the water, and soil as a result of both natural processes and human activities. Most zinc is introduced into water by artificial pathways and may enter from numerous sources including mine drainage, industrial and municipal wastes, urban runoff, coal-fired power stations, burning of waste materials, but the largest input occurs from the erosion of soil particles containing Zn (93,94,95,96).

Taking up large doses of supplemental zinc over extended periods of time is frequently associated with copper deficiency (97,98). This correlation seems to be caused by the competitive absorption relationship of zinc and copper within enterocytes, mediated by MT. Frequent symptoms of copper deficiency in turn include hypocupraemia, impaired iron mobilization, anaemia, leukopenia, neutropenia, decreased superoxide dismutase (SOD) (particularly erythrocyte SOD (ESOD)), ceruloplasmin as well as cytochrome-c oxidase, but increased plasma cholesterol and LDL: HDL cholesterol and abnormal cardiac function (99,100,101)

4(c) Imapct on mental health:

Groundwater in India is a critical resource. However, an increasing number of aquifers are reaching unsustainable levels of exploitation. If current trends continue, in 20 years about 60% of all India's aquifers will be in a critical condition says a World Bank report, Deep Wells and Prudence (102). This will have serious implications for the sustainability of agriculture, long-term food security, livelihoods, and economic growth. It is estimated that over a quarter of the country's harvest will be at risk. This is creating stress on rural communities that depend on agriculture for their livelihoods. Farmer suicide rates have increased in India in recent years, with a total of 11,290 people in the agricultural sector dying by suicide in 2022, a 3.7% increase from 2021. The figures from the National Crime Records Bureau (NCRB) indicate that at least one person engaged in farming dies by suicide every hour. For the first time, suicides among agricultural laborers (6,083) exceeded those of farmers/cultivators (5,207) in 2022, which shows great deal of stress in the rural communities.

Urban water supplies in India are significantly dependent on groundwater, with figures suggesting anywhere from 48% to over 50% of urban demand is met by groundwater. Many urban dwellers rely on groundwater through private borewells as a coping mechanism for unreliable and insufficient piped water from traditional sources. Depleting water aquifers are now full of Contaminated water leading to waterborne diseases and health issues among the urban population, adding to the mental stress of families (103,104).

Water, excess or lack of it, has always been the key determinant of human well-being. Water availability - including both quality and quantity - is considered important for its direct health impacts, such as water-borne diseases owing to bad water quality, or the health impacts caused by the lesser intake of water. The United Nation's defined water security as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability". On the opposite, water insecurity is defined as inadequate or inequitable access to clean, safe, and affordable water for drinking, cooking, sanitation and hygiene. As reported, water and human health are linked inextricably and there is a growing body of literature on the indirect health impacts of water insecurity, particularly its association with elevated emotional and psychological distress (105, 106, 107, 108, 109).

Water insecurity can exacerbate frustrations, shame, and gender-based violence, as women most often bear responsibility for ensuring household access to clean water (109, 110). In addition, water insecurity can result in mental distress due to the opportunity costs of time spent fetching or queuing for water, for example, leading to less time available for employment and education (111).

Growing research has shown evidence of mental health risks associated with inadequate sanitation. These include feelings of shame if seen by others, restricting intake of water and food to limit defecation and urination, suppressing need to use sanitation because of a non-conducive social and physical environment, fearing or encountering sexual or physical violence when using open defecation sites or feeling incapable of changing sanitation conditions (112,113,114). A scoping review was published in 2017, with the aim of summarizing evidence linking water insecurity and inadequate sanitation to psychosocial distress (115).

According to NITI Aayog's "Composite Water Management Index" report 2019, India is suffering from the most severe water crisis in its history, with almost 600 million people experiencing high to extreme water stress. The situation has significantly deteriorated, so much so that India ranked 120 of 122 countries in the water quality index (NITI Aayog 2019). Most recently, Bengaluru experienced "abnormally high temperatures in February and March" of this year, "creating urban heat islands that crank up the heat in cities even more," as per "Bengaluru's Water Crisis" 2024, a piece written by Akshat Mehta and Nancy Saroha at the peak of Bengaluru's strife (116).

This severe water stress not only disrupts the basic functions of daily life, but "in cities like Chennai and Ranchi, it has led to violent clashes, distress, and desperation, as the lakes and reservoirs dried up and people had to fight and fend for water for their everyday needs" (117). Given the extreme nature of the consequences of water scarcity, access to safe and clean drinking water is evidently a fundamental human right necessary for health and well-being as outlined by the United Nations as well.

4 (d) Impact om agriculture and other livelihoods:

According to the World Bank, groundwater in India is being extracted much faster than it is being replenished, so that 60 per cent of India's districts are likely to reach critical levels of groundwater depletion within two decades. Another study of Indian districts shows that in 60 per cent of them, groundwater is already depleted, contaminated or both. This spells serious trouble for the country's farmers, most of whom rely on groundwater. Close to 90 per cent of the groundwater consumed in India is used to irrigate crops (118). Setting up deep boring wells is not an option for all farmers forcing forced migration to the cities which in any case are reelin under high unemployment. Agriculture is a huge contributor to the Indian economy and provides 70% of rural employment. If this sector takes a hit, it could lead to unprecedented inflation and shake the foundation of India's food security and employment. It also adversely impacts industrial growth where water is used.

It is well known that economic downturns can create havoc in India with its widespread poverty. It can significantly worsen health outcomes by limiting access to quality healthcare and nutritious food, increasing the risk of chronic diseases, and amplifying mental health issues like anxiety and depression. Poor health, in turn, reduces productivity and earning potential, making it harder for individuals to escape poverty and contribute to the economy. This creates a self-perpetuating "vicious circle" where poverty and poor health reinforce each other (118,119,120,121,122).

III. CONCLUSION:

Water scarcity is emerging as one of the most damaging issues of our time, conferring a slew of challenges that can no longer be ignored. Limited availability of water puts a chokehold on life as we know it, threatening the stability of fundamental fields, including, but not nearly limited to, public health, development, food security, sustainability, peace and sanitation (123,124).

According to NITI Aayog's "Composite Water Management Index" report 2019, India is suffering from the most severe water crisis in its history, with almost 600 million people experiencing high to extreme water stress. The situation has significantly deteriorated, so much so that India ranked 120 of 122 countries in the water quality index (NITI Aayog 2019). Apart from being the predominant source of drinking water and irrigation for rural India, over 80 percent of the rural and urban domestic water supplies in India are served by groundwater making India the world's largest user of groundwater. As 39% of the total national population is projected to reside in cities by the year 2030 and with the national water demand anticipated to doubly exceed supply, ensuring the judicious use of groundwater is an unignorable point of addressal (124,125).

Lack of good quality has a direct bearing on public health, and it is the responsibility of both, the government and the public to ensure that there is proper monitoring of its quality on a regular basis as the burden of ill health can be prove to be extremely costly for the nation's economy and productivity, besides creating undue burden on the families at the micro level.

Repeated studies have shown that unless there is an integrated approach that looks at both, the demand and supply side solutions, not much difference will be seen at the ground level. IEG case studies in Rajasthan, Telangana and Andhra Pradesh showed that the success of supply-side measures, such as watershed management programs, aquifer recharging and tank rehabilitation activities, did not lead to sustainable use in the absence of demand-side action. Measures such as surface water harvesting through farm ponds and check-dams, the installation of water-efficient irrigation systems (e.g. more efficient drips and sprinklers) and growing less water intensive crops, need to be integrated on the demand side for improved management and reduced depletion (126).

Good ground water management needs Strengthening community participation. World Bank projects in peninsular India, where more spread out and specifically defined hydrological sites prevail, were successful on several fronts by implementing the Participatory Groundwater Management approach (PGM). The PGM approach empowers communities in a defined aquifer area by providing governance rights, community awareness, capacity development, and knowledge and motivation for social regulation and the implementation of coordinated actions. Although the results haven't been as forthcoming due to frequent droughts and climate change impact, the government and other agencies should not give up on it (127).

India also needs to rethink its agricultural policy of giving guaranteed government procurement MSP of water-intensive crops like rice and wheat at pre-determined prices that has become a huge hurdle in crop diversification. This policy was introduced during the Green Revolution of the 1960s in the Punjab region to incentivize the adoption of high-yielding variety seeds to increase productivity and ensure food security for the nation (128). Ironically, further extension of the very same policies could harm the long-term food security of India as crops like wheat and rice covered in the policy are water-intensive crops. Their increased cultivation drives the irrigation needs forcing farmers to use ground water. Together these trends have contributed to rapid declines in groundwater levels. Estimates suggest that in the long run a complete loss in access to groundwater can reduce annual crop production by 28%, dry season crop production by 51%, and cropping intensity by 68%. Furthermore, as groundwater also acts as a buffer against climatic variability, its depletion undermines adaptability to climate change (128, 129, 130, 131, 132, 133).

Government policies around Power subsidies also need to be analysed as they directly increase groundwater extraction using pumps. Studies have reported that states affected by depletion of groundwater provide free or heavily subsidized power (including solar pumps) for pumping groundwater for irrigated agriculture. With little to no financial penalty for heavy electricity usage, farmers are incentivized to extend pumping hours, even in water-scarce areas. One study found that in over-exploited areas of Andhra Pradesh, paddy cultivation saw a 16.83% increase in groundwater extraction after a subsidy was implemented (134, 135,136). It is no different in other agricultural sates like Punjab, Haryana and Madhya Pradesh. Currently, there are nearly 20 million operational groundwater wells in India, in which approximately 70 percent are relying on electricity (137,138). Groundwater should be treated as a precious national resource and not a source to be over exploited to reduce short-term vulnerability and risk its unsustainable depletion, which will ultimately increase vulnerability in the long term.

Government needs to deploy AI driven measures to monitor the extraction and wastage of ground water penalising the offenders to create a deterrent. Implementing policies that encourage diversification of crops and influencing consumer behaviour could be other means of protecting the ground water reserves. Encouraging organic farming and controlling undue usage of Chemical fertilizers in agriculture, adoption of practices like compulsory rainwater harvesting and other water-saving techniques such as drip irrigation, micro-irrigation, and precision farming should be taken up on an urgent basis. There also needs to be greater accountability for the effectiveness of government schemes that are rolled out to ensure that there is noticeable impact because of their Implementation.

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