CHAPTER 8
SUMMARY AND CONCLUSION

The Oil and Gas have become a prime source of energy and become necessary necessity to humanity in present environment. It is also known as ‘Liquid Gold’ because of its value in modern civilization. Oil producing countries have changed the oil industry scenario dramatically in the 1970’s. Free trade zones have led the economic groupings and globalization that became success mantra of today’s world. India is the sixth largest consumer of primary energy in the world where consumption has grown at 4.3 percent Cumulative Annual Growth Rate (CAGR) over the period 1991-2001 vis-à-vis world primary energy consumption growth of 1.1 percent CAGR over the same period. A healthy economy has been the principal driver of growth in energy consumption.

On the earth’s crust more than 600 basins or sub-basins occur, of these, about a quarter as hydrocarbon producing. India is one of most important oil producing country in the world having several oil fields on offshore and onshore. There are 26 sedimentary basins in India stretching over an area of 1.39 Million Sq. Km. on land and 1.7445 Million. Sq. Km. on offshore, including the vast stretch of sediment laden area measuring 1.35 Million Sq. Km. in deep water areas (upto 200 Metric Isobath).

Historically speaking, oil exploration in India commenced well over a century back with discovery of the grand oilfield- Digboi in Assam in 1867. In India, the well known oil and gas producing state is Gujarat. The Cambay-Hazad petroleum system in South Cambay basin, Gujarat, has original in-place oil and gas reserves of 395 Million Tonnes. The system covers 9320 Sq. Km. encompassing 20 different oil and gas accumulations. Sedimentary rocks in this petroleum province range in age from Palaeocene to Recent and were deposited in Tertiary rift basin.
Keeping in view the significant role played by oil in the automobile, domestic, industrial and metallurgical sectors in India, it becomes all the more imperative to have a proper knowledge of oil rationally and efficiently with minimum damage to the environment.

**Gandhar**, the area selected for the present study is a largest oil and gas field in the Cambay-Hazad petroleum system with in-place reserves of 210 Million Tonnes and spreading over 800 sq. km. in the Jambusar-Broach block of Cambay basin. Gandhar Oilfield falls in the Survey of India Toposheet No. 46 C/9 in between 20°51’ & 21°55’N latitude and 72°35’ & 72°40’E longitudes in Wagra taluka, Broach district, Gujarat.

The main aim of present study is to highlight the most significant aspects of Gandhar oils in terms of their origin, migration, accumulation, reservoir rock and their properties, physico-chemical properties, exploration & exploitation and environmental attributes, which have not been attended earlier so far except the properties related to the trade and industries i.e. physico-chemical, exploration and exploitation aspects. The present work includes studies of oils of different characteristics collected from different oil wells of Gandhar Oilfield.

The research work has been compiled in four major stages; the first being extensive literature study followed by detailed survey which involves mapping, sampling and environmental monitoring, the third stage of analytical procedures wherein the oil samples were subjected to several investigations. The last and final stage is data interpretation and evaluation of the total work accomplished.

The work done has been presented in eight (8) chapters, each dealing with a separate aspect. The first two chapters present a general overview of the area in terms of its location, topography and structural set-up of the area. As a result of study of toposheets, geological maps and field visits, the studied area has been found to be a
flat topography having alluvial plain traversed by the river Dadhar on the north and river Narmada on the south which flows from east to west. These rivers ultimately fall in Arabian Sea in the western side of the oil field.

Stratigraphically, the area comprises of the Deccan Trap basement and overlying Tertiary sediments. The Deccan Traps are subsequently overlying by Olpad Formation, Cambay Shale, Ankleshwar Formation, Dadhar Formation, Tadkeshwar Formation, Babaguru Formation, Kand Formation, Jhagadia Formation, Broach Formation, Jambusar Formation and recent Alluvium. Cambay shale is considered to be the source rock of hydrocarbons and belongs to Lower Eocene to Middle Eocene age. The Ankleshwar formation of Middle Eocene to Upper Eocene age is the main oil bearing horizon and act as reservoir rock. The Ankleshwar Formation has been further subdivided into four members- Hazad, Kanwa, Ardol and Telwa. Hazad and Ardol Formations are the most important, contains lot of hydrocarbon accumulations whereas Telwa and Kanwa Shales of Middle Eocene to Oligocene age and the shales intercalated with sandstones in Dadhar Formation form the principal cap rocks. Structurally, it is a structural nose on the western flank of Broach Syncline. The Gandhar accumulation occurs in multiple pay sands in a combination trap where updip pinchout of sands form a structural cum stratigraphic trap. The field has a net pay thickness of 57 m. Total thirteen (13) sand reservoirs, GS-1 to GS-13 occurs between 2700-3500m depth (GS-13 being shallowest). Sands GS-1 to GS-12 is in Hazad Member of Ankleshwar Formation of Middle Eocene age. Sand GS-13 is in Ardol Member of Ankleshwar of Upper Eocene age. These reservoirs are separated by extensive shales. Based on depositional environment, the lower pack of sands GS-1 to GS-4 are deposited as stacked mouth bar with minor tidal influence, the middle pack of the sands GS-5 to GS-8 is aggradational with increasing tidal influence, and the upper pack of sands GS-9 to GS-13 show distributory channel fill character in NE part and bar character in W and SW parts of the field.
Physico-chemical properties of crude oils have been enumerated in Chapter III. Chemically, crude oil is composed of organic, inorganic and metallic compounds. Organic compounds are shown by hydrocarbons (i.e. carbon) and non hydrocarbons (i.e. hydrogen, oxygen, nitrogen and sulphur). Inorganic and Metallic compounds include metal contents present in oils. The studied oil samples contain 63.53 to 73.80% of Carbon, 10.54 to 12.83% of Hydrogen and 0 to 5.15% of Oxygen. Nitrogen is totally absent in all the oil samples whereas Sulphur is present in only one oil sample (0.724%). Metallic compounds in oil samples range between 10.03% and 24.34%.

In present study Average Carbon is 67.68%, Hydrogen 11.93%, Oxygen 1.81%, Nitrogen absent and Sulphur 0.05% and suggest the source rock contains ancient sediments. Very less Oxygen (Nil to 5.15%) suggests that the anaerobic bacteria are involved in formation of crude oil and the source is ancient sediments. Thus many anaerobic organisms, both plant and animal, synthesize hydrocarbon compounds in their normal metabolism, and the progressive concentration and preservation of this material seem a most logical source of petroleum.

Physical properties show that the color of all the oil samples is brown to dark brown which is due to lower API gravity and also suggests that it is lighter crude oil. Odor of all the oil samples is agreeable due to lighter hydrocarbons. Specific gravity of crude oils varies between 0.8009 and 0.8338 g/cc whereas API gravity varies between 40.70 and 46.80° (Average: 43.46°) API gravity, which is similar to Specific gravity and API gravity as suggested by Levorsen at 60° F and also shows the lighter nature of crude oils.

Viscosity ranges from 0.0690 to 0.2770 centipoise (Average: 0.1552 centipoise), which suggest a less number of carbon atom in a member of hydrocarbon series.
In present study, plane polarized light rotates to right (1-35) in oil samples A, B, D, E, G, H, I, J & L and show Dextrorotatory activity whereas plane polarized light rotates to left (0.4-0.5) in oil samples C, F1, F2 & K and show Levorotatory activity. Hence all the samples of oils show optical activity and confirm the organic origin of oils.

Boiling point of crude oil varies between 82 and 91°C and suggests it’s easy to handle between 82 and 91°C and it is hazardous above this temperature.

Cloud point is in between 25 and 35°C and pour point is in between 21 and 33°C, which is very high and not create any problem.

Porosity of reservoir rocks are less than 0.30 P.U. and permeability ranges from 0.01 to 700 millidarcy (md).

Isoprenoid distribution is most commonly measured by gas chromatography (Pristane /Phytane ratio’s) which are mainly related to diagenetic history. Pr/Ph ratios are 0.21 (S. No. J), 0.48 (S. No. D), 1.2 (S. No. I) & 1.6 (S. No. C), which suggest anoxic to oxic marine sediments. Gas Chromatographic analysis also shows that all the oil samples contains wax and also shows the Paraffin’s hydrocarbons.

Borehole data of each well were studied in Chapter IV for the correlation of reservoir rocks. Gandhar has total reserves of 100mmt (733mmb) in-place oil and 94bcm (3.32tcf) in-place gas, of which about 35mmt (256.55mmb) oil is recoverable. Mostly oil has accumulated in GS-1, GS-4, GS-5C, GS-8, GS-9 and GS-11 sands. All the sands have different oil-water contacts and sands in GS-1, GS-4 and GS-5C have gas caps.

All the wells are correlated from West to East direction (Well A is situated in Western side whereas well L is situated in Eastern Side of Oilfield area). After
correlation it is found that well A is situated in deeper side of the basin and well L is situated in the elevated side of the basin. The reservoir units are seen to pinch out updip towards the Nada field which is situated in northwest direction. Studied well log also suggest that the basin is deeper towards North and North-West direction. It is suggested that NW direction of the field is more suitable to search oil in future exploration.

Chapter V includes exploration and exploitation techniques with total reserves and production of oil in Gandhar Oilfield. For exploration of oil in the basin, about 60,000 Line Kilo Meter (LKM) of seismic surveys have been done establishing a large number of structures. About 4350 wells were drilled on about structures. Oil and gas pools have been discovered holding about 1140 Million Metric Tonnes (MMT) of inplace Oil and Oil Equivalent of Gas (O + OEG). The total prognosticated resources in the basin are assessed to be 1830 MMT of hydrocarbons. The Initial Oil In-Place (IOIP) and Initial Gas In-Place (IGIP) (reserves) of Gandhar are estimated to be about 100MMT and 94 Billion Cubic Meter (BCM), of which about 35MMT of oil is recoverable. The cumulative production of oil and water injection from the field is 12.3 MMT and 19.6 Million Metric Cubic Meter (MMm³) respectively. The field is producing oil @ 4600 Tonnes/Day (TPD), and condenset @ 910 TPD, free and associated Gas @ 6.9 Million Metric Cubic Meter/Day (MMm³/d) with average water cut of 33% and water injection @ 6750 Cubic Meter/Day (m³/d).

In the Gandhar area both horizontal and directional drilling method has been used for oil exploitation. Land Rig is used for exploitation of new oil well whereas Workover Rig is used for treatment of old well or perforation of reservoir sand. Oil is taken by both self flow well and Sucker Rod Pump. Water and gas injections are also used for self flow of oil. Oil from all the wells is being collected in the Group Gathering Station (GGS), where oil and gas are separated and collected separately in a tank. After these the oil is send to refinery for distillation and purification where its different products like diesel, kerosene, wax are obtained.
The environmental status of the studied area, its possible impacts and suggestions to control the same has been discussed in the chapter VI. During drilling of well high level of noise is generated which is always more than the permissible limits. A large amount of gases are released along with oil during drilling operation. These gases are separated from the oil and are fired through the chimneys, causes lots of air pollution. Drilling mud carries lots of oils and accumulated in dug, which is mixed with the surface and subsurface water and pollute it. Most studied water samples are not in the permissible limit of ISI, ICMR and WHO. It is recommended to use this water in drinking, domestic, irrigation and industrial purposes after proper chemical treatment and filtration.

Finally, it is concluded that oil and gas contributes 2.36% (2007-2008) of the Gross Domestic Product (GDP) of the country. It is more imperative to search new oil bearing horizons. Though the mineral have no political boundary but the new invention is must to strengthen the nation looking into the increased demand. In present endeavour, it is suggested that the north-west side of the investigated area may be the prime site for future exploration and exploitation.