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COAL BED METHANE

- Clean Energy
- Coal related; cost effective
- India is Looking forward to it

CBM potential evaluation in the country

- A rise in the cost of conventional natural gas and many other energy resources, along with a decline in these conventional resources and issues such as climate change have encouraged a global interest in alternative sources of energy like Coalbed methane (CBM). The estimated quantity of CBM worldwide is around 256 Tm^3 (Cubic Terameter, 10^{36}). Coal seam gas is a significant source of energy (**Hamawand et al., 2013**). In India, Jharia and East Bokaro coalfields were made in 1970s to capture methane for its gainful utilization in view of the associated advantage of mine safety against gas hazard. Coalbed Methane (CBM) ventures and activities started in a systematic manner in India from the late 1990s.
- Coalbed methane (CBM) has emerged as an important unconventional fuel in the Indian energy landscape due to its significant availability and multifaceted benefits, **such as enhancing mine safety and providing an alternative clean energy source**.

- Several Indian companies, both in the private and public sectors, are actively involved in the commercial extraction of CBM. Notable private companies include Essar Oil Limited, Great Eastern Energy Corporation Limited, Reliance Industries, and Prabha Energy Private Limited, while Oil and Natural Gas Corporation (ONGC) represents the public sector's endeavours in this domain.
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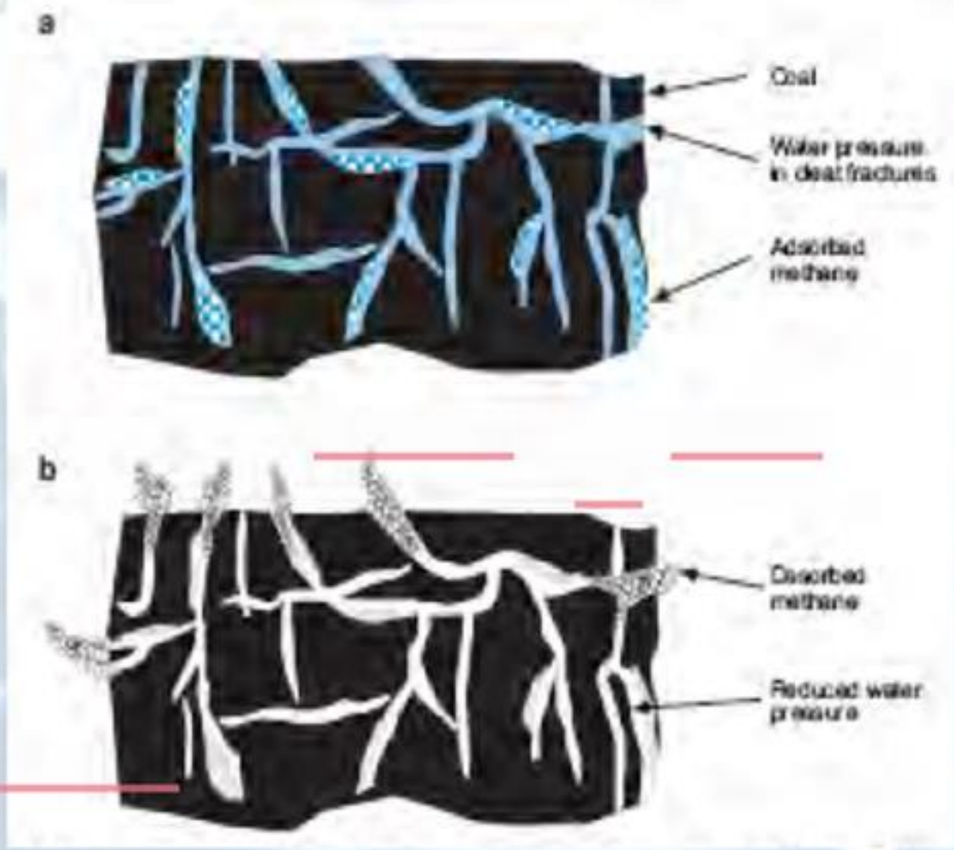
- In India, 32 CBM blocks have been awarded through nomination and bidding under the New Exploration Licensing Policy (NELP). **DGH (2018)** reported that the CBM production was about 2.4 million metric standard cubic meters per day (mmscmd) from six blocks such as Raniganj (2 blocks), Jharia (1 block), Bokaro (2 blocks) and Sohagpur (1 block). The production of CBM in India is anticipated to increase manifold in the near future.

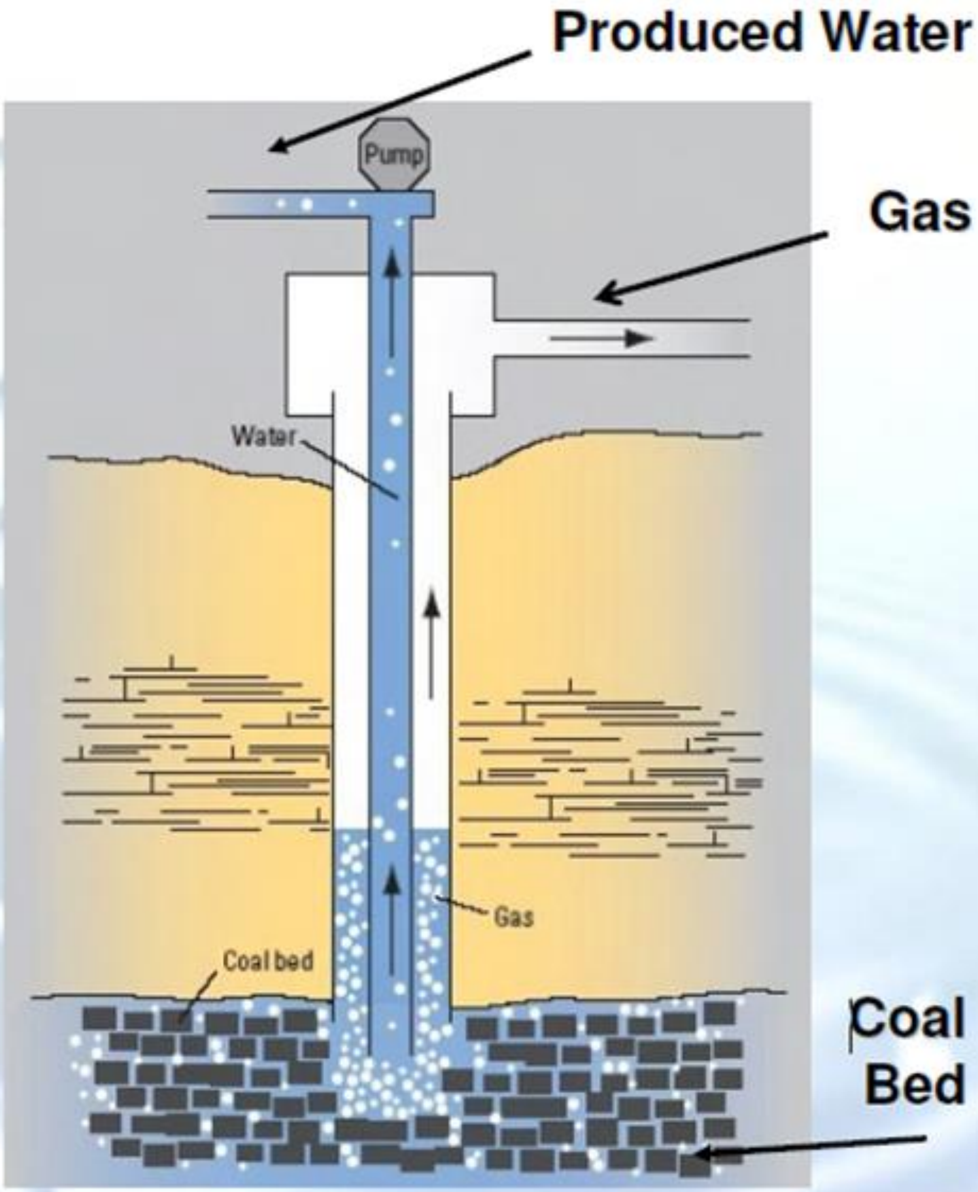
FORMATION

- **Methane forms along with coal**



- CBM **remains adsorbed** or attached to the coal due to overlying pressure

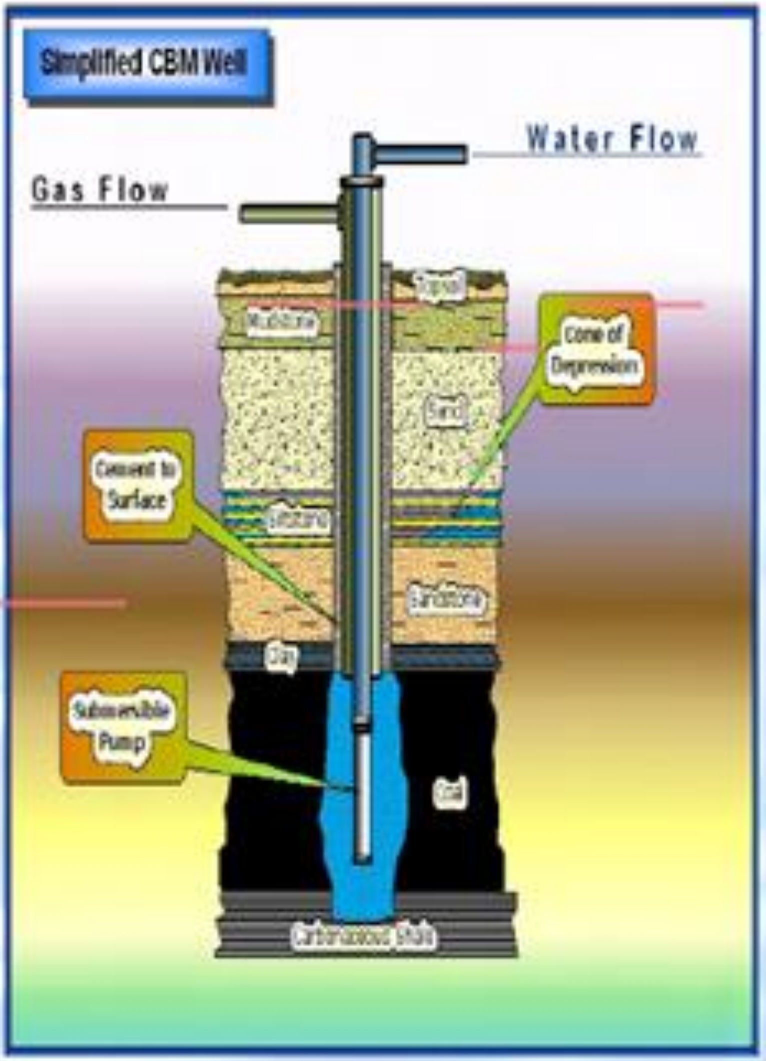
- The **pressure** in the coal seam is **reduced** to facilitate methane production



PRODUCED WATER

- A dewatering stage allows the CBM to separate from the coal and be pumped to the surface

- Water pumped during this stage and subsequent production stages is referred to as **Produced Water**



Coalbed Methane Produced Water

- Coalbed methane (CBM) recovery is associated with production of large quantity of groundwater. It produces large volume of water early in its life and the water volume declines overtime. During the coalbed methane (CBM) extraction process, large pumping systems are installed for dewatering i.e. removal of water from the coal reservoir for gas recovery, which causes a reduction in the reservoir pressure, thereby accelerating gas extraction. **It is reported that the CBM produced water (CBMW) production may be of the order of 10^3 -10^4 litres each day from a single well** (**Flores, 2014**). Coalbed methane-produced water is extracted and transported from the coal reservoir to the surface, where it is disposed of, treated, or reused. In Indian basins, coals serve as aquifers containing varied amounts of groundwater, which in turn apply hydrostatic pressure that holds the gas in the reservoir. The quantity of produced water generation is high in the first few years of operation and then decreases over time as coal seam hydrostatic pressure decreases and gas production increases.

- The process of CBM extraction involves the deployment of large-scale pumping systems designed to dewater coal reservoirs. This dewatering process entails the removal of formation water trapped within the coal seams, leading to a reduction in the hydrostatic pressure and facilitating the release of methane gas. During this process, significant volumes of water, commonly referred to as CBM-produced water (CBMW), are generated. Reports suggest **that water production from a single well can range from 1,000 to 10,000 liters per day, with Indian industries estimating typical values at approximately 30-35 cubic meters per day. More than 1000 wells have already been dug out / actively planned by various agencies in this local region which would unleash more than 30,000 cum of water daily. Consequently, the management of CBMW represents one of the most pressing environmental and logistical challenges for CBM operators**.

- **In India, CBM-produced water is emerging as a threat to land and water bodies that come under CBM blocks because of a lack of knowledge of the source of produced water contaminants, technologies related to their treatment and suitable disposal options. Several researchers reported that sodium and bicarbonate were the major ions in the water samples produced from CBM wells in Indian Coalfields** (**Mendhe et al., 2017; Singh et al., 2018**).

ISSUES

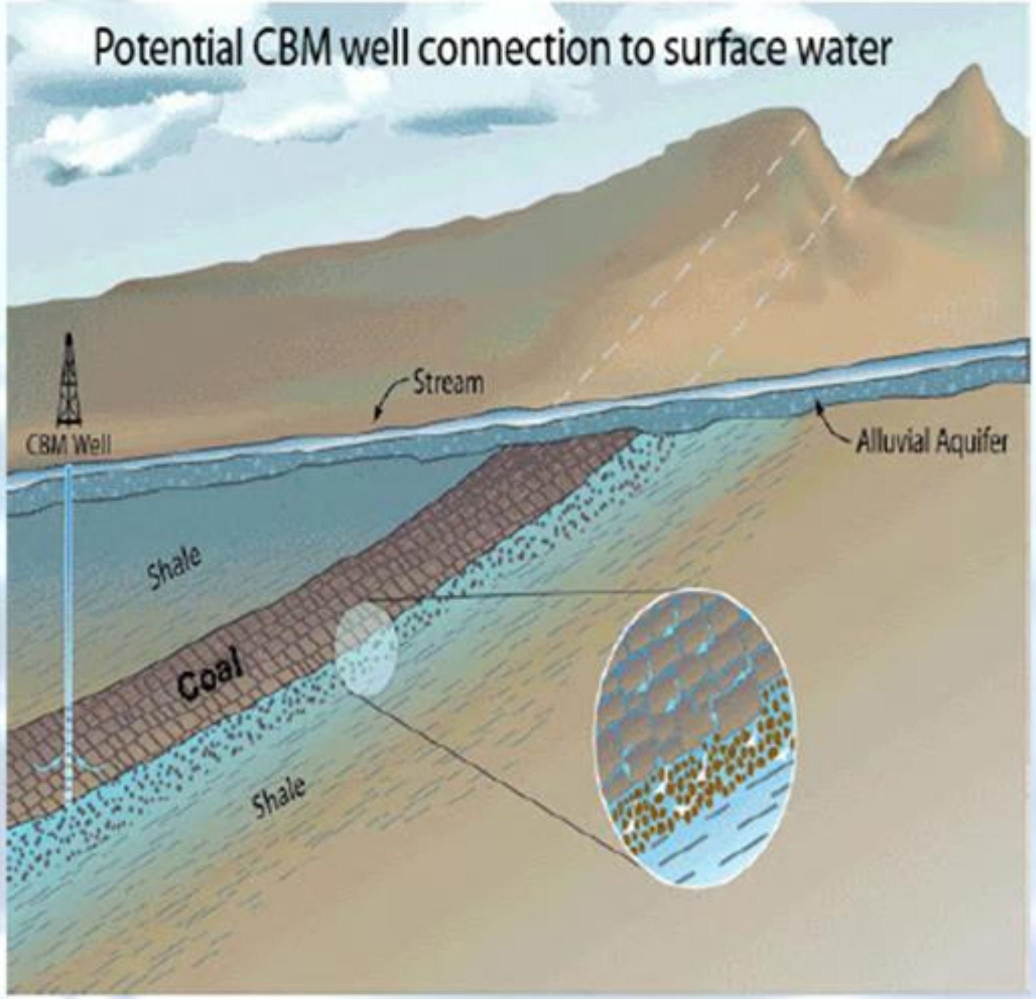
- **Volume of water – surface discharge, aquifer**
- **Degradation of water quality – groundwater, surface water**
- **Ground water table**
- **Enforcing Water Standards**

VOLUME OF WATER

- **Huge quantity:** initially up to 1000m^3 per day, 200-300 m^3 per day in 7th year*

- **Fresh water** is pumped out and thrown in streams

- **Disturb flow** of streams and wells



*Source: Moonidih Pilot Project data, CMPDI CBM Cell

A schematic diagram showing conceptualized connections between coalbed seams, aquifers, and surface water is shown in Figure 5.4.

GROUNDWATER

The primary substantiated effects of CBM produced water on groundwater resources include (1) drawdown of groundwater levels in coalbeds as a result of pumping water from coalbeds during CBM extraction and (2) changes in groundwater quality associated with CBM produced water in surface impoundments.

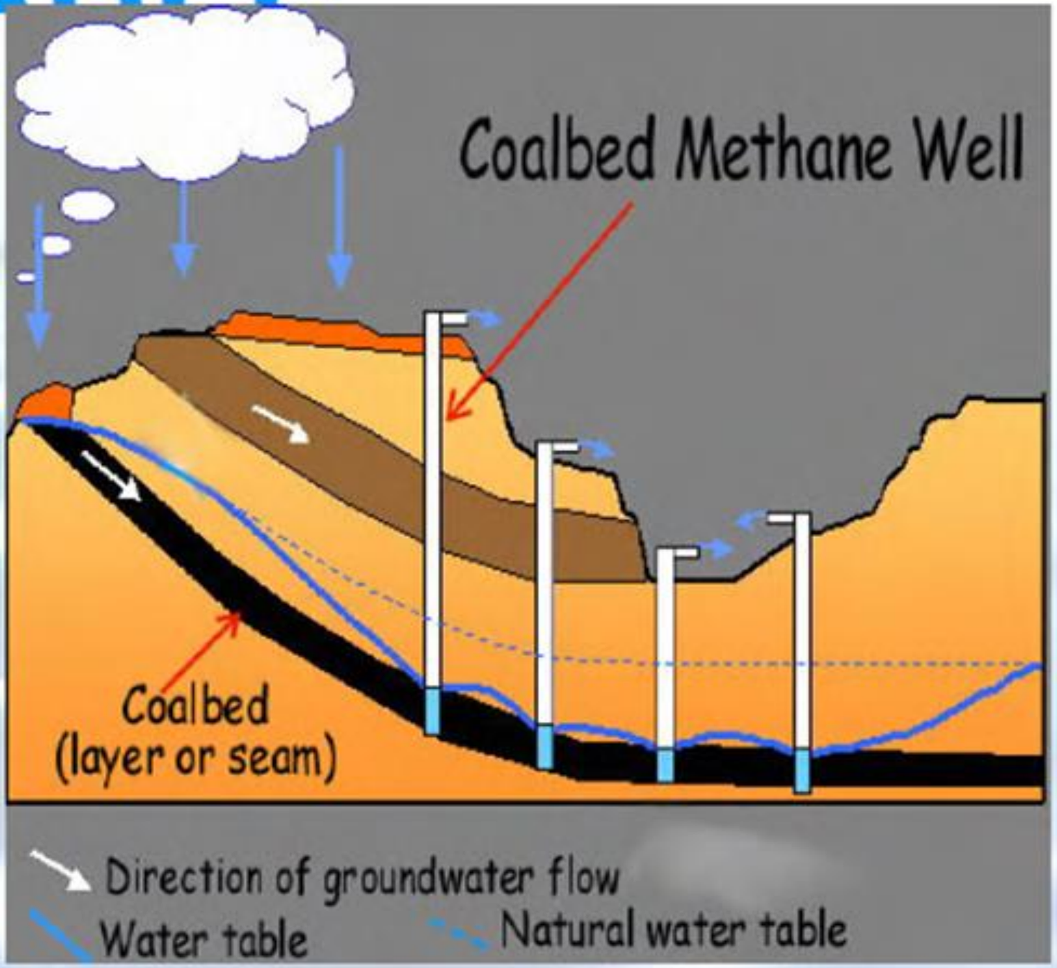
Effects of Groundwater Withdrawal on Aquifers

Research demonstrates that a principal effect of CBM withdrawals on groundwater is reduction of water volume and hydrostatic head within coalbeds from which methane is being extracted. Typically, the CBM well is pumped to reduce the hydrostatic pressure in the coalbed to a pressure approximately equal to atmospheric. However, water is still retained within the coal and generally the head level of water in the coalbed is maintained relatively close to the uppermost physical surface of the coalbed. Any effects of water withdrawal from methane-bearing coalbeds on water levels in other aquifers are a function of the depth of the target coalbeds and the degree of hydraulic connection between CBM targets and the other local or regional aquifers (see Chapter 2 for discussion of hydraulic connectivity).

Pumping water during CBM extraction in basins with deep methane-bearing coals, such as the San Juan, Raton, Uinta, and Piceance basins, is unlikely to cause lowering of the water table of shallow alluvial aquifers because of lack of hydraulic connectivity between the deep coals and shallow aquifers coupled with the great vertical separation between the coalbeds and the shallow groundwater systems (upward of thousands of feet; see also Chapter 2). Typically, methane-bearing coalbeds in these basins are bounded above and below by either aquitards or aquicludes (see Chapter 2) that are responsible for both the positive hydrostatic pressure within the coalbeds and the lack of hydraulic connectivity or communication between the coalbeds and overlying and underlying aquifers. An exception to this circumstance is that reported by Riese et al. (2005) for the San Juan Basin, in which the authors documented movement of water from below the methane-bearing coalbeds upward and into the coalbeds (see Chapter 2).

GROUND WATER TABLE

- **Depletes Ground Water,** lower boreholes and surface water flows.
- **Changes flow of groundwater** drawing fresh water into the coal seams.
- **Lowering the water table may allow methane and other gases to be released indiscriminately**



WATER QUALITY

- Groundwater contain many impurities
- Nitrate, Iron, Fluoride are common problem in groundwater in India. (CGWB, 2010)
- Surface water may also get contaminated

- **Produced water may contain Impurities** (drill bit cuttings, lubricants, oil and diesel), **can pollute surrounding water bodies when discharged.**

- **In addition to the impacts from the discharge of produced water, other issues including Methane Migration.**

Composition of the CBM co-water

- CBMW characteristics, including volume and composition, exhibit substantial variability across coalfields. For example, **previous research has reported that waters from the Jharia coalfield predominantly exhibit Na-HCO3 type compositions, whereas those from the East Bokaro coalfield are characterized by Na-Cl type speciation. Furthermore, the total dissolved solids (TDS) in these waters can vary significantly, ranging from 1,000 mg/L to as high as 10,000 mg/L.** This variability underscores the importance of adopting region-specific strategies for the management and utilization of CBMW. On the demand side, the most efficient end-use of these waters often hinges on the local context of water scarcity and resource requirements.

- **Large volumes of water have become an integral part of coalbed gas production. This results in produced water having high total dissolved solids (TDS) and rich toxic elements, posing management and environmental issues that are the major hurdles in operating coalbed methane blocks** (**Meng et al., 2014**). **Further, the surface discharge of produced water has adverse environmental effects, such as changes in natural vegetation and salt deposition** (**Ganjegunte et al., 2005**). The coalbed methane-produced water is an emerging issue related to quality, treatment, utilisation and disposal in different methane-producing basins. Produced water is generally rich in salts, and the literature review indicates that the coalbed methane fields have high suspended solids and TDS concentrations (**Engle et al, 2011; Mahato et al., 2017**). **In addition, the produced water may also contain some heavy metals, such as boron and fluoride, which further restrict its beneficial use. Disposal or treatment (as the case may be) of this produced water is one of the major issues in a CBM project because this water is highly brackish and unhindered disposal may create challenges of soil degradation. The use of produced water for irrigation can result in deterioration in soil quality and changes in physical and chemical parameters of the soil** (**Veil and Clark, 2011**). Therefore, the produced water requires long-term water management solutions to maximize beneficial outcomes for the local community and environment. The proper management of large quantities of produced water requires fundamental information on quality, volume, reliability of supply, regulatory restrictions, and access to storage locations.

- **Investigations were carried out to evaluate geochemical and hydrogeological conditions of CBM blocks in Raniganj Basin. The chemical signature of CBM produced water in Raniganj Basin reveals high sodium and bicarbonate concentrations with low calcium and magnesium, and very low sulphate. It is comprehended that CBM water is mainly of Na–HCO_3 type. However, use of this huge volume of CBM produced water for irrigation or other beneficial purposes may require careful management based on water pH, EC, TDS, alkalinity, bicarbonate, sodium, fluoride, metals content and SAR values.** CBM produced water in Raniganj Coalfield typically has rich concentrations of total dissolved solids. The distribution of major ions and SAR shows that bicarbonate and sodium concentration in CBM water are relatively high ranging from 2129.40 to 2771.30 and 349.80 to 976.10 mg/L, respectively (**Mendhe et al., 2017**). Water that is produced from deeper coal formations can contain NO_3-, Cl- ,metals and high levels of total dissolved solids, which makes it unsafe for drinking purposes (**Jamshidi and Jessen 2012**).

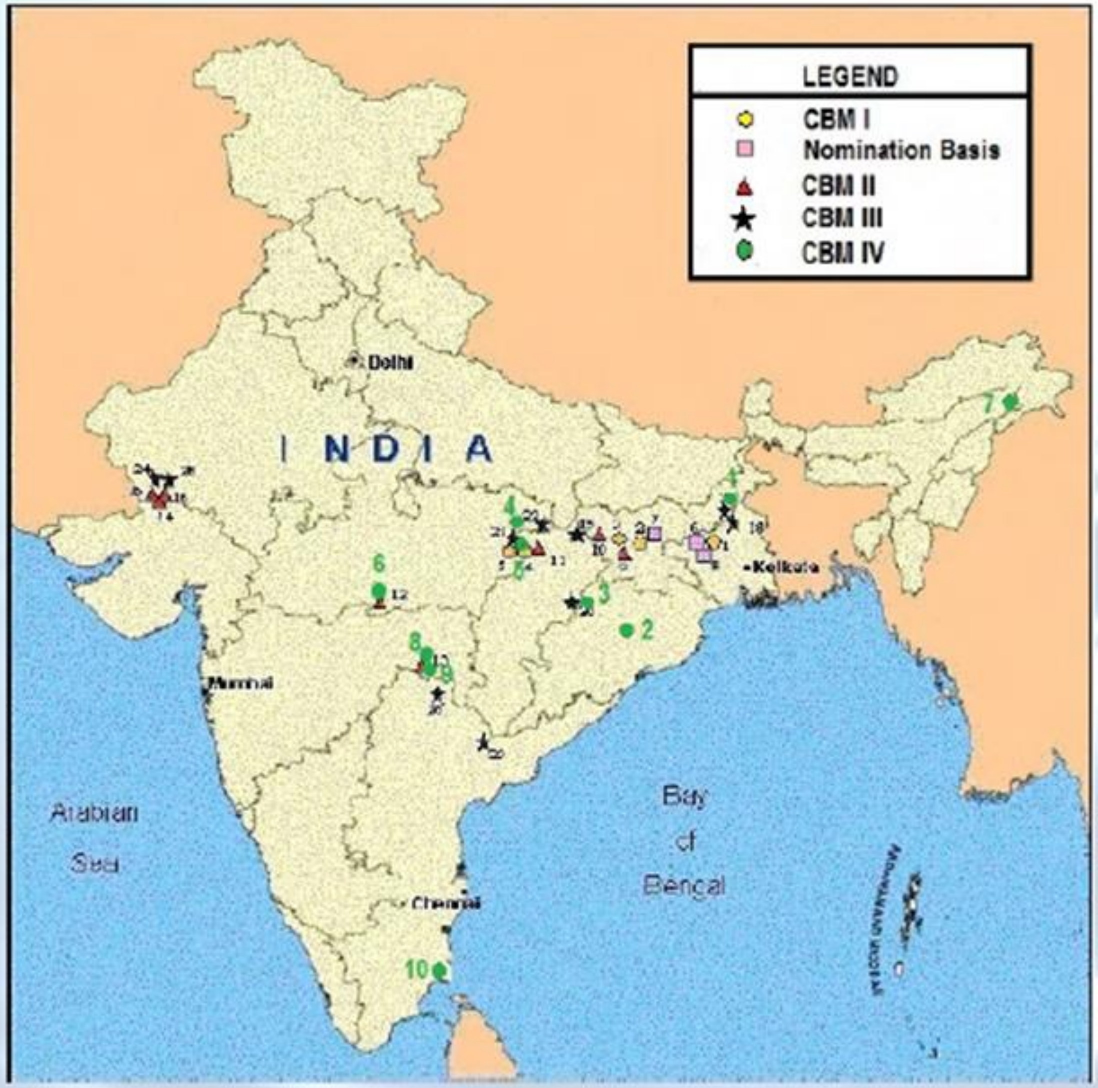
STANDARDS

- Standard for drinking water
- Standard for Discharging water in Streams
- Standards getting stringent
- Bokaro Thermal Unit was shutdown, 24 Oct 2013

ISSUES

- Volume of water
- Degradation of water quality
- Ground water table

CBM IN INDIA



Source: CMPDI CBM CELL

- West Bengal
- **Jharkhand**
- Madhya Pradesh
- **Chhattisgarh**
- Rajasthan
- Andhra Pradesh
- Maharashtra

CBM IN CHHATTISGARH

- Champa
- Raigarh
- Koriya

Source: CBM Cell CMPDI

GROUNDWATER ISSUES

- **Fluoride** – Koriya, Champa
- **Iron** – Koriya
- **Nitrate** – Koriya, Champa, Raigarh
- **Salinity** – Champa

Source: CGWB, 2010

WATER QUALITY

- Electrical conductivity, Hardness, TDS, Fluoride are present above drinking permissible limit in Korba*.

- Electrical conductivity , TDS are present above drinking permissible limit in Raigarh**

- Electrical conductivity, TDS, Nitrate, Iron are present above drinking permissible limit in Jharia***.

* Source: Renu Nayar and Deepak Tiwari, 2010
** Source: CPCB, 2010-11
*** Source: Abhishek et al, 2007

CASE STUDY

- **CMPDI/BCCL** has successfully implemented a **Demonstration Project** in BCCL mine at Moonidih under GOI/UNDP/GEF funding

- **Initial Produced Water quality :**

S No	Parameter	Sampling Stn 1	Sampling Stn 2	Standards IS: 10500
1	pH	7.84	8.05	6.5-8.5
2	Alkalinity (mg/l)	1514	890	200
3	Iron (mg/l)	1.5	6.7	0.3
4	Chlorides (mg/l)	1432	79.4	250
5	Total Dissolved Solids (mg/l)	4015	842	500
6	Calcium (mg/l)	8.01	43	75

STABLE PRODUCED WATER QUALITY

S No	Parameter	Sampling Stn 1	Sampling Stn 2	Standards IS: 10500
1	Turbidity	6	4	5
2	pH	8.24	8.18	6.5-8.5
3	Alkalinity	552	604	200
4	Iron	0.08	0.04	0.3
5	Chlorides	76	58	250
6	Total Dissolved Solids	716	842	500
7	Calcium	8	11.2	75
8	Mn, Zn, SO_4^{2-} ,NO^-, F, Ar are below the detection level.			

WATER QUALITY ISSUES

- **Fluoride related :** Fluorosis - affects teeth and bones
- **Iron related :** Brackish Colour, Digestive disorders, skin diseases and dental problems
- **Nitrate related:** Blue Baby disease, Cancer problem
- **Alkaline Water:** Corrosive , Scale formation

AFFECT

- **Groundwater Impurities (Nitrates, Fluorides, Iron) are thrown in Streams**
- **Streams cater Water treatment plant for population.**
- **If Not Equipped to tackle Nitrates, Fluoride**

PROBLEM WORLDWIDE

- **Produced Water quality** is a Issue worldwide.
- Sodium, Calcium, Iron, Salinity

- **Restricted usability** of water

- **Treatment Cost** High
- RO plants

QUALITY COMPARISON

S No	Parameter	Black Warrior Basin, USA*	Moonidih, India
1	Iron	400	0.08
2	Chlorides	36000	76
3	Total Dissolved	16000	842
4	Sodium	21500	NA
5	Sulfate	1350	BDL
6	Calcium	200	11.2

*Source: USEPA, 2011,Coalbed Methane Extraction: Detailed Study Report

ADVANTAGES TO INDIA

- **Water quality** is generally portable

- **Little treatment** / no treatment can make water usable (Agri, bathing etc..)
- **Treatment cost** will be lower

MITIGATION

- **Depends on Composition of the produced water quality**

- **Depends on Use**
- **It is either disposed of or used for beneficial purpose**

MITIGATION

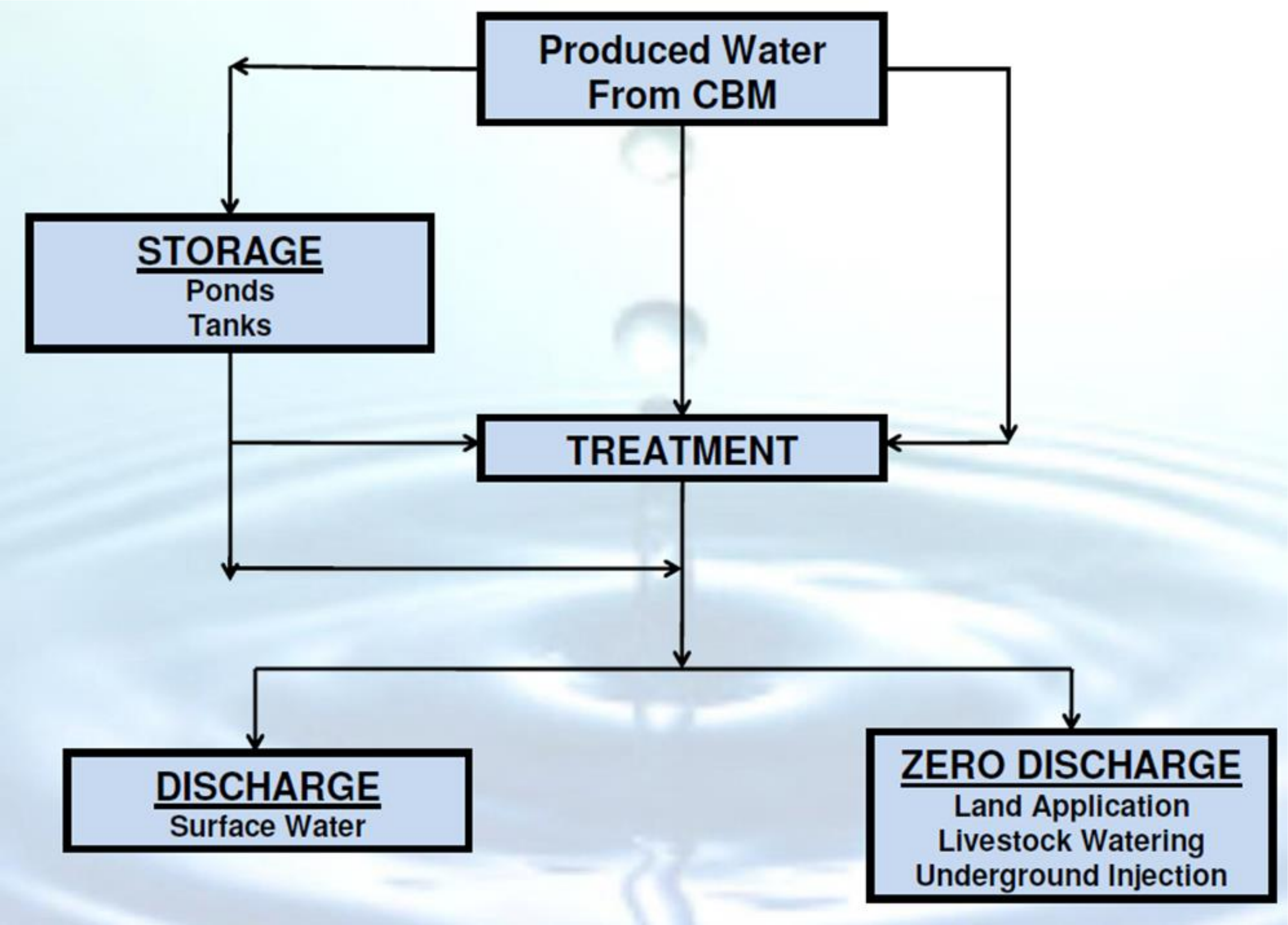
- **Surface discharge**

is a common method of disposing CBM water in India.

- **Idea is not to throw this water in streams.**

MITIGATION

- CBM water could be **used for irrigation and to supplement water supplies** if little or no treatment is required for it to meet specifications under CPCB regulations.
- The other method of water disposal is **subsurface injection**


Produced Water
From CBM
STORAGE
Ponds
Tanks
TREATMENT
DISCHARGE
Surface Water
ZERO DISCHARGE
Land Application
Livestock Watering
Underground Injection

Operational and management aspects

- **Several potential end-uses for CBMW have been proposed, including domestic and potable reuse, agricultural applications, disposal into water bodies, and reinjection into coal seams. The selection of an appropriate water management approach depends on a complex interplay of factors such as water quality, regional demand, and environmental regulations.** These factors, in turn, influence the energy consumption and cost implications associated with water handling.
- **The treatment of coalbed methane (CBM) co-produced water poses several challenges due to its unique chemical and physical properties. The treatment of CBM-co-produced water has been a pertinent issue for a long. Untreated water so produced is affecting the local water bodies and also degrades the soil fertility due to high salination. It is, hence, the dire need of the hour to address this issue.**

- **Further, drinking water availability is a major societal issue in these coalfields. The large quantity of water generated from CBM production wells can be potential freshwater sources for various applications, including potable consumption. These challenges include high treatment cost, potential chronic toxicity of the treated produced water and public acceptance. Because of the need of desalination and removal of a large number of chemical compounds, reverse osmosis (RO) may likely be used for potable reuse applications. Nevertheless, the disadvantage of this technique is that a huge volume of untreated water is bypassed. The initial cost of reverse osmosis membrane is high and they are subject to fouling, require pretreatment and may be expensive to replace, temperature sensitive, significant infrastructure, relatively immobile, high per-unit treatment cost and waste stream disposal cost. Thus, for achieving goals, it requires the use of multiple desalination technologies (Fakhru'l-Razi et al., 2009).**

CBM WATER MANAGEMENT

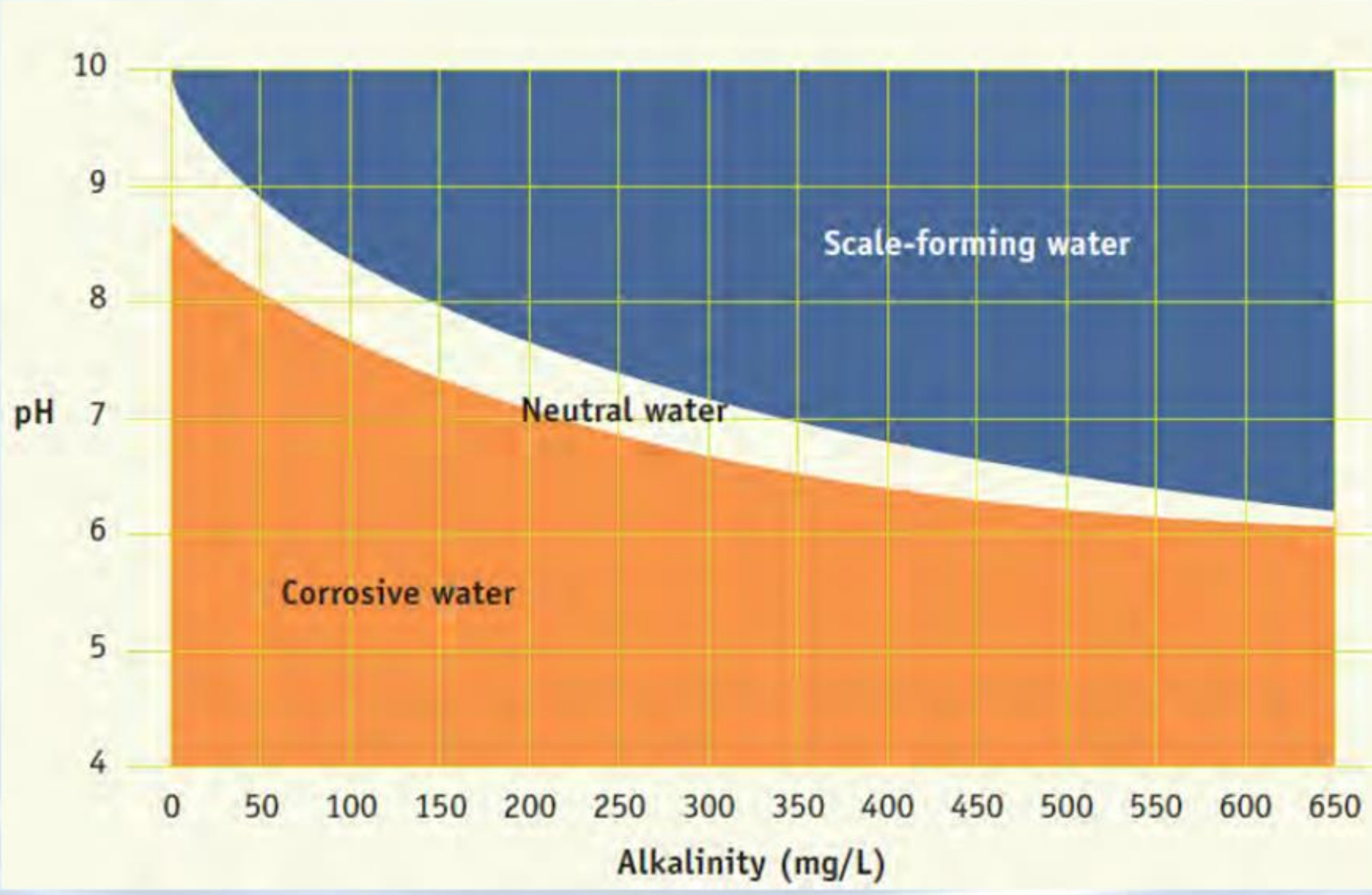
- For Crop Irrigation


BeneTerra subsurface irrigation site in Wyoming, USA

- For Livestock Watering

- Constructed Wetlands

pH – ALKALINITY



CBM WATER TREATMENT

- Lime softening

- Aeration Ponds

TREATMENT TECHNOLOGY

- **Iron:** Oxidizing Filter , Green-sand Mechanical Filter
- **Fluoride:** Activated Alumina, Distillation, Reverse Osmosis, Ion Exchange
- **Salinity:** Reverse Osmosis, Distillation, ion exchange
- **Nitrates:** Ion Exchange, Reverse osmosis

CONCLUSION

- **Continues Monitoring of CBM water is required.**

- **Routine chemical and microbiological analysis done on the well water through an accredited laboratory**

- **With fluorides and Nitrates in water, Requires some level of treatment before it could be discharged or used**

- **Further Studies / Research** are required.

- Treated produced water can make CBM **Cleaner and Greener Energy**

- Reliable data on the quality of coalbed methane-produced water are needed for decision-makers regarding the handling, disposal, and possible beneficial uses of this water. TDS is an essential parameter for mixing with any surface or groundwater for water disposal issues. Thus, it is worthwhile to systematically collect and evaluate the coalbed methane-produced water to understand its physical and chemical characteristics so that these data suit can be used in designing the methodologies for their effective management and disposal without causing adverse impact on the surrounding environment.

DRINKING WATER STANDARDS

IS: 10500

PARAMETER	REQUIREMENT DESIRABLE LIMIT	REMARKS
Fluoride	0.6 to 1.2 mg/l	If the limit is below 0.6 water should be rejected, Max. Limit is extended to 1.5
Nitrates	45 mg/l	No relaxation
Iron	0.3 mg/l	May be extended up to 1
Total Dissolved solids	500 mg/l	Beyond this palatability decreases and may cause gastro intentional irritation

DISCHARGE STANDARDS

PARAMETER	REQUIREMENT DESIRABLE LIMIT
Fluoride	2.0 mg/l
Nitrates	10 mg/l
Iron	3 mg/l
TDS	2000 mg/l

Environment Protection Rules, 1989

Water Quality Criteria as per Central Pollution Control Board (CPCB)

Designated best use	Class	Criteria
Drinking water source without conventional treatment but after disinfections	A	*Total coliform organisms MPN/100ml shall be 50 or less.
		*pH between 6.5 and 8.5
		*Dissolved oxygen 6 mg/l or more
		*Biochemical oxygen demand 2 mg/l or Less
Outdoor bathing (organized)	B	*Total coliform organisms MPN/100ml shall be 500 or less
		*pH between 6.5 and 8.5
		*Dissolved oxygen 5 mg/l or more
		*Biochemical oxygen demand 3 mg/l or Less
Drinking water source with conventional treatment followed by disinfection	C	*Total coliform organisms MPN/ 100ml shall be 5000 or less
		*pH between 6 and 9
		*Dissolved oxygen 4 mg/l or more
		*Biochemical oxygen demand 3 mg/l or less
Propagation of wild life, fisheries	D	*pH between 6.5 and 8.5
		*Dissolved oxygen 4 mg/l or more
		*Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, controlled waste disposal	E	*pH between 6.0 and 8.5
		*Electrical conductivity less than 2250 micro mhos/cm
		*Sodium absorption ratio less than 26
		*Boron less than 2mg/l

4.3.1 Water Pollution Parameters

4.3.1.1 **pH :** The pH is a dimensionless number that indicates the strength of an acidic or a basic solution. It can be defined as the negative logarithm of the hydrogen ion concentration. The pH scale ranges from 0 – 14. Pure water is neutral (pH = 7) because it contains the same number of hydrogen ions (H^+ ions) as hydroxyl ions (OH^- ions).

4.3.1.2 **Total Suspended Solids :** Solids occur in water either in solution or in suspension. These two types of solids are distinguished by passing the water sample through a glass fiber filter. By definition, the suspended solids are retained on top of the filter and the dissolved solids pass through the filter with the water.

Total suspended solids (TSS) can be calculated by the following equation

$$TSS = (A - B) / C$$

Where, A = weight of the filter plus retained solids
B = weight of the clean filter
C = volume of sample filtered

4.3.1.3 **Bio-chemical Oxygen Demand (BOD) :** The amount of oxygen required to decompose the biodegradable organics present in the waste water is called the bio-chemical oxygen demand. BOD is used as an indirect measure of the total amount of biodegradable organics in the water. The amount of oxygen required to decompose all the biodegradable organics in a given volume of water is called the ultimate BOD or BoD_L.

BOD at any time of a given solution can be determined by the following equation

$$BOD_t = BOD_L * (1 - 10^{-kt})$$

Where, BOD_t = BOD at any time t, mg/L
BoD_L = ultimate BOD, mg/L
k = a constant representing the rate of the BOD reaction
t = time, day

4.3.1.4 **Chemical Oxygen Demand (COD) :** There also might be non-biodegradable substances present in the water which cannot be decomposed by the microbes to use as food. In COD test a strong oxidizing agent ($K_2Cr_2O_7$) is used to oxidize the organics rather that relying on microorganisms to do the job. COD test indicates the oxygen required decomposing the organics (biodegradable + non-biodegradable) present in the waste water and thus it is always greater than the BOD. The result of the COD test can be obtained in just 2 hour whereas for BOD test standard time required is 5 days.

4.3.2 Standards of Effluents Discharge from Coal Mines

The standard of effluents discharge from coal Mines is given in Table 4.4.

Table 4.4 : Standards of Effluents Discharge from Coal mines

Parameters	Maximum permissible value
pH	5.5 - 9.0
Total Suspended Solids	100 mg/L [200 mg/L in case of discharge into Land for Irrigation]
Bio-chemical Oxygen Demand (BOD)	~~250~~ mg/L 30
Chemical Oxygen Demand (COD)	~~30~~ mg/L 250
Oil & Grease (O & G)	10 mg/L