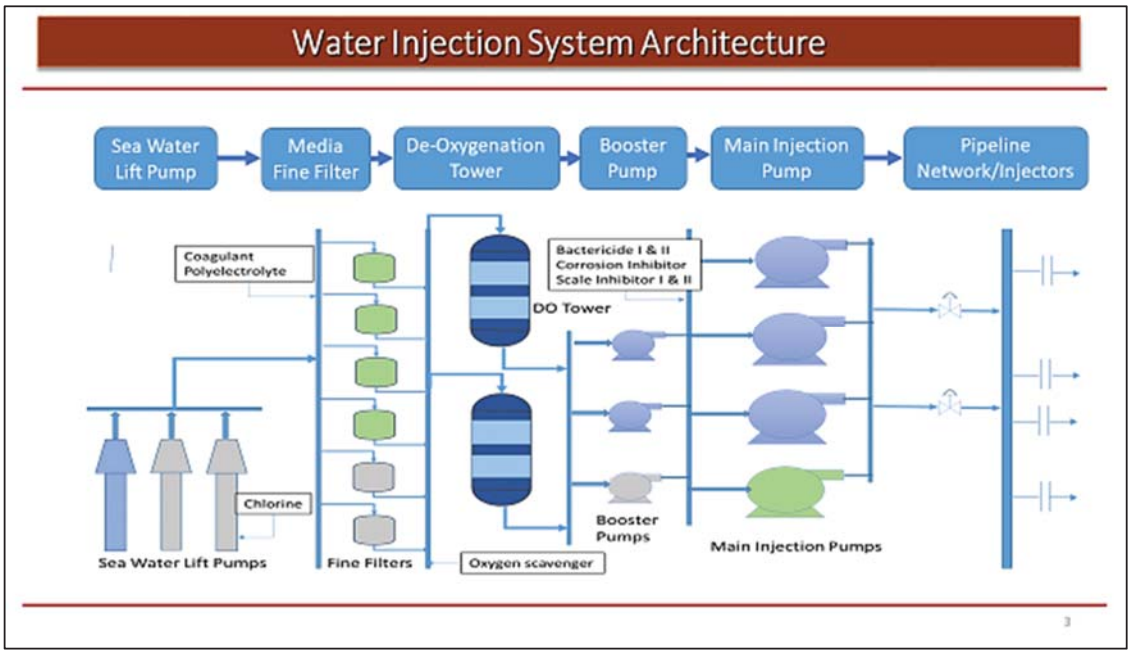
Chapter 5
Quality of water injection

In Western offshore oil fields of the company, seawater is the only source of water for injecting into reservoir, especially due to its ease of access. It, however, contains excessive salts, suspended solids, dissolved oxygen and is rich in flora and fauna. Therefore, its use may lead to number of operating problems like:

- Formation of scales in the injector and producer, which can be due to incompatibility between injection and formation water;
- Bacterial growth;
- Corrosion of equipment in the processing installation and pipeline injection network due to combined effect of oxygen and sodium chloride; and
- Plugging injection wells due to suspended solids, corrosion and bacterial by-products.

Hence it is essential that the seawater is treated effectively before it is injected. The treatment scheme for injection water is therefore designed to be such that water is free from above problems.

Fig 5.1 Water injection system architecture



5.1 Treatment of seawater

The equipment used in the water injection process has been described in Para 4.2. The treatment of seawater on water injection platform mainly comprises of following sub-processes:

- **Seawater lifting:** Seawater is lifted by seawater lift pumps and pumped to the coarse filters. Hypochlorite solution generated in chlorinator units is injected at the pump suctions to control marine growth in the seawater piping system.

- **Filtration:** The seawater is then passed through fine filters to remove suspended solids. The fine filter elements are automatically cleaned in a continuous backwash cycle with filtered water while operating. Coagulant/ polyelectrolyte are dosed into the filter inlet to help coagulate suspended solids.

- **De-oxygenation:** The filtered water is passed through de-oxygenation towers to reduce oxygen level to 200 ppb and oxygen scavenger chemical further reduces the dissolved oxygen to a permissible limit of <20 ppb. This prevents internal corrosion of equipment and pipelines. Dissolved oxygen ideally should be 'nil' in injection water.

- **Chemical injection:** A chemical injection system is provided for storing and injecting various chemicals into the water flood stream at various points in the system.

The treated water is pumped with the help of booster pumps and main injection pumps to water injection network.

5.2 Water quality parameters adopted by the company

The company has fixed water quality parameters suitable for injection of water into reservoir. The desired quality parameters and recommended dosing of water injection chemicals in western offshore oil fields is given at table 5.1.

Table 5.1: Desired quality parameters and recommended dosing of chemicals

Quality parameter	Quality limit		Name of chemical used to maintain quality parameter	Recommended dosing of chemical injected-MH/ N&H	Function of chemical	Dosing point	Measuring method to check quality parameters	Measuring point
	unit	limit						
Total suspended solid	Mg/ lt	<0.2	Coagulant/ Polyelectrolyte	0.4-0.8 ppm/ 0.2-0.3 ppm	Assist in coagulation and filtration	Filter inlet	Lab check	Filter outlet/ Main Injection Pump outlet
Millipore	Lt./ 30 minutes	>6	Coagulant/ Polyelectrolyte	0.4- 0.8 ppm/ 0.2 -0.3 ppm	Assist in coagulation and filtration	Filter inlet	Lab check	Filter outlet/ Main Injection Pump outlet
Turbidity	NTU	<0.2	Coagulant/ Polyelectrolyte	0.4 -0.8 ppm/ 0.2-0.3 ppm	Assist in coagulation and filtration	Filter inlet	Lab check	Filter outlet/ Main Injection Pump outlet
Particle count	No./ ml	<2000	Coagulant/ Polyelectrolyte	0.4 – 0.8 ppm/ 0.2-0.3 ppm	Assist in coagulation and filtration	Filter inlet	Lab check	Filter outlet/ Main Injection Pump outlet
Dissolved Oxygen	ppb	<20	Oxygen scavenger	10 ppm/ 2-10 ppm	Remove dissolved oxygen from	De-Oxygenation Tower	Lab check/ online	De-Oxygenation Tower outlet

Quality parameter	Quality limit		Name of chemical used to maintain quality parameter	Recommended dosing of chemical injected-MH/ N&H	Function of chemical	Dosing point	Measuring method to check quality parameters	Measuring point
	unit	limit						
					injection water			
Residual sulphite	Mg./ lt.	>1	Oxygen scavenger		Indicate residual presence of oxygen scavenger		Lab check	De-Oxygenation Tower outlet
Iron counts	Mg/ lt	<0.05	Corrosion inhibitor	20 ppm/ 10 ppm	Prevent corrosion	Booster pump inlet/ Main Injection Pump	Lab check	Main Injection Pump outlet
Sulphide	Mg/ lt.	Nil			Not a treatment parameter	Main Injection Pump	Lab Check	Main Injection Pump
Mumbai High (MH), Neelam & Heera (N&H) ***Source: Management response received from Mumbai High, Neelam & Heera regarding desired water quality parameter adopted.***								

5.2.1 Downgrading water quality parameters

Over the period, the company diluted some of the water quality parameters as detailed at table 5.2.

Table 5.2: Dilution of water quality parameters

Quality parameter	Regional chemical lab report on test methods of water quality monitoring parameters (Feb 1984)	IRS Manual on 'Offshore Injection Water Quality' issued (Mar 1994)	Quality control testing procedures for chemist at offshore process platforms (Dec 1997)	Currently followed specifications (2014 - 19)
Suspended solids	0.1 mg/ litre		<0.1 mg/ litre	<0.2 mg/ litre
Particle count		<70 No./ litre	< 300 No./ litre	<2000 No./ litre
Millipore			> 10 litre/ 30 min	>6 litre/ 30 min
Dissolved Oxygen	15 parts per billion (ppb)			< 20 ppb
Residual Sulphite			> 0.1 mg/ litre	>1 mg/ litre
Source: Data/ Reports furnished by the company in response to Audit requisitions				

Management/ Ministry stated (January 2020/ February 2021) that based on the field experience, reservoir conditions and other technical inputs, the injection water parameters were re-designed from time to time. The quality dilution needs to be seen in the context of the ageing of the water injection equipment as mentioned in Chapter 4.

5.3 Quality of injection water

The average quality of water measured at water injection platforms in Mumbai High and Neelam and Heera fields is given at **Annexure-IX**. It can be observed from the annexure

that quality of water in almost all water injection platforms was inferior to the quality parameters currently followed by the company. The company failed to meet desired quality parameters, despite dilution of some of the quality parameters over a period of time. Further, some of the quality parameters (like dissolved oxygen, particle count, turbidity) showed a deteriorating trend.

Management/ Ministry stated (February/ June 2021) that the company had taken/ is taking requisite modifications/ revamping of water injection facilities to cater to the desired quality. The reply needs to be seen in the context of failure to maintain the quality of water over a long period of time which resulted in corrosion in pipelines/ equipment and affected injectivity of the wells. The delayed action is reactive and has consequential impact on costs involved and its efficacy.

5.4 Incorrect reporting of water quality parameters

Audit observed the following discrepancies and inconsistencies in reporting of the water quality:

i) While working out the monthly average of quality parameters, instances where it was beyond acceptable limits were excluded.

ii) Average water quality parameter of dissolved oxygen was reported as 'nil' even when dissolved oxygen was recorded at more than 200 ppb. Similarly, annual average was inconsistent with monthly figures.

iii) Dissolved oxygen in injection water was recorded within prescribed limits even though there was no consumption of oxygen scavenger.

iv) Consumption of oxygen scavenger was recorded even in days where the quantity was 'nil' in the chemical injection tank.

Thus, the quality of water recorded and reported by the company is not reliable. Management/ Ministry stated that some error in manual data entry has taken place and teams at offshore have been advised to take due diligence while recording the data and feeding in SAP system.

Recommendation No. 8

Due diligence while recording the data and feeding in SAP system should be ensured so that the desired quality parameters required for injection into the reservoir can be monitored and ensured.

5.5 Causes for poor water quality parameters

Poor quality of injection water was due to ageing of water injection facilities/ lack of proper maintenance which had already been discussed in Chapter 4. Non-availability of required water injection chemicals at water injection platforms, non-availability/ inefficient operation of chemical injection pumps also directly contribute to failure in maintaining the quality of injection water as mentioned at table 5.3.

Table 5.3 Details of 'nil' consumption of water injection chemicals during 2014-19

Platform	Both Coagulant and PAC		Oxygen scavenger		Water corrosion inhibitor		Bactericides	
	Days of nil consumption (a)	(a) / 5 years (in %)	Days of nil consumption (b)	(b) / 5 years (in %)	Days of nil consumption (c)	(c) / 5 years (in %)	Months* of nil consumption (d)	(d) *30 / 5 years (in %)
WIN	102	05.59	152	08.33	457	25.04	02	3.33
MNW	152	08.33	254	13.92	663	36.33	00	00
SHW	907	49.70	492	26.96	618	33.86	05	8.33
ICW	407	22.30	357	19.56	424	23.23	07	11.67
WIS	250	13.70	412	22.58	480	26.30	06	10.00
NLW	98	05.36	57	03.12	59	03.80	-	-
WIH	25	01.61	11	-	70	04.51	-	-

WIN- Water Injection North, MNW- Mumbai North Water Injection, SHW- South High Water Injection, ICW- Infill Complex Water Injection, WIS - Water Injection South, NLW – Neelam Water Injection and WIH – Water Injection Heera
Source: Platform daily production reports (DPR) and Chemistry monthly reports

*Company doses three types of bactericides alternatively each one after every 10 days.

As can be seen from the table, in large number of cases there was 'nil' consumption of chemical against recommended dosing norm (as denoted at table 5.1) due to non-availability of chemical at water injection platform and/ or deficiency of chemical injection pump.

In Mumbai High, in all the platforms there was low dosing of chemicals against the recommended dosing adopted by the company (details at **Annexure-X**). Water Corrosion Inhibitor was less than the recommended norms during 2014 - 2019 in Mumbai High. In case of Oxygen scavenger, except for Water Injection South and Infill Complex Water injection platforms during 2018-19, the dosing was less than the recommended norms during 2014-15 to 2018-19.

Wherever there was 'nil' consumption of oxygen scavenger, higher dissolved oxygen was recorded in injection water. In Neelam Water Injection platform for 54 days out of 1,826 days, there was 'nil' dosage of oxygen scavenger and it correlated with high dissolved oxygen levels at main injection pump (25 to 800 ppb) in those days and in Heera, in 43 months out of 60 months the consumption was less than 10 ppm. The residual sulphite was found to be 'nil' in 323 days (out of 1,826 days) in Neelam and 241 days (out of 1,551 days) in Heera, which indicated that desired level of dissolved oxygen was not maintained. In Heera, for 70 days, there was no dosing of water corrosion inhibitor at platform, of which 59 days it was due to no stock of the chemical at platform. Similarly, in Neelam, for 57 days there was no dosage of water corrosion inhibitor. During 52 months out of 60 months of 2014-15 to 2018-19, the dosage of water corrosion inhibitor at Neelam was lesser than the levels adopted by the company and in 1,756 days (out of 1,826 days) the iron count was more than 0.05 ppm at Neelam main injection pump end.

In case of water corrosion inhibitor, the company considered lesser dosage at 8 ppm for procurement against the dosage requirement of 20 ppm. The procurement was revised to 20 ppm from 2016-17 but the average consumption remained lower than the recommended norms.

Manuals[22], in-house research institutes[23] and committees[24] set up to study failure of pipelines and corrosion issues cited lack of injection of chemicals at required dosage as one of the main reasons for corrosion of equipment/ pipelines, injectivity impairment due to clogging of injection network. Despite time-to-time reiteration by various committees/ institutes, recommended levels of dosing of chemicals was not ensured. From the SAP data it was observed that pipeline leakages was the most significant reason for non-flowing of water injection wells.

Without proper dosing, the quality parameters could not be maintained. Corrosion inhibitors were required to prevent corrosion. Oxygen scavengers were required to absorb remaining oxygen molecules in downstream of De-Oxygenation towers as removal of dissolved oxygen is essential for internal corrosion of pipeline/ equipment. Poly Aluminium Chloride/ Polyelectrolyte/ Coagulants assist the filters to coalesce small, suspended particles. Insufficient dosing of the filtration chemicals and consequently presence of suspended solids may lead to formation plugging. Bactericides ensure that injection water is free from micro-organisms and thereby prevent microbial induced corrosion.

Management/ Ministry stated (February/ July 2021) that the concern of Audit regarding injection water quality is well taken and that various surface facilities are not working at their full efficiency at almost all platforms due to ageing. Management further stated that the company has taken up many initiatives from time to time to improve the water injection quality and quantity and it is a regular ongoing process considering the matured field environment and the ageing of installed equipment/ systems/ sub-systems. Management added that there are some extraneous factors also related to offshore operations like inclement weather conditions, limited storage space at platform, logistical problems and dosing pump issues.

Management reply is not convincing as the constraints brought out are controllable and poor quality of water is a long standing issue. In-house committee of the company also observed that excessive dissolved oxygen in injection water was the predominant reason for pre-mature failures of pipelines; besides frequent leakages, clogging of wellbores ultimately affected the water injection operations. Reply regarding logistics/ storage

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[22] ***Regional Chemical Laboratory (RGL – February 1984), Manual on Offshore Injection water quality (March 1994), Corporate Oil Field Chemical specifications (2007) Premature failure of chemicals (August 2014).***

[23] ***IRS study report March 2011, 2012, IOGPT – Corrosion Study report (April 1994), IEOT (August 2012, October 2012).***

[24] ***Committee study report on premature failure of pipelines (August 2014), In-house committee report on water injection improvement (July 2012.***

constraints is also not convincing considering such large number of nil/ less consumption of chemicals. The average storage capacity of various types of water injection chemicals is more than two weeks' consumption. In addition, the company may consider storing chemicals at unmanned platforms and transporting to water injection platform when needed through dedicated boats assigned.

Management/ Ministry further stated (February/ June 2021) that Audit suggestion regarding storage of chemicals at unmanned platform is noted for further due diligence in order to avoid stock out situations.

Recommendation No. 9

Dosing of adequate chemicals as per norms should be maintained so that quality parameters of water are monitored for timely corrective action.

5.5.1 Incorrect reporting of chemical dosing

Audit observed that the method used for calculating average dosing of chemical during a particular month was incorrect as non-consumption days were exempted while calculating the average dosing. Since chemicals (except biocides) are to be dosed continuously to maintain quality of injection water, the methodology adopted resulted in incorrect reporting. Audit analysed the average dosing of chemicals for one year and observed that there was incorrect reporting in 43.33 *per cent* cases.

Management/ Ministry assured (February/ June 2021) corrective action.

5.5.2 Non-functioning of quality measurement instruments

Average life of the quality measurement instruments was seven years. Important quality parameters of particle count and total suspended solids were not captured due to non-functioning of quality measurement instruments. Particle count was not captured from April 2014 onwards in Infill Complex Water platform. Particle size analysers for Water Injection South, Infill Complex Water, South High Water Injection and Water Injection North and turbidity meter for Water Injection South platform were purchased long back. The equipment was non-functional/ outdated without original equipment manufacturer support.

Management/ Ministry stated (February/ June 2021) that new particle analysers have been installed at Water Injection South, Water Injection North and Mumbai North water injection platforms and under commissioning in Infill Complex Water injection and South High Water injection platforms. Turbidity meters have been installed at platforms Water Injection South, Infill Complex Water, South High Water Injection and Water Injection North at main injection pump end.

Management action needs to be seen in light of continued disuse/ failure to capture crucial quality parameter.

5.5.3 Inefficiency/ non-availability of chemical injection pump

Various water injection chemicals at desired doses at pre-defined frequency are required to be injected (dosed) continuously to maintain the desired quality of injection water. Thus, sufficient dosing capacity of chemical dosing pumps is required to be in operation mode continuously.

Audit observed that in 26 *per cent* of nil dosage days (1,597 out of 6,127 days), there was no dosing of chemicals even though chemical was available in the Mumbai High platforms and in Heera, in 50 days out of 106 days of nil consumption, stock was available but not dosed. However, status of injection pump was invariably shown as in operative mode. Further, system availability of all the injection pumps was shown as 100 *per cent* even though in large number of cases, actual dosing of chemicals were lower than the recommended doses despite stock available on platform (38 *per cent* excluding the nil dosage cases mentioned above). This was due to dosing constraints (non-availability of chemicals and dosing pump issues) as admitted by the Management. Audit is of the view that definition of 'system availability' needs review.

In the absence of day wise data, month wise chemical injection pump data furnished to Audit could not be relied upon.

Management stated (August 2019) that being small pumps, running hours of the pumps are not monitored/ captured in SAP and hence equipment availability of these pumps could not be verified. Management/ Ministry added (February/ June 2021) that running hours of chemical dosing pumps are now maintained at platform and feasibility of installing hour meters for each dosing pump and logging them in Distributed Control System (DCS)/ SAP system would be explored.

Recommendation No. 10

The Company needs to properly maintain the data of system and equipment availability of chemical injection system in future for monitoring and timely corrective action.

5.6 Non-measurement of water quality at wellhead

Quality of water is measured at water injection platform from where it is despatched and reported as quality of water injected into reservoir. From water injection platform, treated water flows through pipelines to various wellheads from where it is injected into reservoir through various water injection wells/ strings. The quality of water further deteriorates before it reaches the reservoir due to corrosion in water injection lines. Thus, actual quality of water injected into reservoir was inferior to the quality measured and reported at water injection platform. This has led to plugging of wellbore and impairment in injectivity of injection wells/ streams and ultimately impacted planned water injection program.

Various in-house committees, ONGC institutes - Institute of Reservoir Studies and Institute of Oil and Gas Production Technology in their study reports recommended to measure quality parameters at wellhead. The observations and recommendations of these study reports is summarised in **Annexure-XI**. Audit observed that in spite of specific guidelines for measuring all water quality parameters at wellhead issued by the Regional Chemical Laboratory (RGL) in February 1984 and reiterated by the Institute of Reservoir Studies (March 1994 and March 2011), in-house committee (July 2012) and Institute of Oil and Gas Production Technology (August 2014), the same is not regularly measured and reported at wellhead end.

Audit compared the quality of water measured at water injection platforms and wellhead for one year (2017-18) and the details are placed at **Annexure-XII**. It may be seen from the Annexure that there was significant deterioration in the quality of water from water injection platform to wellhead. The average iron content and turbidity in Mumbai High platforms increased up to 30.24 times and 25.42 times respectively from water injection platform to wellhead. Injection water with higher particle counts and turbidity measurements is more prone to plug the formation faster. This showed the ineffectiveness of the chemicals used to combat corrosion due to severity of corrosion in water injection pipeline network.

In case of Neelam and Heera, there was no planned periodicity for recording the samples in unmanned platforms and the coverage was not for all platforms. The Institute of Engineering and Ocean Technology (IEOT) in its report had observed (October 2012) that it may not be prudent to draw any inference from the unmanned platform readings as systematic and adequate data of water quality is not available. The monitoring of water quality injected into reservoir at unmanned platform had not improved yet (March 2019). Chemistry analysis also did not cover all the water injected quality parameters as covered in Mumbai High (for example, general aerobic bacteria/ sulphate reducing bacteria was not covered in case of Heera). Samples from backwash/ back flow from wells were not being taken. In unmanned platforms of Heera, particle count was reported in only five days during 2014-15 to 2018-19 and in all these five days, it was not within the adopted limits

of 2,000 units/ ml (ranging from 2,855 to 4,818). In Neelam, where the unmanned platform data was reported (222 cases), turbidity was not maintained within the limits in 218 cases, particle count not within prescribed limit in 177 cases; Millipore and total suspended solids were not determined in 211 out of the 222 cases. In case of Heera, turbidity deteriorated from main injection pump end to the unmanned platform up to 11.54 times.

In its study, Institute of Reservoir Studies stated (March 1994) that "*…if the continuous presence of high concentration of iron in injection water at wellheads indicate that the pipeline network carrying the injection water might have become severely corroded. Once the pipeline becomes severely corroded then the possibility of the effectiveness of a corrosion inhibitor gets considerably reduced"*.

Management stated (January 2020) that quality monitoring at unmanned platforms is carried out, as and when required and all out efforts are made to maintain quality through regular pigging of water injection lines, backwash of wells as well as intermittent monitoring of various quality parameters at unmanned platforms. Management further stated that quality at wellhead platforms is measured manually once in a quarter in Neelam and Heera due to logistic/ manpower constraints even though it is to be checked once in a month and there is no provision in SCADA/ DCS to get the online parameters presently. Management admitted that it is difficult to monitor the injection water parameters at the wellhead end on a regular basis due to logistical constraints and diversion of manpower in attending unplanned/ unexpected process upsets or shutdowns which occur in mature fields.

The response did not explain the deviation from documented guidelines/ recommendations by various institutes/ in-house committees for not measuring the water quality parameters at all the wellheads regularly (weekly/ monthly) and identifying reasons for deterioration of water quality on the way to wellheads. The company needs to measure the water quality parameters at all the wellheads as per the recommended periodicity to monitor the quality of water injected into the reservoir for timely corrective action.

Management/ Ministry stated (February/ June 2021) that sampling coverage of unmanned platforms has been enhanced in last six months and sampling is carried out at individual platforms instead of only at the endpoints as followed earlier. Management assured that monitoring of water quality parameters at well head platforms will be ensured as per SOP/ recommended periodicity. Analysis of general aerobic bacteria/ sulphate reducing bacteria has been started at well head platforms (Heera).

Recommendation No. 11

Requisite quality of water injected into reservoir should be monitored throughout the water injection process and ensured till the well-head end for all parameters.

5.7 Summing up

Audit noticed gaps in maintaining the quality of water injected vis-a-vis the quality parameters adopted by the company and downgrading of its own accepted quality parameters. Audit also noticed incorrect reporting of water quality parameters and continuing gaps of control in ensuring compliance to corrective actions recommended by internal agencies. Non-availability of equipment coupled with non-adherence to quality parameters by not dosing the chemicals at required level casts serious concern on efforts to enhance production and reservoir health. Thus, desired quality of water was not injected into the reservoirs.

Water Injection Well