International Water Resources Association

Nitrates & Contaminants of Emerging Concern (CECs) in Irrigation Water & the Influence of Climate Change

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Objectives of Presentation

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- Learn about Nitrates & CECs in Irrigation Water

  How are Corn, Wheat, Rice & Soy Affected by Nitrates & CECs?

  Learn about CECs that are Endocrine Disrupting Compounds (EDCs)?

  How is Climate Change Influencing the Impacts of Nitrates & CECs?

Main Takeaways from the Presentation

Background: Increasingly, groundwater resources are exploited for irrigation purposes.

The Main Global Pollutant = Nitrates, from fertilizers & human & animal waste

The Main Toxins:

Corn: Molds-Fumonisins, Aflatoxins

Wheat: Molds-Fusarium

Rice: Inorganic Arsenic

Soybeans: The Pesticide Glyphosate

These foods now contain CECs, including EDCs

Climate Change affects transport CECs, Nitrates

Endocrine Disrupting Compounds (EDCs)

Many emerging contaminants are **EDCs**; interfere w/ the body's endocrine system by mimicking, blocking, or altering hormones.
They are **natural or man-made chemicals**.
They **disrupt essential functions** like metabolism, reproduction, and development

EDCs are common constituents in plastics that include phthalates
Dietary consumption and bioaccumulation of EDCs is in part a result of ingestion of soy, corn, wheat and rice

Increasing evidence has been documented for adverse health effects associated with the uptake of **EDCs: Premature birth** and associated health problems for mother and child, **infertility, developmental effects, and neurologic and attention deficit/hyperactivity disorder**

Endocrine Disrupting Compounds (EDCs)

Wastewater treatment plants **(WWTPs) are collection points for EDCs**.

EDCs are not removed from effluent from most WWTPs because removal technologies, most commonly granular activated carbon, are not required in most regulatory frameworks (e.g., USA 2026; European Commission 2026).

Effluent with EDCs is spread in surface waters, and to recharge areas that replenish drinking water wellfields.

WWTPs also generate enormous amounts of sludge, or biosolids. The European Union (European Commission 2026) is one of the few governmental bodies that **restricts the surface disposal (land farming) of WWTP sludge, because EDCs such as phthalates & PFAS will leach into groundwater drinking water aquifers.**

Largest Ag Basins Using the Most Groundwater
(km²)

U.S. Corn Belt	~400,000–500,000
U.S. Great Plains (High Plains/Ogallala region)	~1,300,000
California Central Valley	~50,000–60,000
France – Paris Basin	~140,000
Germany – North German Plain	~200,000
Indo-Gangetic Plain	~700,000–1,000,000 (depending on definition)
China (North China Plain–weighted national estimate)	~300,000–400,000 (North China Plain core)

Indo-Gangetic Basin

Indo Gangetic Basin (IGB) alluvial aquifer system is one of the world's most important water resources which is formed with sediments eroded from the Himalayas by the Indus, Ganges and Brahmaputra rivers and is spread in a flat fertile plain across Pakistan, northern India, southern Nepal and Bangladesh

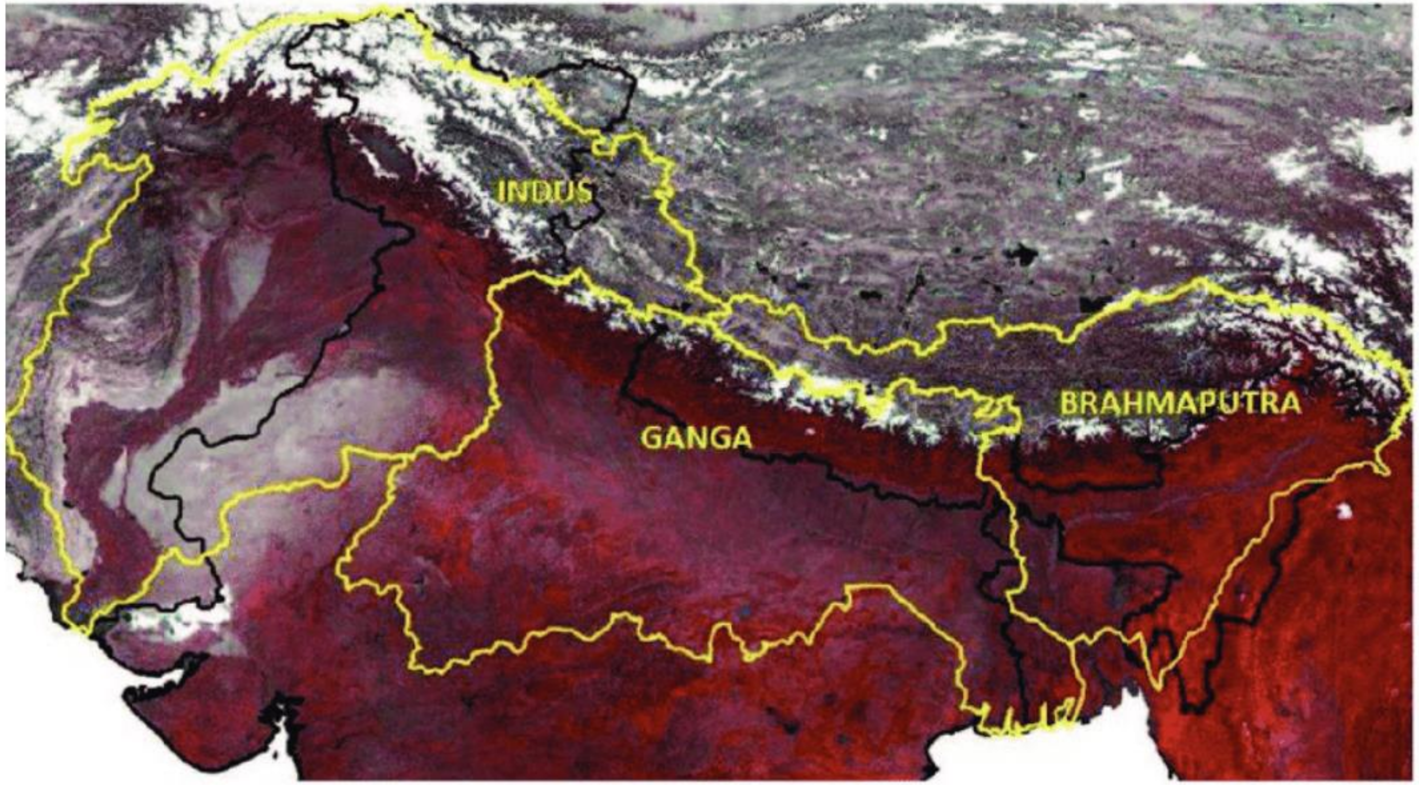
85 – 95% of the irrigation water comes from groundwater

700,000 – 1,000,000 km^2

Indo-Gangetic Basin

Hydrologic Regimes under Climate Change in Indo-gangetic Basin 271.

Krishan, G, Rao, M.S., Kumar, B., Kumar, C.P., Kumar, S., Jaiswal, R.K., Rao, Y.R.S., Tripathi, S., Kumar, M., Garg, P.K. and Kumar, P. 2014d.



U.S. Great Plains

- The US Great Plains is a broad, semi-arid expanse of flatland and prairie in North America.
- It lies east of the Rocky Mountains and stretches between the Mississippi River basin and the Canadian border, forming a critical agricultural and ecological region often referred to as America's “breadbasket"
- **Agriculture:** Dominated by large-scale farming and cattle grazing. It is a massive producer of cereal crops, especially wheat, and acts as a primary feeding ground for the U.S. cattle industry.
- 45 – 55 % of irrigation water is from groundwater

- ~45–55% of irrigation is from groundwater

U.S. Great Plains

U.S. Great Plains

Toxins in the Groundwater

- Corn is dominated by fungal toxins (mycotoxins: Fumonisins and Aflatoxins),
- Wheat by Fusarium toxins (a mold, which is in the broad family of fungi,)
- Rice by inorganic arsenic plus some cadmium, and
- Soy often shows more pesticide residue (e.g., Glyphosate) than uniquely severe individual toxins.

- The impact of the toxins changes by geography and storage conditions (Chemical & Engineering News 2025).

- In tropical and subtropical systems with poor drying/storage, fungal toxins in corn becomes much more dominant.
- In temperate cereal systems, Fusarium toxins in wheat are more prevalent.

- In rice-consuming populations, concerns for inorganic arsenic can dominate even when concentrations are lower.

Adverse Health Effects From Toxins

Corn - aflatoxins: Potent hepatotoxic & carcinogenic compounds; highly studied foodborne toxicants

Corn - fumonisins: Organ toxicity & population-level health concerns in maize-dependent diets

Rice - inorganic arsenic: Human carcinogen; chronic exposure risk via diet

Wheat - deoxynivalenol: Vomiting, diarrhea, abdominal pain, immune suppression

Soybeans – pesticides (e.g., glyphosate) are highly absorbed, interfere with digestion & mineral absorption

How Climate Change Affects CECs & Nitrates

- Climate Change does not act through a single mechanism.
- It alters the hydrologic cycle, groundwater recharge, evapotranspiration, redox conditions, wildfire frequency, soil organic carbon cycling, and flood dynamics simultaneously.
- These changes can increase contaminant mobility, redistribute legacy contamination, or create geochemical conditions that transform one contaminant into another.

How Climate Change Affects CECs & Nitrates

- **Nitrates Concentrate in Surficial Soils from Over-Fertilizing**

- **CECs Concentrate in Surficial Soils from:**

- Spreading of Biosolids from Wastewater Treatment Plants (WWTP) – this is often biosolids-amended agricultural land

-Migration from landfills

-Releases from industrial sites

-For PFAS, releases where aqueous firefighting foam (AFFF) is used for firefighting or training

How Climate Change Affects CECs & Nitrates

- Climate models consistently project:
- more intense precipitation events, often = less recharge/more runoff
- larger flood pulses
- The **Indo-Gangetic Basin** is especially vulnerable because:
- irrigation intensity is extreme,
- groundwater tables are often shallow,
- and monsoon recharge can rapidly connect contaminated surface water with aquifers.

Example: How Climate Change Affects CECs (e.g., PFAS) Part 1:

- PFAS contamination is not chemically static.
- **Certain PFAS precursors can transform into other PFAS compounds that may retain similar toxicity or persistence.**

- Many PFAS released historically were not terminal compounds such as:
- PFOA,
- PFOS,
- PFHxS,
- PFNA.
- Instead they were precursor compounds including:
- fluorotelomer alcohols (FTOHs),
- polyfluoroalkyl phosphates,
- fluorotelomer sulfonates,
- side-chain fluorinated polymers.
- **These compounds can transform in groundwater and soils.**

Example: How Climate Change Affects CECs (e.g., PFAS): Part 2:

- **Important concept:**
- Some precursor compounds initially appear less mobile or less toxic, but later degrade into:
- terminal perfluoroalkyl acids (PFAAs),
- which are highly persistent and bioaccumulative.
- **Climate change can accelerate or alter these transformations by changing:**
- temperature,
- redox conditions,
- oxygen availability,
- microbial community composition,
- and groundwater residence time.

Note the Opposing Effects of Climate Change, Based on Latitude

Temperatures are rising due to climate change.

Warmer temperatures increase the rate of evaporation

into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water.

Increased evaporation is causing **drought in some areas** and dropping water levels, but also causing **increased precipitation** in other areas.

Note the Opposing Effects of Climate Change, Based on Latitude

- **Climate change is expected to affect recharge, but the effects may not necessarily be negative or decrease in all regions worldwide** (Gurdak et al., 2010).

- Recharge is projected to increase in northern latitudes and decrease strongly (e.g., 30-70%) in some semi-arid zones (Doll et al., 2008); this effect may be occurring now in South Africa and neighboring countries.

Note the Opposing Effects of Climate Change, Based on Latitude

- In some basins, heavy rainstorms induced by climate change have led to increased runoff and decreased aquifer recharge.

- **However, caution must be used in applying sweeping generalizations in all climatic environments about less recharge year-over-year due to more extreme storm events due to climate change.**

- This effect appears real in many surface water/groundwater basins but requires more region-specific study.

Note the Opposing Effects of Climate Change, Based on Latitude

- Studies by Cuthbert et al. (2019) & Owor et al. (2009) present data that some aquifers in arid & semi-arid environment significantly benefit from recharge during extreme storm events, perhaps more so than all day rainfall episodes.
- Here, storm-related runoff is not causing as much of a decrease in groundwater levels as may have been originally hypothesized.
- Thus, aquifers can show significant resiliency in capturing recharge during extreme storm events.
- To reiterate, multiple studies indicate that climate change is causing fewer, more extreme, heavy rain events (Richard Taylor, UCL ,2020)

Questions?

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