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Odisha State Open University, Sambalpur, Odisha
Established by an Act of Government of Odisha.

Master of Arts
HISTORY (MAHI)

MHI-08

History of Ecology and Environment : India

Block – 4

APPROPRIATION OF ENVIRONMENT-OTHER FORMS

UNIT-11 ENERGY RESOURCES

UNIT-12 WATER RESOURCES

UNIT-13 FOREST RESOURCES

UNIT-14 METAL & MINERAL RESOURCES

UNIT 11 : ENERGY RESOURCES

Structure

11.0 Introduction

11.1 Forms of Energy

11.2 Energy Consumption: Historical Patterns

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11.0 INTRODUCTION

As we have explained in the introductory passages given at the beginning of this Block several fresh possibilities of appropriating environmental resources emerged as sedentary societies based on agriculture began to settle. The foremost among these related to energy resources. New forms of energy resources were discovered by the societies and energy consumption on an ever increasing scale became a uniform practice. The appropriation of energy resources depended on the availability of different forms of energy as also on the accessibility of the sources of these forms. It was also directly related with the pattern of consumption of energy by different societies which obviously showed a diversity adapted to the stratified social structure.

The historical information on energy resources for pre-industrial societies is thin and so is the case with the patterns of energy consumption. Yet we have attempted to weave a narrative based on this evidence that describes the forms of energy resources and the pattern of energy consumption as it evolved historically. In addition, details on the imperative of conservation have also been included. You will find the Unit interesting since it opens before you a relatively less explored and discussed subject. We recommend that you pay attention to the relationship that specific environmental conditions obtaining in India had with the appropriation of energy resources. It will help you understand better the next Block (5), on **Indian Philosophy and Environment** and help you place colonial policy with regard to environmental resources (discussed in **Block 6**) in the correct perspective.

11.1 FORMS OF ENERGY

Energy is generally understood to carry the meaning of the source of strength that is necessary for performing various kinds of activities. Most of the forms of energy are shapeless and not easy to be subjected to physical verification. They can be verified mostly in terms of the work performed with their support. The word energy is derived from the Greek *energeia* which is made up of *en,* "in" and *ergon* meaning "work". Evidently its meaning centres around the work done by using energy. The idea of energy in the above sense goes back to Galileo in the seventeenth century. He recognised that in lifting weight the force that was applied was in fact a form of energy. The idea was further developed by Newton who suggested that the quantum of force applied on an object was associated with the acceleration gained by that object.

The forms of energy broadly range between inanimate natural forms and animate forms of energy; and when we step on the industrial societies electrical and nuclear forms add up. Humans and animals perform work with the help of their physical energy. This is the simplest form of animate energy. Similarly natural or inanimate forms of energy are located in most of the physical matters. They are available at the primary level in the form of solar energy and wind and water energy and at the secondary level in the form of thermal, mechanical and chemical energy.

It is, however, difficult to enumerate all the various kinds of energy. The sources of energy are visible, but the energy itself is transitory, recognisable through the process of activity generated by it. Therefore in our attempt to identify the forms of energy we are greatly helped if we focus our attention on the sources of energy. The forms, as we have said above, are closely connected with the sources; it is easier to recognise the sources which are more tangible in character. The sources of energy can be broadly divided into two categories more or less compatible with the two main forms of energy: first being animate sources of energy and the second, inanimate sources of energy.

For a very long span of time in history, barring the energy emitted by sun, humans have depended upon the animate sources of energy. In the initial stages of development human physical power was considered as the primary source of energy. For all those long centuries of human existence when agriculture had not developed and hunting-gathering activities were the principal mode of living the physical prowess of the humans was the principal source of energy. This prowess was augmented with the help of stone tools and implements that were manufactured under an organised method. We have read in Block 2 how stone tools and implements were continuously upgraded and diversified. The effort obviously was to sharpen the human physical energy and carefully segregate most of the work done for a differential use of energy to be applied to them. The detailed classification of stone tools into core and flake tools and into microlithic tools of various kinds bears ample testimony to this effort.

Mention may be made here of a mechanical device called spring which accumulates energy and releases it suddenly when required. Its first known use, and of continuing importance was in the bow used to shoot arrows in hunting and in battle. The first unequivocal representation of it, dating back from later Paleolithic times, is from North Africa. However, the effectiveness of the simple bow was limited by the strength of the arms of humans who would use the device.

Next to be utilised by the humans was perhaps the animal energy. The domestication of wild animals was a major advance in the field of the use of energy resource. The details on the emergence of pastoral practices have been given in Block 2. Animals as the source of energy were utilised in numerous spheres of life. They were also an important source of food for the humans. Animal power was harnessed for use as draught power to be utilised in agriculture. You have already read in Block 2 about the symbiotic relationship that had developed between the nomadic pastoralists and the settled agriculturists. The utility of animal power had become so evident to agriculturists that in peninsular India the Neolithic sites (mid-third millennium BC) from their inception exhibited a high imperative of large number of livestock maintaining (Cf. *Archaeology and Interactive Disciplines, op.cit*, p.166). Animals provided the energy for the transportation purposes right upto the beginning of the mechanised modes of haulage. One of the earliest references of this kind of energy harness is available in the rock paintings at Morhana Pahar near Mirzapur in Uttar Pradesh. There two chariots have been shown drawn by two and six horses respectively. You must have read about this pictorial evidence in Block 2 where it has been described at length. Another important area where animals supplied energy was in the field of irrigation/water lifting devices. Similarly cow also provided cow-dung, extensively used to fire the hearth. Human as well as animal excretion has been extensively used in the fields as fertiliser to increase the agricultural production.

Early humans first made controlled use of an external inanimate energy source when they discovered the use of fire. Burning dried plant matter and animal waste, they employed the energy from this biomass for heating and cooking. For the heating purposes humans were greatly dependent upon the forest resources. The forest resources were also extensively used as raw material for various other purposes such as housing, and the making of furniture, carts, agricultural tools, musical instruments and numerous other handicrafts. Wood has been an integral component of human housing since ancient times. Even in the mud houses roofs were usually made of wood. The necessity for wood was greater in the absence of technological support. The demand for forest resources for this kind of activity kept on growing with the increase in the population and material development of human societies.

In humanity’s early attempt to harness inanimate, natural forms of energy, water occupies a central position. Besides being a key life sustaining resource for most of the living beings including humans, the irrigation potential of water for sustaining agriculture had also been discovered fairly early. The first civilization in India as also elsewhere in the world was riparian in character. But we shall discuss this and the other aspects of the appropriation of water as an environmental resource in the next unit. Here we are concerned with the use of water as an important energy resource. Not much early evidence on this matter has been garnered. We may however speculate that the flow of water in major streams and rivers would have been used for transporting the large tree trunks and logs from one place to the other. This practice has been in use even today. A greater use of water energy however become possible after the development of a few mechanical devices that were energy saving by themselves. Perhaps the earliest use of water in this fashion was in driving waterwheels. In the hilly regions of India and in similar terrain elsewhere too, the flour mills are even today driven with the help of waterwheels.

It was with an increased use of contrivances and mechanical devices that the era of uncontrolled exploitation of inanimate sources of energy began. Most of the natural inanimate resources were now harnessed. The pressure on them gradually increased and the stage of exploitation began endangering the existence of most of the natural resources. All this, however, relates with the onset of modern age. We shall discuss these developments in Block 6 and Block 7.

11.2 ENERGY CONSUMPTION: HISTORICAL PATTERNS

It can be conveniently argued that the social evolution of humans has been closely tracked by developments in similar manner in the levels and patterns of energy consumption. In the early stages of human society the nature of energy consumption was more or less equal in terms of its horizontal and vertical expanse. The levels of energy consumption had remained confined to bare necessities and the possibilities of surplus retention were very limited. Most of the demands for energy by these societies were available in the form of food procurable locally. It was with the growth of agriculture on the one hand and the domestication of animals on the other hand that the need for newer sources of energy arose and the consumption of energy multiplied. The most important change was in the basic source of energy: manpower was gradually replaced, first by the power of draught animals. Donkey-driven mills were employed as early as the fifth century BC to crush ore from the silver mines at Laurion, and their use had extended to the grinding of corn in Greece by about 300 BC.

The next major development was the use of the water and wind energy. One of the most important uses of water energy was in agriculture for irrigation purposes. The distribution of water to cultivated fields through channels has been an old practice. An early evidence pertaining to irrigation of this type relates to Mesopotamia and dates back to about eighth century BC. This irrigation was helped by the proximity of the Tigris and the Euphrates, which assured a constant supply of water. As described by Seton Lloyd, “Almost the whole of the alluvial plain is capable of being prodigiously fertile agricultural land; and a great part of it has clearly at one time or another been under cultivation. Evidence of this is the profuse network of ancient irrigation canals, now abandoned, whose spoil-banks, like parallel ranges of small hills, run far out into the plain beyond the scanty farmlands of the present day" (*Foundations in the Dust, The Story of Mesopotamian Exploration,* Thames and Hudson, London, Revised 1980, p. 23).

The evidence from Harappan settlement suggests that small **bunds** were erected across the rivers to use the flow energy of water for spreading fresh alluvial soil along the banks. This soil was then used as agricultural field. The knowledge of the Harappans about water energy is further supported by the discovery of the famous dock-yard at Lothal. It points to the fact that knowledge relating to the tidal currents was tactfully used in creating the dock so that ships could come in with flow-tides and could go out into the sea with ebb-tides (Cf. S.R. Rao, *Lothal, A Harappan Port Town*, Vol. I, A.S.I., New Delhi, 1979, pp. 123-132).

A very early use of water energy was in driving wheels. The evidence relates to about second or first century BC in Egypt. The wheel was submerged in running water which made it turn. This rotary movement was transferred via a fixed axle to a flat millstone. This type of mill was used for grinding cereals or oil-producing plants. In fact this was the stage when natural energy and mechanical contrivances were combined. This gave a remarkable boost to the use of energy as it enhanced its driving power substantially.

The early waterwheels, first used to drive mills for grinding grain, were subsequently adopted to drive sawmills and pumps, to provide the bellow action for furnaces and forces, to drive tilt hammers or trip-hammers for forging iron, and to provide direct mechanical power for industrial mills. Until the development of steam power during the industrial revolution waterwheels were the primary means of mechanical power production, rivalled only occasionally by wind mills. Thus, many industrial towns sprang up at locations where water flow was perennial. In an old reference to a watermill dating back to about 85 BC, appearing in a poem by an early Greek writer, the liberation from toil of the young women who operated the querns (primitive hand-mills) for grinding corn was celebrated. According to Greek geographer Strabo, King Mitheradates VI of Pontus in Asia used a hydraulic machine, presumably a watermill, by about 65 BC. Early vertical-shaft water mills that drove querns were known in China by first century AD, and were used throughout Europe by the end of the third century. A horizontal-shaft water mill was first described by the Roman architect and engineer Vitruvius about 27 BC. The Roman mills were adopted throughout much of medieval Europe and waterwheels of increasing size were made almost entirely of wood. In addition to flowing stream water, ocean tides were also used though rarely to drive waterwheels.

Like watermills, windmills were among the original prime movers that replaced animal muscle as a source of energy. They were used for centuries in various parts of the world, converting the energy of the wind into mechanical energy for grinding grain, pumping water, and draining lowland areas. The first known wind device was described by Hero of Alexendria (c. first century AD). The earliest known references to wind driven grain mills, found in Arabic writings of the ninth century AD, refer to a Persian millwright of AD 644, although windmills may actually have been used earlier.

One of the limitations of both the waterwheel and the windmills was that it was usually necessary for the power they generated to be utilised on the spot. There were, nevertheless, systems for transmitting power over land, often for considerable distance, but the power-loss must have been much.

As with waterwheel, it is difficult to estimate the power output of windmills. A large Dutch windmill of the eighteenth century, with a 100 feet (approx. 30 metres) sail-span, probably generated about 10 horse power (h.p.) in a 20 miles per hour wind speed. Smaller mills, with a 24 ft (approximately 7 m.) span, probably yielded about 5 h.p. Theoretical considerations show that the windmill in its traditional form could not, at best, yield more than 30 h.p. It was not, therefore, a powerful prime mover by modern standards, and a substantial proportion of such power as it did develop must have been dissipated in the clumsy transmission system, even after iron gearing had been introduced.

The foundations for the use of steam power are often traced to the experimental work of the French physicist Denis Papin. In 1679 Papin invented a type of pressure cooker, a closed vessel with a tightly fitting lid that confined steam until high pressure was generated. It was given more efficient and workable form by a Scottish instrument maker James Watt in 1765 who developed a steam engine. Although far more difficult to build, Watt's rotative engine opened up an entirely new field of applications; it enabled the steam engine to be used to operate rotary machines in factories and cotton mills.

Other important development with regard to energy utilisation had been the discovery of a device by Michael Faraday who converted mechanical energy into electric energy. This led to the development of electric generators whereby thermal energy was used to power the mechanical energy and in turn generate electric energy. The greatest advantage with the electric energy has been the possibility of transmission of energy to distant places from the source of its generation. Similarly another major energy resource has been the nuclear energy which has a great potential.

11.3 CONSERVATION

The concept of energy conservation is related with the theory that the energy remains constant and it only changes its form. The conservation of energy is not a description of any process going on in nature, but rather it is a statement that the quantity called energy remains constant regardless of when it is evaluated. The law of conservation of energy can be applied not only with regard to nature, but to any isolated system as well. Energy exists in various forms and is convertible to one-another within the constraints of conservation law. These different forms of energy include thermal, kinetic, gravitational, chemical, nuclear, radiant, electric, mass energy, etc. It is the universal applicability of the concept of energy, as well as the completeness of the law of its conservation within different forms, that makes it so attractive and useful. However, one must remember that all the forms of energy are still not in control of the humans. Most of the energy we consume has led to increase in the other unwarranted forms of energy. The most visible example can be the uncontrolled consumption of combustion energy which has led to increase in the chemical energy causing Ozone depletion. Therefore it is necessary to realise the spirit of the law of conservation of energy and either control over-consumption of energy or develop other non-conventional sources of energy.

Most of the energy resources consumed by humanity are exhaustible and non-renewable therefore it is necessary to be prudent in one’s consumption of finite sources of energy. At the same time, we must realise that there are several renewable sources of energy and it is suggested to develop the technology to harness the potential that is going waste.

11.4 SUMMARY

The analysis of energy resources attempted here suggests a possible relationship between social stratification and the pattern of consumption. Along with the changes in the patterns of consumption of energy we can also trace the changes in the source of energy. In the beginning, the primary source of energy had been the plants, animals and humans themselves. Subsequently the inert potential of the land energy was harnessed by the humans and soon the potential of various minerals as sources of energy was also harnessed. The trend of greater energy consumption continued with the growth of urbanisation witnessed during the emergence of civilisations across the world. This phase onwards, crystallisation of social stratification led to a variation in the energy consumption across the different sections of the society. Hereafter and until the advent of industrial revolution the consumption of energy varied vertically, whereas it remained more or less similar horizontally. The pattern of energy consumption witnessed, radical changes with the emergence and growth of industrial revolution. Industrial revolution provides a paradigm shift in the nature of energy sources, and the process of appropriation and distribution of energy resources. The changes introduced during and after the industrial revolution have been very rapid and have resulted into a serious deterioration of our environment. The loss of forests, pollution of water and air are some of the manifestations of the change in the sources of energy.

11.5 EXERCISES

1) How do you distinguish between animate and inanimate forms of energy? Discuss briefly their historical evolution.

2) Write a note on the historical patterns of energy consumption.

11.6 SUGGESTED READING

T.K. Derry & Trevor I Williams, *A Short History of Technology*, Oxford, 1960.

Maurice Daumas, ed. (tr. Eilean B. Hennessy), *A History of Technology & Invention*, Vol I: 'The Origins of Technological Civilization', Bombay, Eng. Tr. 1969.

S.R. Rao, *Lothal, A Harappan Port Town*, Vol. I, A.S.I., New Delhi, 1979.

UNIT 12 : WATER RESOURCES

Structure

12.0 Introduction

12.1 Water As a Resource

12.1.1 Properties and Distribution

12.1.2 Resource Use

12.2 Water Conservation

12.3 Water Rights

12.4 Summary

12.5 Exercises

12.6 Suggested Reading

12.1 INTRODUCTION

The earth is sometimes called the watery planet as this is the only member in our solar system which has an abundant supply of water. Water is used as a raw material for various metabolic processes. It is an important ecological factor. It is also a very good solvent medium and has sustained life on earth ever since the biological origins of the living organisms. Water as a resource has been known to humans since the remotest past and has been used by them as an essential life-supporting ingredient. We propose to study resource-use practices pertaining to water. The Unit also proposes to analyse the various traditional methods of water conservation as practiced by human societies. Utilisation patterns adopted by various civilisations of the world which kept on changing with the developments in the technology for better appropriation of water and with the growing demand of water for various developmental activities is also our concern. Finally, we also examine the issue of water rights in the historical perspective along with the theoretical propositions connected with water rights in the Unit.

12.1 WATER AS A RESOURCE

Water is one of the important substances necessary for life. Water covers about 75% of the earth's surface, occurring in lakes, rivers, and oceans. The oceans alone contain 97% of all the water on earth. Much of the remainder is frozen in glaciers and frozen ice. Hardly 1% water constitutes ice-free fresh water in rivers, lakes, ponds, etc. It is this negligible amount of total available water that sustains all forms of terrestrial and aquatic life. There are subterranean reserves of water at very deep levels and also at shallow depths trapped in the soils. This trapped water is very useful for agricultural production and even for direct human use. The use of water as a resource has focused on this small amount. It has also been guided by some of the properties of water which we discuss below.

12.1.1 Properties & Distribution

Water in its' fluid form does not exist on any other planet in our solar system and is thus an exclusive privilege available to the inhabitants of planet earth. Only at a certain distance from the sun do we find the right temperatures that permit water to exist in liquid form. The other unique property connected with water is that it becomes most dense as temperature falls to plus 4° centigrade. If it were at its heaviest at freezing point then our lakes and waterways would freeze from the bottom up, jeopardising fish and other aquatic life. Water has surface tension and great capillarity, that is, the ability to rise in narrow tubes. This makes it possible for water to defy the laws of gravity and remain at the surface of the earth where plants can absorb it through the roots. Water is also one of the world's most important sources of energy. Inexpensive, non polluting, hydroelectric power is a boon to all. Water dissolves salts of various kinds; it can also emulsify indissoluble substances. Blood and lymph are both water solutions which supply body tissues with nutrients and obligingly remove waste from cells. Plants also get the nutrients they need via water based salt solutions.

These properties also have some disadvantages. The same water also dissolves pollutants, acidifying our lakes and waterways and poisoning living organisms. It also spreads disease in flora and fauna. Though water is considered a renewable resource it is finite and governed by a natural water cycle.

The stable water supply of earth is used again and again in this cycle. About one third of all solar energy is dissipated in driving the water cycle. Sun makes water evaporate from the oceans, lakes and streams. This evaporation forms clouds which fall back on earth in the form of water or snow. Some of this water percolates through the soil until it reaches saturation point. Rest of the water returns to its origin point. This whole process of evaporation, condensation and rains is known as water cycle. This cycle keeps replenishing the water requirements of the world.

The global distribution of water shows that only 35% of the total quantity is fresh water, which is available in various forms. The following chart will explain this:

Form	**% of fresh water**
Frozen	80
Ground	19.7
Lakes	0.2
Rivers	0.02
Soil	0.04

Atmosphere	0.02
Biological	0.001

Water resources can be classified in two groups: a) surface water resources, b) ground water resources. India has a total of 1122 cubic km of water of which 690 cubic km is surface water and 432 cubic km is ground water, and it is unequally distributed.

India is a country of rivers. There are 12 major rivers with the total catchment area of 252.8 million hectare (m.ha.). Tanks and ponds have around 2.9 m. ha. area, reservoirs have around 2.1 m. ha. area, where as smaller rivers and canals occupy 7 m. ha. area. Most of the area under tanks and ponds are located in southern states of Andhara Pradesh, Karnataka, Tamil Nadu, followed by West Bengal, Rajasthan and Uttar Pradesh accounting for almost 62% of the total. In the case of reservoirs, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan and Uttar Pradesh dominate. Orissa ranks first as far as brackish water is concerned and followed by Gujarat, Kerala and West Bengal. The annual precipitation including snowfall which is the main source of the water in country is estimated to be around 4000 cubic km. The resource potential of rainfall for the country is estimated to be around 1869 cubic km. Clearly, the water resources are thus unequally distributed over the country. Further if we consider the average availability it is 2208 cubic meter per capita annually. Average availability in Brahmaputra is as high as 16589 cubic meter while it is as low as 360 cubic meter in Sabarmati basin. Any situation of availability of less than 1000 cubic meter is considered as scarcity situation.

The ground water situation in different parts of the country is as varied as the surface water situation. In the high relief areas of the northern and north-eastern regions occupied by the Himalayan ranges, the various hill ranges of Rajasthan, the central and southern Indian regions, the presence of very steep slope conditions and geologic structures offer extremely high run-off and thus very little scope for rain water to find favourable conditions of storage and circulation as ground water. The large alluvial tract extending over 2000 km, known as Sindhu-Ganga-Brahmaputra plains is the most potential region as far as ground water resources are concerned. Almost the entire central and southern India is occupied by a variety of hard rocks with hard sediments in the inter-tectonic and major river basins. Rugged topography, hard and compact nature of rock formations, the geological structures and metrological conditions have yielded an environment which allows ground water to store itself in the weathered residuum. It is a potential region for ground water development. The coastal and deltaic tracts, particularly of the East Coast, are caused by vast and extensive alluvial sediments and are very productive in terms of water availability but in the vicinity of coasts suffer from salinity.

12.1.2 Resource Use

As water is an essential condition of life on this planet, water resources have been a decisive factor in the growth and sustenance of human civilisation since ancient past. All the early civilisations were distinctively and predominantly riparian. Prime examples of ancient river valley civilisation of the world are Egyptian civilisation in the Nile valley, the Mesopotamian civilisation in the valleys of the rivers Tigris and Euphrates, the Harrapan civilisation in the Indus valley and the Chinese civilisation in the Ho valley. Harness of water from natural resources and its careful use in agriculture and other activities is a hallmark of these civilizations. Archaeological evidence shows that certain engineering measures were also adopted to enhance as well as sustain water resources.

As we step on a period of history for which written records become available we get regularly occurring information on the use of water as a resource and methods employed to use this resource in the most beneficial manner. Reservoirs are made, embankments are raised, wells are dug up, channel screated for transporting water to desired destinations and devices invented for utilising the various properties of water. The written records are replete with such information and a sizeable number of structures have survived the ravages of time to surprise us by their ingenuity even today. The evidence is rich and dense and any efforts at listing all of them are likely to use a huge space. We shall attempt a random recall which is also likely to be a rewarding exercise.

We can begin by recalling some of the characteristic features, related with the use of water as a resource, of the first civilization on the Indian sub-continent. The environmental settings were arid or semi-arid. The importance of water as a resource was clearly understood. The habitation sites were selected with a lot of care so that deposit of good alluvium soil for agriculture resulting from seasonal floods was regularly available. Canals were excavated in the river basin to take water to agricultural fields. A canal of this type has been traced near Shortughai drawing water from Kokcha river (Irfan Habib. *The Indus Civilization*, p. 25). The wells were made for use by individual households that seldom changed their location – the earliest evidence of the exploitation of ground water. Drainage was carefully planned so that the waste did not pollute the fresh sources of water. Towns like Dholavira, surrounded by brackish water, paid great attention to water storage. “In its heyday, the entire city might have looked like a lake city or a *jala durga* (waterfort). The area reserved for the tanks was immense, approximately 750 m. in length and the southern and northern margins, while the width varied from 70 to 80 m. In the west, the tank area was about 590 m. In the south-eastern area, for example, the reservoir covered about 5 ha (hectare), the largest within the walled area. The walls acted as effective bunds. Both faces of the wall were plastered with fairly water-repelling sticky clay. Special and vulnerable areas, mostly on the exterior face, were vencesed with hammer-dressed stones.

Keeping in mind the general slope of the city, several bunds were constructed across the width of the tanks to reduce the pressure of the stored water body on the city walls. The bunds also served as conseways for easier movement. In times of scanty rainfall, they enabled the water to get stored in selected tanks instead of being spread out over a large area and reduced quickly by evaporation and seepage. In the area designated as the citadel, an interesting networks of drains, both small and large, was discovered. Most of the drains intersect each other and ultimately link up with an arterial drain.

The entire drainage system could have been set up to assiduously conserve every drop of rainwater that fell in the city. The water must have been a treasured commodity in an area lacking in perennial source of surface water and where the ground-water, largely brackish and saline, tends to dry up during droughts" (J.P. Joshi, R.S. Bisht, *India and the Indus Civilisation*, New Delhi, 1994, p. 31).

The importance of water for agricultural societies during the Vedic period must have increased. Flow of water in channels for irrigation purpose was practiced. There are references to artificial waterways — *kulya* and *khanitrima apah* — in Rig Veda. These perhaps refer to irrigation channels. The other expressions used for the same device are *Sushira* and *Soormi*. Wells – *avat* – were dug up. Lifting devices to draw water from the wells were also in use, called *ansatrakosh* and *ashmchakra*. These were probably composed of a leather bucket drawn over a pulley for lifting water from the wells (Cf. G.C. Pandey, *Vaidic Sanskriti*, Allahabad, 2001, p. 263; R.C. Majumdar, ed. *The Vedic Age*, Bombay, 1951, p. 403).

Mauryans, as the founder of one of the earliest empires, gave special importance to water resources. On the authority of Kautilya we know that the building of reservoirs by damming streams was an important public work the king was encouraged to construct. Similarly Ashoka refers in his edicts to the construction of wells and watering-places along the major routes. The epigraphic evidence testifies to the construction of a big reservoir of water by damming a stream in the Junagarh district of Gujarat by Pushyagupta, the governor of the region during Chandragupta Maurya's reign. The reservoir was named as Sudarshan. Under Asoka his Greek governor Tushasf maintained the dam and the reservoir. In AD 150 there occurred a breach in the dam which was repaired by Rudradaman. The dam seems to have been maintained till the fifth century AD when the last known repairs were carried out by Parndatt during the reign of Skandagupta, in AD 457-8. (Cf. P.K. Majumdar, *Bharat ke Prachin Abhilekh*, Delhi, undated, pp. 109-115 & 149-158).

Since medieval India was also a largely agricultural society, the resourceuse practice with regard to water was basically geared at providing irrigation to the fields. Besides using most of the prevalent methods, a few new techniques were introduced during this period. The prominent among them were *arghatta* and *arhat* (Persian wheel), which improved irrigation significantly.

In the 14th century a very elaborate network of canals was constructed by Firuz Tughlaq. The rivers from which the canals were cut were Yamuna, Sutlej and Ghagghar. An additional water tax was levied on the farmers of the irrigated areas. Due to greater and more secure availability of water, production of cash crops had increased. The same concern for the use of water resources was shown by the Mughals. They also promoted irrigation facilities by providing loans to farmers to install irrigational devices. There was a general concern for better use and regulation of water resources.

In South India, too, great emphasis was laid on a careful use of water resources. The system of tanks, small and large both and the mechanism of their regular upkeep from a very early time is too well known. The streams and rivers were also channellised by raising empanlements and dams. The famous *anaikattu* (anicut) on Kaveri river was built by Chola rulers for the irrigation of the lands in Tanjore. Large dams were also built in this region for creating big reservoirs of water. Ka Katiya rulers are known to have built three big dams in Warangal. Another dam located at Kamthana, near Bidar built by the Kakatiyas, supplied water for irrigating the neighbouring region. The epigraphic evidence and archaeological remains support this picture. This picture changed drastically after the colonial power established control over India. The apathy and neglect shown by the new dispensation towards these age old resource-use practices resulted in the ruin of most of these devices. Francis Buchanan noted this pitiable state during his travel along the eastern coast in eighteenth century. A major consequence of this was a series of famines and consequent loss of life. Thereafter new policy was initiated to redeem the situation, though considerable damage had already been done.

A comprehensive survey of traditional water harvesting systems in India has been undertaken by Centre for Science and Environment and their compilation of the results of survey published under the title *Dying Wisdom* (*State of India's Environment: A Citizen's Report*, Vol. 4, ed. Anil Aggarwal & Sunita Narain, New Delhi, 1997). We strongly suggest to you to use this book to get larger information on the subject.

The optimal management of available water resources today has become a major issue world over. The spatial and temporal variability of rainfall along with high evaporation and runoff is posing a major challenge to the scientific community. Added to these is the increasing demand resulting from an exponential population growth. It has created more and more pressure on dwindling supplies and per-capita access to fresh water is falling. We shall discuss these issues in Block 6.

12.2 WATER CONSERVATION

Water is a renewable resource, but it is also finite. We have no more than what we had in the days of Harappan culture but the demand has multiplied. Water has become at least as important a resource as oil. Water shortage and deteriorating water quality are the two major concerns today. It is thus evident that there is an urgent need to initiate measures for water conservation. We have to join hands in day-to-day battle to protect the lands, rivers, lakes, aquifers and seas against pollution. In this regard past practices of water conservation need to be examined in some detail.

Water conservation has a long history going back to earliest times. The need of conservation at that time was perhaps to save water for the lean period of the year. It was conservation directed at quantity as quality conservation did not seem to be their concern. The evidence for water conservation is available from ancient literature, epigraphy, archaeological remains and local oral traditions. Conservation was a special feature in habitats that were located a little away from source of water or were naturally deficient in water. Digging well was a regular old practice. It provided avenues to harness the ground water. Wells have been as old as a Harrapan tradition. Almost every dwelling unit of Harrapan culture had a well. Mohenjodaro records over 700 wells. Unlike other running sources like rivers or streams wells provided an option to fetch only the required amount of water – an early evidence on judicious use of water.

Another source of water, that is the running water, but particularly the flood water was very nicely utilised by past cultures. We have the evidence from Srinagaverupura situated near Allahabad on the banks of river Ganga. During the monsoons, the river swells up by about 7-8 meters and spills into the nearby artificial canals. This canal was dug by settlers of the region to carry superfluous floodwater. This diversified water was stored in tanks, to be used during lean periods of the year. The water from the canal first entered a silting chamber where the dirt settled down. Relatively clear water entered the first tank which was made of bricks. Thus next tanks received cleaner water.

The mechanisms of rainwater conservation however differed according to the physiographic features of the respective regions. In Rajasthan it was basically rooftop method whereas in the case of south India it was tank based method. In Rajasthan these mechanisms were known as *Kund/ Kundi*. Individually rooftops were used as catchment area which collected rainwater and stored it in an underground tank. This water was even potable. In other words *Kund/Kundi* were artificial wells conserving rain which would have otherwise run-off. The mechanism was also used in open field for general public where similar *Kund/Kundi* were built and the neighbouring area used as the catchment.

A very indigenous method to secure drinking water was practiced in the Runn of Kutch by Maldharis. They knew that the density of sweet water was less than the saline water. On this theoretical premise they were able to store rainwater afloat on underground saline water. It is known as *Virdu* method of water conservation.

In the North-East Himalayan region people developed methods of carrying natural spring water for drinking purposes. As the region is mountainous, the rainwater runs off very fast. However, the upper range natural springs survive throughout the year. The people there used intricate network of bamboo pipelines to carry water to convenient points where it was stored and subsequently used.

A very interesting method of water harvesting is practiced by Jarwas in Andaman. Although Andaman Islands have an annual rainfall of 3000 mmit runs-off rapidly due to ragged physiography of the place. The Jarwas use full length split bamboos. An entire length of bamboo is cut longitudinally and placed along a gentle slope with the lower end leading into a shallow pit. These serve as conduits for rainwater which is painstakingly collected in pits called Jack wells. These split bamboos are also placed under trees to collect the fall of rains through the leaves. A series of increasingly bigger Jack wells is built, connected by split bamboos so that overflows from one lead to the other, the bigger one. This stored water is basically used for domestic purposes.

We have already read about Sudarshan lake near Junagarh which was constructed to store water for domestic and irrigational purposes. Similar evidence for tank and canal construction from ancient past from different regions is also available Hanthigumpha inscription of 2nd century BC. describes that a canal was dug in Tosali division near capital city of Kalinga. According to the Kuntagiri plates, the Kadamba king Ravivarmann ordered construction of a tank bund for irrigational purposes. Most of these were developed to channelise water for optimal use which otherwise would have gone to waste. Such an awareness of water conservation emerged due to unequal seasonal distribution of rains. The plateau region- Deccan is full of artificial tanks which stored rainwater for irrigation. These are known by various names like *arakes, volakere, derikere, katte, kunte, kola,* etc. depending upon the difference in structure and nature of use.

Similar structures are called *zing* in Ladakh and *ahar* in south Bihar where water from seasonal streams or rainwater is stored to be used in ensuing period for domestic and agricultural purposes. *Ahars* are rectangular catchments receiving water flowing through hilly rivers. On similar lines we have indigenous methods employed in Bengal. They created broad and shallow canals to carry floodwater of rivers. These canals ran parallel to each other at a reasonable distance. By creating cuts in the canals floodwater was released to fields.

A very useful method of water conservation for irrigation was developed by Paliwal Brahmins in the arid region of Rajasthan. They created rainfed water storage structures, which allowed runoff to stand over and moisten the soil bed of the storage structure itself. This piece of land was later used for growing crops. These structures were known as *khareen*.

Another unique method of rainwater harvesting is known as *haveli* as practiced in Madhya Pradesh. The area has heavy black clay which can hold a large amount of water but when it dries it becomes hard and develops wide cracks. Bunds are created to tap rainwater and released few days before sowing by an opening into embankment. This release makes soil soft and allows the sowing of wheat and gram to rarely need second helping.

The above description make it amply clear that various methods of water conservation were practiced traditionally depending upon the local needs. These methods utilised every kind of water supply – rains, floods, ground water, etc.

12.3 WATER RIGHTS

The details of resource-use practice given above make it clear that water has been considered a useful essential resource. Therefore rights to it have also been zealously safeguarded. In early times, however, population was limited and it was often possible for individuals or communities to settle differences in many cases by simply moving on and exploiting a new source. The scale of water available in most situations and consumptive uses, even for irrigation, seldom threatened others with deprivation. Customary rights/uses regulated most transactions.

Gradually greater rights began to be exercised and in many cases the state initiated the practice of levying cesses on the use of water especially on the water drawn from state built reservoirs or such similar devices. No codified procedure though had come into practice. It was, however, from the nineteenth century onwards that water laws for various uses began to be invoked. This trend was further strengthened with the multiple uses and increasing diversions for consumptive/commercial use which were often conflicting in practice. The problem has since then become more acute because of increasing population. The increasing demand over the availability has been creating scarcity and resultant disputes. Over the world a serious and intensive thinking on availability of earth's fresh water resources and possibilities of exploitation has begun .

With rapid population growth placing more and more pressure on dwindling supplies, per-capita access to water is falling. Ancient usage pattern is being challenged by new claims. More than 200 countries in the world have to share their common resources of surface and ground water transcending their political boundaries. The competition for the world's water resources is becoming a major contentious political issue of our time. Shortage of water, quality of water, and management of water are the three issues being discussed in contemporary world. Hence, there is a need to define the rights over water and their historical evolution.

It was believed for a very long time that water in a natural stream was not the subject of property but a wandering thing without an owner. However, this understanding underwent a significant change in the industrial world and the issue of water rights came into existence. The genesis of water rights is generally traced to the rights of navigation in rivers that often formed the boundary between two states. Rivers that formed natural boundaries or flowed through successive domains or territories and came to be used as a common highway were supposedly open to all for communication and commerce. However some states began to exercise greater control over them thereby denying others, or reducing their, usage of the resources. This necessitated framing of some kind of laws as the dispute over ownership rights of water increased. Conventions pertaining to the Danube between Austria and Turkey in 1619 and the Rhine between Germany and France in 1697 were among the early landmarks in the making of modern International law on navigation. Inland navigation was an item on the agenda of the Congress of Vienna in 1815.

These disputes were basically on consumptive uses. The scenario changed as world saw rapid pace of industrialisation. Political issues of boundary alignment along wayward rivers tended to be settled on the principle of the median line - a line purporting to demarcate the deep water course of a river. However, braided rivers and those prone to make large erosive invasions of territory on either bank have continued to pose problem of jurisdiction.

Historically there have been following principles defining the water rights:

- *Riparian Doctrine*: The private property right in water only to those whose land abutted the river was a viable theory so long as people living away from the river satisfied their needs from other sources. However, with the change in nature of utilisation/needs it is no more viable.

- *The Prior Appropriation Theory*: According to this theory water in the natural course is the property of the public. It is in fact a suitable version of the riparian theory which puts the earlier appropriation right holders on advantage over all subsequent users.

- *The Territorial Sovereignty Theory*: According to this theory the owner has an absolute user right. This notion of private property when extrapolated for the entire domain of natural resources generates territorial sovereignty principles.

- *The Equitable Apportionment Theory*: Equity is a legal or a judicial notion therefore it provides basis for legal interpretation. It says: treat all claimants as equal right holders and through fair legal means apportion the resources in accordance with their individual needs.

- *The Equitable Utilisation Theory*: It says distribute the resources equitably such that optimum utilization occurs for all concerned when all relevant factors are taken in to account. It is based on the guidelines laid down by (Article 5 of) the Helsinki rules for equitable utilization of water resources.

- *The Community Interest Theory*: In 1851 the English common law made a distinction between *bonus vacans* and *public–juris* that is between no one's property and every one's property. The notion of every one's property is appropriate for water resources, which are to be used by numerous communities all along their flow. As a principle of distribution this theory allows the groups, participatory in the distribution, to be defined as communities in various ways, as culture specific groups or domicile specific groups. Otherwise it is based on the equitable utilisation theory.

- *The Public Trust Theory*: It emphasises that the principles of distributive justice need not be based only on the notion of private property, rather one should consider natural resources a common property and the sovereign or the state as its only trustee. This theory says that the state, which holds the natural water as a trustee, is duty bound to distribute or utilise the water in such a way that it does not violate the natural rights of any individual or group and safeguards the interests of the public and of ecology.

12.4 SUMMARY

In this unit we attempted to highlight the significance of water as a resource for human survival. It also dealt with the question of availability of water in various forms on earth and the amount of water available for human use. It was followed by an examination of the various resource use practices of the past societies. Further the mechanism developed by these societies for the conservation of water were also discussed. The unit also gave a brief survey of various theories of water rights and its applications.

12.5 EXERCISES

1) Examine the historical practices of use of water as a resource.

2) What mechanisms did pre-modern societies in India adopt for water conservation? Elaborate.

3) Write a note on water rights and their environmental significance.

12.6 SUGGESTED READING

Chhatrapati Singh, *Water Rights and Principles of Water Resources Management*, New Delhi, 2001.

Anil Agarwal and Sunita Narain, ed., *Dying Wisdom: Rise, fall and potential of India's traditional water harvesting systems*, Centre for Science and Environment, New Delhi, 1997.

Madhav Gadgil & Ramchandra Guha. *This Fissured Land, An Ecological History of India*, Delhi, 1992.

UNIT 13 : FOREST RESOURCES

Structure

13.0 Introduction

13.1 Understanding the Forest

13.2 Forest Coverage

13.3 Forest in History

13.4 Levels of Interaction

13.4.1 Sole Provider

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13.5 Conservation Practices

13.6 Summary

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13.0 INTRODUCTION

Meaning of the term forest has been highly debated among the social scientists. Social interaction with the forest has been part of human existence since beginning as hunter-gatherers, agricultural societies and even the industrial society has been having contact with the forest in some form. It has been a dilemma for the social scientists to define the meaning of forest as the uses of forest have been culture specific and therefore the perception of forest has been different in different cultures. The general historical understanding of forest has been that of an area that is wooded, is the habitat of wild animals and many species of birds and reptiles and is not subjected to the laws of civility. This understanding extends further to also include the notion that many articles of use to man are grown in the forest naturally and have to be obtained from there. It is with regard to these articles and their extraction that some variance gets induced which is culture specific. Notwithstanding this variance, forest is imagined in history as a repository of many natural resources that have to be subjected to varying resource-use practices.

This unit attempts to make you aware of the changing notion of forest as a resource. Forests have been examined here with respect to various raw materials they supplied and at another plain have also been seen as providing an alternative to the agrarian landscape. Ever since the emergence of agriculture based monarchical political structures from sixth century BC, there is evidence for the coexistence of forest dwellers as another distinct socio-political entity. The monarchical political formations and forest dwellers shared a dichotic relationship where both were dependent on each-other not simply in terms of economic gains but also for the identity formations. Forests were visualised as places of safe refuge by the recalcitrant peasantry and other social elements raising a voice of dissent. With the expansion of agriculture there have also been disputes over the proprietary claims, though these disputes assume noticeable features only with the advent of colonial state in the 18th-19th centuries.

We take forest as an entity and discuss issues like an understanding of the forest, its treatment in history, the present day coverage of the forest and different levels at which humans have interacted with the forest. The underlying consideration in this discussion shall be the resource-potential of forest and the practices adopted for its use.

13.1 UNDERSTANDING THE FOREST

Evidently there is a complexity related with the historical understanding of the forest as a concept. In the same time span forests were understood differently by people belonging to different cultures. It is very difficult to provide universally applicable set of characteristics of forest. The term *jungle* used to denote forest in contemporary India is problematic. Michal R. Dove has argued that, “in contemporary Urdu, *jungle* is defined as ‘a wood; a forest; a jungle’. In classic Sanskrit, the cognate term, *jangala* is defined as arid, sparingly grown with trees and plants. There is major difference in meaning between the two terms: the latter denotes an open, arid savanna stage of vegetation, while the former denotes a closed, tree dominated cover (with unspecified aridity).” Francis Zimmermann in the preface of his book *Jungle and the Aroma of Meats*, writes, “An extraordinary misunderstanding has overtaken the history of this word (jungle). *Jangala* in Sanskrit meant the ‘dry lands’, what geographers would call ‘open’ vegetation cover, but in the eighteenth century the Hindi *jangal* and Anglo-Indian *jungle* came to denote the exact opposite, ‘tangled thickets’, a luxuriant growth of grasses and lianas. Let us agree to abandon that misunderstanding for the time being’’ (p. vii). We must emphasise that in this unit we deal with the traditional meaning of the term forest in English language as described above. Forest has been attributed a rawness where rules of civil society do not apply. The term *jungle-raj* seems to refer to this law-lessness. This attribute of the forest perhaps originated in the context of relatively stable production of food in the early-agricultural societies. The agricultural societies were glorified and non-agricultural social formations devided.

The characteristics of the forest are best understood in terms of man forest relationship in history. Recent past has shown increasing incongruity in the man-forest relationship. We shall have to see if in a more remote past the situation was any different. However, in order to give a simple coherent picture, intricate and micro-regional variations shall be given relatively less attention. We would possibly benefit if we decide a few major indicators guiding the relationship between man and forest. The foremost indicator is the user-resource arrangement put in place by humans vis-à-vis forest resources. The next significant pointer is the level of technology available for operationalising this user-resource arrangement. The final pointer is the availability of alternative resources, say agricultural resources as alternative to forest resources.

13.2 FOREST COVERAGE

Complex physiographic, climatic and pedagogical conditions have given rise to as many as 30,000 species of plants in the country ranging from thorny bushes (Rajasthan etc.) to evergreen forests (Assam, etc.). Forests are dominant natural vegetal cover in India. The present day distribution of forest is very uneven ranging almost from nothing in some regions (Delhi 1.5%, Rajasthan 2.5%, Punjab 3%) to nearly one-third in other regions (Himachal Pradesh 33%, Madhya Pradesh 31%, Kerala 28%). Exception-ally high shares are exhibited by Tripura (63%) and the Andaman-Nicobar Islands. This distribution can hardly reflect the true nature of the original cover in the past; much of the forest cover, especially in the Great Plains, has been removed as a consequence of Human occupance.

The climate, land, and species singly or in combinations, define the forest types. These have been described in Unit 2 of Block 1 at length. Indian forests species, do well in certain environments. There are however some species such as bamboo, cane, reeds, neem, pipal, banyan, tamarind, palm etc., which grow all over the country.

Grasslands, on a sizeable scale, no longer exist in India. Much of the surface area (about 59%) is either under cultivation or under forest cover. The pastures with scrubs and grasses are found in patches usually in the arid to sub-humid areas of the country. Like forests, grasslands also have a variation in accordance with the natural environment and soil. In the western margin of Uttar Pradesh, the sub-humid Madhya Pradesh, and Andhra Ghats, etc., are found patches of coarse grasses, much more sensitive to over-grazing. Sandier and humid soils are covered with poor quality grasses and scrubs. Sub-tropical Himalaya, above 1400 m has considerable stretches of mostly induced grasslands from western Himalaya to the Burma border. (R.L. Singh, ed., *India: A Regional Geography*, National Geographic Society of India, Varanasi, 1971, reprint 2001).

13.3 FOREST IN HISTORY

The earliest references of human settlement in India can be traced back to the culture of 2-million years old (approximately) stone choppers. Two technological traditions are known from this stage: the Sohanian and Acheulian. Sohanian culture was confined to Siwaliks and Acheulian spread from Siwalik Hills in the north to near Madras in the south. Acheulian sites are particularly densely populated and richer in Central India and the South Eastern Ghats. Both these regions received adequate rainfall, had a thick vegetation cover, and were rich in wild plants and animal food resources. The only areas devoid of early human settlement were tropical forests. Acheulian tool assemblage comprises chopping tools, polyhedrons, discoids, hand-axes, cleavers, scrappers, denticulates, notches, flakes and blades. Though our knowledge of the exact functions of most of these tools at this stage is very imperfect, it is fair to assume that they served a variety of functions like hunting, butchering, digging of roots and tubers, processing of plants and making of wooden tools and weapons. In this arrangement human dependence on forest resources is clearly visible. Moreover this dependence lasted for a considerably long time. The subsequent periods of cultural development do not match with this early stage in terms of the time span occupied by them. The man forest relationship based on a heavy sustenance of man on forest resources was the hallmark of this early phase. There were several substages in this relationship which were all located in an evolutionary framework and about which detailed information has been read by you in Units 5 and 6 of Block 2.

The next important phase of human settlement in India is termed as Harappan civilisation. This civilisation emerged basically in the semi-aridregions of North-Western India and in the absence of written records we have to depend solely on the archaeological information for this phase. In fairness to the efforts made by a galaxy of eminent archaeologists though, it must be said that material evidence unearthed for Harappa civilization provides significant clues to man-forest relationship for this phase. It is suggested that the size of Harappan urban settlements would have required wood that could only be supplied by a forested region not far from the sites. The requirement of wood as fuel to support the firing of bricks, a conspicuous building material of Harappa culture, is another supporting argument for the existence of forest and the dependence of the inhabitants of Harappan settlements on the forest resources. A quick inventory of the objects in which wood was used would read as below:

- Toys made of wood;
- Wood handles for copper-tools such as sickles, axes and adzes;
- Wooden carts, their assembly components and their wheels;
- Wooden boats and their sails and oars;
- Potter’s wheel;
- Wooden beams in roofs and wooden beams in door openings and in windows. (Cf. Irfan Habib, *The Indus Civilization, People’s History of India 2*, New Delhi, 2002, pp. 30-33).

Moreover the animals depicted on Harappan stamp seals such as elephants, tigers and rhinoceroses require forest as their habitat. Borrowing comparisons from other contemporary bronze are civilizations, it seems certain that forest resources must have been in good demand. A significant point for us to note in this regard is that the borders of the Indus zone towards the east were covered with dense forests which the copper wielding cultures such as the Harappans were in no position to cut and clear. Perhaps these eastern regions were heavy rainfall areas and had no significant human habitation. The forests on the fringes would therefore be available for exploitation of forests resources (Cf. Irfan Habib & Faiz Habib, 'The Geography and Economy of the Indus Civilization' in *Proceedings of Indian History Congress*, 1987, p. 61).

The next significant period is the one occupied by the Vedic civilization. Vedic sources portray a close relationship between man and forest. Malamoud suggests: "The forest lies on the village's horizon and is, in a certain sense, integrated into village life. … Yet, this fusion of village and forest is so beautiful in the eyes of the Indian authors, and fundamentally so unrealistic, that they exclude it, at times, from the realm of the possible in our present age of iron, declaring that it can only be found in a distant past, in the wonderful age of the *rishis*, of those inspired seers who received the Vedic revelations" (Charles Malamoud, *Cooking the World: Ritual & Thought in Ancient India*, New Delhi, 1996.). However, there has been a problem with the presentation of this kind of harmonious relationship between man and forest. Indologists, working on a general conceptual level, have shown that the dichotomy of *grama* (village) and *aranya* (forest) is omnipresent in the Vedic literature. It is discussed as a duality between wilderness and civilization and has the basic, fundamental opposition. According to this concept, forest always remains *outside*, distanced and more or less detatched from the sphere of human praxis. Malamoud and Sprockhoff argue that there is evidence that the interpretation of *vana* and *aranya* as synonyms can be found only in the late Vedic and post-Vedic literature. Both draw attention to the etymological origins of *vana* and *aranya* and their usage in the earlier Vedic literature. They come to the conclusion that both terms have different connotations. *Aranya*, translated as wilderness, desert, sometimes also as forest, is linked etymologically with alien, distant; it is the dangerous, the frightening space, inhabited by demons, wild animals, but also by brigands, it is the space which one tries to avoid, it is linked with death. *Aranya* and *grama* appear as reciprocally exclusive categories. Malamoud and Sprockhoff take up another conceptual pair, namely that of *vana* (forest) and *ksetra* (fields, inhabited space), often *vana* and *grama*. *Vana* and *ksetra interact* with each other and this interaction is seen as positive. *Vana* is the forest which supplies villagers with timber for house construction and tools; here herbs and wild plants are found, single trees may get special ritual significance as *vanaspati*. But the boundaries between *vana* and *aranya* are fluid; the same space, which was seen as*aranya*, as wilderness in previous times may become *vana*, utilizable forest, or land for cultivation (Antje Linkenbach, 'Forests in Garhwal etc.'in *Social Construction of Indian forests*, ed. Roger Jeffery p.86-87)

The period from 500 BC to 300 AD saw large scale colonization of fertile forest lands both in the northern India and the river valley areas (for example Krishna, Godavari, Cauvery, Vaigai) in the peninsular India. Greater colonization meant greater availability of surplus. Thus tribal chiefdoms started giving way to large states; Mauryas and Kushanas in northern India, the Chalukyas and Sangam Cholas in south India. The ground for further exploitation of forest resources was made ready in the logic of the empire building exercise. Of course trade was also coming up in a big way and the ships and boats had to be built out of the forest wood. Elephants assumed significance, and elephant forests started coming up. The number of towns increased and the houses in towns began to use wood on a greater scale. Moreover, superior timber had to be used for construction of furniture, carts, chariots, wooden bridges etc. During the Mauryan period, the concept of 'hunting reserves' also came up, as hunting became a recreational activity. Chanakya says that Brahmanas should be provided forests for plantations, for religious learning and for performance of penance. As we shall see in Block 5, many philosophical treatises were written in the forests. Upanishads and Aranyakas were the major ones. The importance of forests is further borne out by the treatment it receives in Kautilya's *Arthashastra*. Two important forest produce noted in the text are sandal-wood and the aloe-wood, obtained from the forested regions of Kamarupa, in Assam (Cf. Irfan Habib & Faiz Habib, 'The Economic Map of India, AD 1-300' in *Proceedings of Indian History Congress*, 1986, Vol 2, p. 149). Though Kautilya's treatise mainly pertains to the Mauryan period the principles enunciated in it were accepted as the bed-rock of further writings on the subject. A well-known scholar (of ninth century AD) Kamandaka who wrote *Nitisara* acknowledges the importance of *Arthashastra.* After the Mauryas, the other important empire builders were the Guptas. But during the Gupta times and more particularly later Gupta times economy began to decline. There was a manifest slump in trade and towns and in the use of monetary system. Inscriptions belonging to the period indicate a trend towards naturalization of the economy and thus greater pressure on land and consequently on the forest. Amidst all these developments, the forest question lost its prominence and in the later sources lesser attention was given to the forests. It is however pointed out by some scholars that during Harshavardhan's time (seventh century AD) agriculture and forestry had been in a prosperous condition. For this period we have an important account, by Hsuan Tsang, the Chinese pilgrim who travelled in India and the border lands between 629-45 AD. He records the following regions as forested areas:

- Kosambi, infested with wild elephants;
- Monghyr, a forest between Magadha and this region;
- Kalinga, forest between it and Kongeda having wild elephants;
- Andhra, forest between it and South Kosala;
- Chole, wild jungle;

- Malaya Mountains, giving Sandalwood and Camphor. (Cf. Irfan Habib & Faiz Habib, 'Economic Map of India, AD 500-800'' in *Proceedings of Indian History Congress*, 2001, pp. 105-110).

The Delhi Sultanate phase saw a change in the situation. The total population (both human and livestock) increased, as did the number of cities and towns. Consequently urban population also increased. All this led to a proportionate quantitative increase in the demand for fuel wood, fruits, food, fodder etc. Demand for quality timber for construction of boats, bridges, houses, carts etc. also went up considerably. In addition to all this, the concept of 'hunting reserves' for the nobility came into vogue. There are also instances of large scale clearing of the forests in the Doab region such as under Balban. This was done to destroy brigandages in the region inhabited mostly by the Mewatis.

As we come to Mughal India the information increases, in terms of quantity as well as quality. Most of this information has been plotted by Irfan Habib in his *Atlas of the Mughal Empire* (New Delhi, 1982). It is thus convenient to get details about forest resources at an all-India scale and at regional scale. The main forested areas in Mughal India were:

- The Northern Mountains or the Himalaya;
- Foot-hills/*terai* region of the Himalaya;
- The Central Indian Forests (between Narmada-Son rivers towards north to the eastern coastline between Narsapur and Balasore);
- The Ghat Range (along West coast);
- The Aloe-Wood Forest (in north-east);
- Brahmaputra Forest; and
- Lac Forests (in the Ganga delta).

Among the forest resources there was a big demand for timber particularly the superior variety. Timber was required for construction of buildings, furniture, bridges, boats as well as ships used in internal and external trade. There are ample references to fleet of boats/ships owned by merchants and some members of the nobility and royalty. Forests served another utilitarian purpose; the forest produce formed an important component of the non-agrarian production during the Mughal period. The production and use of many forest products like timber, fruits, roots, fibres, barks, resins, herbs, lac, babul tree for leather tanning, gumlac (red dye, sealing wax), and mulberry silk has been recorded in the sources.

Forest Produce (as recorded in *Atlas of the Mughal Empire)*

1. *Punjab*:	**Sal** timber, Spikenard (aromatic plant used in an ointment). Gum lac, Turpentine, Indian Jalap (tuberous roots used in a purogative drug), Chebulic Myrobalns (astringent fruit), Costus root.
2. *Gujarat*:	Teak timber, Gum lac, Aloe-wood, Honey, Chebulic Myrobalans.
3. *Uttar Pradesh*:	Sal timber, Ebony, Bamboo.
4. *Central India*:	Sandal-wood.
5. *Bihar*:	Bamboo, Long-pepper, Sun lac, Musk.
6. *Bengal*:	Timber for masts and boats, Aloe-wood, China-root (*Simlax gabra*, not *Smilax china*), Gum lac, Beeswax.
7. *Orissa*:	Timber, Gum lac, Beeswax.
8. *Assam*:	Aloe-wood, Gum lac, Musk.
9. *Deccan (West)*:	Teak timber, Sandal-wood, Gum lac.
10. *Deccan (East)*:	Timber for ship-building, Gum lac, Bezoar Stone, Beeswax.
11. *South India*:	Teak timber, Timber (Anjeli wood), Sandal-wood, Bamboo, Cinnamon, Cassia Fistula (Senna leaves), Nux Vomia (herb), Myoobalams, Lac, Bees wax.

It is evident that on the whole, the forest cover did not suffer any major problem of depletion. It is true that royal patronage as under the Mauryas, was absent but there were other factors, which kept things under control. Though the demand for forest produce increased but the land- man ratio was still very favorable. Land was abundantly available and as such the problem of converting forest land into agricultural land was not so strong which was the main reason for loss of forest. Added to this was the factor of natural regeneration of the forests, which kept the larger forest cover under more or less 'normal conditions'.

13.4 LEVELS OF INTERACTION

Forest-man interaction should be visualised in the context of the social relevance of the forest. The process of evolution from the simple social formations of 'hunting-gathering' to the complex social formations of 'industrial society' has influenced the level of interaction between man and forest. It is difficult to define this kind of interaction because there are tremendous regional variations in the physical nature of forests. However, we will attempt a broad generalisation to elucidate the intricacies of the social interaction with forests.

13.4.1 Sole Provider

The earliest stage of social formation has been termed as 'hunting gathering' where to a great extent the physical needs of the humans were catered to by the forest resources. During this phase the forests were the sole provider of sustenance to humans. 'Hunter-Gatherers' survived by exploiting resources of the forest but in the process exerted little control over their natural environment. They were omnivorous; the proportion of meat, plant food, etc varying from region to region. In the absence of tools human dependence on animal meat was limited, initially to scavenging and only gradually to hunting. All along this phase human dependence on fruit and other plant food remained quite high.

Human dependence on forest witnessed a change with the introduction of tools, initially of stones (generally known as Palaeolithic tools) but soon also made of wood, one of the most versatile raw materials known to humanity. Unfortunately, timber rarely survives in the archaeological records and we are left mostly with stone tools as evidence. Introduction of flakes, choppers, and later on axes influenced the human-forest interaction. They were multipurpose artifacts, used for grubbing up roots, working wood, scraping skins, and especially skinning and butchering large and small game. By analysing the geographical location of the sites of tool industry scholars have suggested that the hand axe was in fact a form of primitive discus used primarily for hunting purposes.

Forest also provided shelter to the humans. Traditionally it were trees that provided shelter though with the growth of terrestrial adaptation rock shelters became an alternative. Even today we have evidences for this kind of existence. Varied ecological niches in these ecosystems are exploited today by traditional ethnic groups (tribes/adivasis) whose economies are geared to hunting and gathering, riverine fishing, marine fishing and shifting cultivation. Typical examples are those known as Van Vagri (Thar), Birhor (Chota Nagpur), Chenchu, Yanadi, Konda, Reddi, Koya, Voda Baliji(Eastern Ghats), Kadars (Kerala), Baiga, Gond, Muria, (Madhya Pradesh), Kandh, Savara, Gadaba, Juang (Orissa), and Walri and Koli (Maharashtra). All these ethnic groups, pursue their traditional modes of food procurement notwithstanding the fact that they are now integrated into village economies. Since big game is now both scarce and its hunting is prohibited, they hunt small game and birds, and collect insects and honey and wild plant foods. The fact that Stone Age occupations occur within the tribal habitats indicates that the game and other forest foods now exploited must have formed the subsistence base on a much larger scale. [V.N. Misra, 'Stone Age India: An Ecological Perspective', in *Man and Environment* XIV (I)-1989].

13.4.2 Ancillary Product

With the development of agriculture as source for food, the relationship between man and forest underwent a drastic change. For the agricultural societies, forest assumed secondary position. However, one should be careful to realise that the shift to agriculture was not a quick process neither a smooth one. Initially agriculture was a risky proposition and forest resources provided sustenance in case of crop failure. At the same time the possibilities of surplus generation and accumulation led to fresh demand on forest resources. Earlier forest resources were required basically for consumption purposes and possibilities of storage were limited. The growing shift towards agriculture necessitated sedentary life style, that too usually away from the rock-shelters and other natural sheds. It forced humans to develop dwellings for themselves, for which the easiest procurable raw material had been wood, i.e., forest resource. Another important feature of settled agriculture was the emergence of stratified society. Trade had been another marked feature of the agriculture society. All these factors supported greater demand for the forest resources.

Growth of agriculture, sedentary life-style, and greater possibilities of surplus generation increased the demand for energy. At one level the demand for energy was met by utilising the draught power of animals and on the other hand it increased the demand for fuel-wood. Both the situations demanded greater utilisation of forest resources, as fuel-wood and as fodder. The dry leaves from the forest were used as manure for agriculture. As far as food was concerned, with the growth of agriculture, forest products were ascribed secondary position as discussed above. However, forests remained sole supplier of numerous ancillary products. Another essential requirement was that of wax for candles which could be procured only from the forests. Similarly forest gave gum, resin, lac, honey, rubber and querns which were used by humans in many day to day activities.

Wood was one forest product that was extensively used as raw material for housing, furniture, agricultural tools, musical instruments, and numerous other handicrafts. The necessity of wood was greater in the absence of technological support otherwise heavy materials like stone or brick could be used for raising the roofs of the building/ house in a cost effective manner. Similarly, wood was extensively used to provide beam for the construction of windows, doors and other openings. Wood was also required for construction of bridges, carts, and chariots. Most of the tools used in the agriculture sector were made of wood. Good quality wood was required for the preparation of plough and other materials.

13.5 CONSERVATION PRACTICES

The importance of timber, as discussed above, had grown enormously. Wood had multiple usages ranging from use as the basic source of energy, to a key ingredient of furniture and tools, particularly agricultural tools. As the civilization progressed the need to conserve such an important and critical forest resource became more and more evident. Moreover the forest was also giving many other products which too needed to be conserved and judiciously used. The policies adopted by different states often reveal their anxiety as also the measures initiated in this regard. We shall deal with the issue of conservation at length in Block 5. Here we are giving some interesting conservation episodes from the region of Rajasthan which have mantled the robe of cultural practice in the region. Some of the well recorded episodes of this practice are recounted below.

The attitude towards tree conservation is reiterated in the following anecdote written by Nainsi, in the Seventeenth century. King Maldevji got *babool* trees of Merta cut. In response to this, and by way of revenge, Viram Deo said that he would cut the mango trees of Jodhpur. However, people advised him not to do so as trees were to be protected. Hence hechipped a small branch of Mango tree symbolising that he had settled the account. In this anecdote, the chief is restrained from cutting trees by his advisors. The latter probably realised that denudation of trees would cause irreparable damage.

Another important example in this regard was the representation of *khejari* tree in the official flag of Bikaner kingdom in the Seventeenth century. Flags in medieval India generally depicted animals- lion in the case of the Mughals. The representation of the *khejri* was unusual. What is striking is that even to this day it plays a critical role in sustaining agriculture and animal husbandry. Similarly, concern for vegetation was visible in the construction of *bund* Jaitsar, near Jaisalmer. Maha-Rawal Jaitsingh sponsored the construction, in 1570 VS. (AD 1513) to capture the runoff water from the adjoining northern hills. The construction of the *bund*/embankment created a reservoir. This in turn was used to supply water to the other side where a garden was planted. A small canal with sluices was also provided to carry and control the water from the *bund* to the garden. This reservoir could contain water for four to five months only. However, the moisture retained by the ground was sufficient to sustain the garden round the year. Moreover, the dry bed of reservoir was utilised to cultivate *unali/rabi* crop (winter season crop).

The practice of punishments for cutting of trees was also prevalent there. It should be seen in the context of regional environment and socio-religious practices. The social concern for environment in medieval Rajasthan manifested itself in various forms. The attitude towards natureis apparent in the teachings of sects like Bishnois. The founder of Bishnoi sect, Jhambhoji (AD 1451-1536) had prescribed twenty-nine rules for his followers. Most of these were related to keeping harmony with the environment like prohibition on cutting green trees and animal slaughter. It is said that the followers of Jambhoji were known as Bishnoi (*bish* is twenty and *noi* means nine) because it means twenty-nine in vernacular dialects of Rajasthani language. One plausible explanation is that the economy primarily sustained on animal husbandry. Hence any slaughter, even during droughts, would reduce the means of livelihood. Similarly, the cutting of green trees was prohibited, as it would reduce the availability of green fodder for the animals. It became more important in this region where natural vegetation was very thin and sparse. Jambhoji’s teachings, congruent with the interests of the common man, became immensely popular. The number of followers increased manifold but primarily in thearid regions of Bikaner and Jodhpur. His sect became so influential thatthe rulers of these states were forced to respect his sermons. Maharaja Ajit Singh issued a *parwana*- official order, restraining cutting of green trees in 1754 VS (AD 1698). Anup Singh, King of Bikaner prohibited cutting of green trees in the villages dominated by Bishnois in 1752 VS (AD 1696). Similarly, in 1878 VS (AD 1821), Man Singh the king of Jodhpur issued a similar order with respect to *khejari* tree.

The founder of the Bishnoi sect was not alone in attempting to influence conduct towards living beings via religious and ethical transformation. Another popular saint, Jasnathji (AD 1482-1506) who was a contemporary of Jhambhoji also endorsed such a viewpoint. His followers were known as Jasnathi. Like his contemporary saint, Jasnath ji was also aware of the importance of preservation of environment. In his teachings tree of *jal* had been accorded special protection, which was natural vegetation of the region. These teachings became popular in the region, which had traditionally sustained goat and sheep rearing. Conservation of green vegetation and prohibition of slaughter of animals seemed to be attempts towards conservation of their livelihood.

In Rajasthan, especially in the central and western parts, the vegetation was very sparse; there were very few forests. In such a situation it was necessary to protect the already existing ones with care. Lalchand complained to Amber ruler on *Jeth Vadi* 1, 1756 VS (AD 1699) about tree felling in his *pargana* (Sawai Jaipur) and expected punishment for the culprit. In village Saithal, *pargana* Bahatri, in 1745 VS (AD 1689) a person was punished for cutting a *neem* tree. Similar cases were reported from numerous villages and *Qasbas*. *Patel* (headman) of village Kharkhura was punished in 1780 VS. (AD 1724) for the same crime. It appears that trees could be cut only with the permission of state authorities. The *Patel* ofvillage Kundala, Pargana Mariana was punished in 1789 VS. (AD 1733) for the unauthorised cutting of tree in his area. The term unauthorised (*bin hokum neem ka dala kate*) cutting of tree has been used in a context that implies permissions were granted for the purpose. This also suggests control enjoyed by the state with respect to vegetation.

Neem having tremendous medicinal properties, needed protection. Being a medicinal plant, it was considered inauspicious to cut *neem*, thus, punishment. Similarly, cutting the tree of *peepal* has been reported from village Chandpur *pargana* Bhartri in 1775 VS. (AD 1719). Ritually, the tree of *Bad* was considered auspicious, hence attempts to axe the tree were punished by rulers as reported from village Chauroti, *pargana* Hindaun in 1785 VS (AD 1729). Moreover the trees of *peepal* and *Bad* were worshipped by women of the royal household. Thus, perhaps religious considerations were an added justification for the enactment of punishment.

Alongside, we have evidence of punishments for cutting *Jamun* (*Syzygium cumini*) tree from village Nadu pargana Bahatri in 1774 VS. (AD 1718). *Babool* was a tree adapted to the specific conditions of Rajasthan and it needed little or no care in its rearing. In the arid part, *babool* was the dominant tree and provided food for the camels. Considering the economic and ecological value of *babool*, it was considered necessary to punish those who tried to cut it.

Furthermore, it is to be noted that even unauthorised cutting of grass was punished. Our documents clearly point out that there were reserved grazing lands. The cutting of grass grown even on the hills and forests was punished. Meadows were important for the military as cattle and horses used in warfare needed fodder. The primary source of draught and transportation was cattle and their need for pasture played an important role in state policies. State used to actively procure the grass and maintain a reserve stock. for the cavalry- horse, camels and elephants- the mainstay of their army.

13.6 SUMMARY

The unit stresses the fact that the forest is natural growth of vegetation not requiring human intervention. The variety of vegetation is: to strength and testimony of its originality. Literature has been important source for the reconstruction of forest in early as well as medieval times in India. The unit has documented the extent of the forest chronologically to map the forest coverage and at the same time it also dwells upon the popular renditions of forest. The unit also examines various social practices which encouraged the conservation of the forests. The role of social customs, practices and taboos are important areas of exploration to situate and comprehend the forest. The unit also looks at the various issues related with the claims over the forest produce. The notion of forests as common property resource and claims laid by state portrays a complex picture.

Forest as a resource has been used by humans ever since the origins of humans. Man-forest relationship has for a large part of human history been one where human dependence on forest resources for sustenance has been near total. The situation changed only with the emergence of agriculture. Hereafter the food resources were mostly obtained from cultivation that was not dependent on the forest. A complete independence from the forest was however not yet feasible. Several products used by humans in daily life were even now produced and obtained from the forest. The growth of civilizations however increased the demand of wood and forest again became one of the most important resources for human societies.

13.7 EXERCISES

1) Write an essay on the changing perception of forest in history.

2) Discuss the various levels of interaction between man and forest.

3) Write a note on the reasons for tree conservation in Rajasthan.

13.8 SUGGESTED READING

Irfan Habib, *The Indus Civilization, People's History of India 2,* New Delhi, 2002.

Irfan Habib, *An Atlas of the Mughal Empire,* New Delhi, 1987.

Briget & Raymond Allchin, *The Birth of Indian Civilization,* Penguin, 1968.

Romila Thapar, *Early India,* Allen Lane, 2002.

Francis Zimmerman, *The Jungle and the Aroma of Meats,* London, 1987.

UNIT 14 : METAL & MINERAL RESOURCES

Structure

14.0 Introduction

14.1 Metal Resources

14.2 Historical Evolution of Metals

14.2.1 In World

14.2.2 In India

14.3 Mineral Resources

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14.5 Exercises

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14.0 INTRODUCTION

Metal is a solid material which is hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity. Similarly mineral is defined as an inorganic substance of natural occurrence that is usually obtained by mining. The term mineral itself is derived from the term mine, i.e. excavation. Minerals are important inorganic substance needed by the human body for good health. There are very few metals and minerals available independently in the nature. The significance of metals and minerals is that they have a variety of applications for the humans. The social significance, since the ancient past, has been clearly brought out by Gordon Childe in the book, *Man Makes Himself* . He argues that the implications and consequences of developments in metallurgy meant four major discoveries: the *malleability;* the *fusibility*; the *reduction* from ores; and *alloy* making. Metal 'seemed a superior sort of stone that can not only be sharpened to cut like flint, but can also be bent, shaped by hammering, and even beaten out into sheets which can be cut up'. Secondly, 'when heated metal, especially copper, becomes as plastic as potter's clay; nay it will become liquid and will assume the shape of any container or *mould* into which it is poured. Yet on cooling it not only retains this shape, but becomes as hard as stone and can be given as good a cutting edge as flint. For tools copper possesses all the virtues of the older materials –stone, bone, wood– with other superadded. The possibilities of shape became unlimited as sole limit to shape was the mould.

The utilisation of these advantages required in practice a complex of ingenious inventions– a furnace with a draught fusion to produce the relatively high temperature requisite for fusion, crucible to contain the molten metal, thong to lift them with, and above all moulds to confer upon the casting the desired shape'.

The sciences applied in metallurgy are more abstruse than those employed in agriculture or even pot-making. The chemical change affected by smelting is much more unexpected than that which transforms clay into pottery. The change from the solid to the liquid state and back again, controlled in casting, is hardly less startling. Hence, it is not surprising that in the earliest historical societies, metallurgists are always *specialists*. Probably from the beginning metallurgy was a craft as well as a technique. The operations of mining and smelting and casting are too elaborate and demand too continuous attention to be normally conducted in the intervals of tilling fields or minding cattle. Metallurgy is a full-time job.

The most important consideration for the spread and extensive use of any metal would have been its availability. The spread of bronze age civilisation was very limited compared to later civilisations using iron as base metal. The limited availability of copper and tin had restricted extensive use of the metal by the common man/peasantry in particular. Even in the field of agriculture, it was not extensively used. Almost all the bronze age civilisations were located on the banks of rivers as flood plains sustained the agriculture. Corollary to this was the limited utility of bronze in the process of forest clearance. Therefore, expansion of civilisation in the thickly forested areas was restricted and the change in the landscape would have been limited.

The situation changed dramatically with the introduction of iron. Iron is one of the commonest elements in the earth's crust and with continuous experiments the production of iron became relatively cheap. Cheap iron democratised agriculture and industry and warfare too. Any peasant could afford an iron axe to clear fresh land for himself and use iron ploughshares to break up ground. The common artisan could own a kit of metal tools that made him independent of the household of the kings or nobles. Thus in the Iron Age civilisation not only spread over a wider area than in the Bronze Age, it also spread deeper.

The purpose of this Unit is to familiarize you with the use of metal and mineral resources and the complex process of their appropriation. The pattern of appropriation and consumption has marked a definite stage in the evolution of civilizations in the world. The consumption of metal and mineral resources to a great extent depended upon the stratification in the society and the availability along with accessibility of these resources. Our focus is on the significance of metal and mineral resources for humans, the broad spatial distribution of metal and mineral resources in India, and the historical evolution of methods of appropriation and patterns of consumption especially in India.

14.1 METAL RESOURCES

Metallurgy is one of the oldest applied sciences. Its history can be traced back to 6000 BC when its form was rudimentary. However, to gain a perspective in Process Metallurgy, it is worthwhile to spend a little time studying the initiation of mankind's association with metals. Currently there are 86 known metals. Prior to nineteenth century only 24 of these metals had been discovered and, of these 24 metals, 12 were discovered in the eighteenth century. Therefore, from the discovery of the first metals - **gold and copper** – until the end of the seventeenth century, only 12 metals were known. Four of these metals, **arsenic, antimony, zinc and bismuth**, were discovered in the thirteenth and fourteenth centuries, while **platinum** was discovered in the sixteenth century. The other seven metals, known as the Metals of Antiquity, were the metals upon which all early civilisations were based. These seven metals in the descending order of their discovery from the earliest, are:

- Gold, (ca) 6000BC
- Copper, (ca) 4200BC
- Silver, (ca) 4000BC
- Lead, (ca) 3500BC
- Tin, (ca) 1750BC
- Iron, smelted, (ca) 1500BC
- Mercury, (ca) 750BC.

Some of these metals were known to the Mesopotamians, Harappans, Egyptians, Greeks and the Romans. Of the seven metals, five can be found in their native states, e.g., gold, silver, copper, iron (from meteors) and mercury. However, the occurrence of these metals was not abundant and the first two metals to be used widely were gold and copper.

In metallurgy it was important that the metal deposit must be identified. In the case of the first metals color was the most important factor as it allowed the metal to be recognized in surrounding rock, stones, gravel and dirt and separated from these. Separation was then the next problem followed by concentration. These three steps are very important and the economics of these steps usually defines whether it is viable to produce the metal from a deposit or not. In the early days all three steps were carried out simultaneously. In the following pages we will take a brief account of the early metals, their nature and their availability to understand their significance as resources of value to the man.

Gold

Gold articles are found extensively in antiquity mainly as jewellery. Early gold artifacts contain significant silver contents. Man learned to convert gold into jewellery and ornaments, on the basis of knowledge that it could be formed into sheets and wires easily. However, because of its malleability, it has little use value except for decorative purposes. As gold is a noncorrosive and tarnish free metal, it served this purpose admirably.

Gold is widely dispersed through the earth's crust and is found in two types of deposits: lode deposits, which are found in solid rock and are mined using conventional mining techniques, and placer deposits which are gravelly deposits found in stream beds and are the products of eroding lode deposits. Since gold is found uncombined in nature, early goldsmiths would collect small nuggets of gold from stream beds etc., and then weld them together by hammering. The scarcity of gold and its value, due to mankind's fascination with its color, have resulted into gold becoming one of the more important metals in daily life.

In the early stages of the development of metallurgy all metals were reduced by either carbon or hydrogen, however, the majority of the metals once smelted were not available in a pure state. Refining of gold, that is the separation of silver from gold, has a very old history. During the second millennium BC, an amalgamation process using molten lead was used to separate the metal from crushed quartz. The lead then being cupelled (refine in a small flat circular vessel) to separate the gold and the silver. Purification was then carried further (but not until the first millennium BC) by a cementing process where a mixture of the alloy was closely mixed with common salt. The silver reacted, formed a chloride which was soluble and easily rinsed off. The cementation process was used until about 1100 AD when other refining processes became popular. One method used sulphur addition to the molten bullion to form silver sulfide which was removed as "black" during gentle beating. Mineral acids were developed by the alchemists. Nitric acid was used to dissolve silver as a purification technique. By the end of the fifteenth century, stibium (antimony sulfide) was also used in the cementation process. Generally, a mixture of salt, stibium and sulphur was heated with thegold foil. Amalgamation processes were also popular. The gold was dissolved in mercury. The amalgam was coated onto the piece and then heated to drive off the mercury leaving a gold coated piece.

Copper

The use of copper in antiquity is of more significance than gold as the first tools, implements and weapons were made from copper during the Chalcolithic period. By 3600 BC the first copper smelted artifacts such as copper rings, bracelets, chisels were found in the Nile valley. By 3000 BC weapons, tools etc. were widely found.

Malachite, a green friable stone, was the source of copper in the early smelters. Earlier it was thought that the smelting of copper was the result of a chance dropping of malachite into campfires but that was found improbable due to low campfire temperatures. It is more probable that early copper smelting was discovered by ancient potters whose clay firing furnaces could reach temperatures of 11000-12000 C. If Malachite was added to these furnaces copper nodules would easily be found. Although the first smelted copper was found in the Nile valley, it is thought that this copper was brought to Egypt by the Gerzeans and copper smelting was produced first in Western Asia between 4000 and 4300 BC.

Although copper can be found free in nature the most important sources are the minerals cuprite, malachite, azurite, chalcopyrite and bornite. Copper is reddish colored, malleable, ductile and a good conductor of heat and electricity.

Bronze (Tin and Copper Alloy)

Smelted copper was rarely pure. In fact, by 2500 BC the Sumerians had recognized that if different ores were blended together in the smelting process, a different type of copper could be made which flowed more easily, was stronger after forming and was easy to cast. An axe head from 2500 BC revealed that it contained 11% tin and 89% copper. This was of course the discovery of bronze. Bronze was a much more useful alloy than copper as farm implements and weapons could be made from it. However, it needed the discovery of tin to become the alloy of choice.

Native tin is not found in nature. The first tin artifacts date back to 2000 BC. However, it was not until 1800 BC that tin smelting became common in western Asia. Tin was reduced by charcoal and at first was thought to be a form of lead. The Romans referred to both tin and lead as *plumbum* where lead was *plumbum nigrum* and tin was *plumbum candidum.* Tin was rarely used on its own and was most commonly alloyed to copper toform bronze. The most common form of tin ore is the oxide casserite. By 1400 BC bronze was the predominant metal alloy.

Silver

Although silver was found freely in nature, its occurrence was rare. Silver is the most chemically active of the noble metals and is harder than gold but softer than copper. It ranks second in ductility and malleability to gold. It is normally stable in pure air and water but tarnishes when exposed to ozone, hydrogen sulfide or sulfur. Due to its softness, pure silver was used for ornaments, jewellery and as a measure of wealth. In a manner similar to gold, native silver can easily be formed.

Galena always contains a small amount of silver and it was found that if the lead was oxidized into a powdery ash a droplet of silver was left behind. Another development in this process was the discovery that if bone ash was added to the lead oxide, the lead oxide would be adsorbed and a large amount of material could be processed. By 2500 BC the cupellation process was the normal mode of silver manufacture.

Iron

Iron was available to the ancients in small amounts from meteors. This native iron was easily distinguishable because it contained nickel. There is some indication that man-made iron was available as early as 2500 BC, however, iron-making did not become an everyday process until 1200 BC. Hematite, an oxide of iron, was widely used by the ancients for beads and ornaments. It is also readily reduced by carbon. However, if reduced at temperatures below 7000-8000 C it is not suitable for forging and must be produced at temperatures above 11000 C. Wrought iron was the first form of iron known to man. It is interesting to note that in the early days iron was five times more expensive then gold and its first uses were as ornaments.

Iron weapons revolutionized warfare and iron implements did the same for farming. Iron and steel became the building block for civilization. Interestingly, an iron pillar dating to 400 AD., remains standing today in Delhi, in Qutab Complex. It is made of forged iron and corrosion to thepillar has been minimal. Iron is rarely found in its native state. The only known sources of native iron are in Greenland where iron occurs as nodules in basalt that erupted through beds of coal and two very rare nickel-iron alloys.

Lead

Lead is not found free in nature but Galena (lead sulfide) was used as an eye paint by the ancient Egyptians. Galena has a very metallic looking appearance and was, therefore, likely to attract the attention of early metalworkers. The production of metallic lead from its ore is relatively easy and could have been produced by reduction of Galena in a camp fire. The melting point of lead is 327 C, therefore, it would easily flow to the lowest point in the fireplace and collect. At first lead was not used widely because it was too ductile and the first uses of lead were around 3500 BC Lead is highly malleable, ductile and non-corrosive making it an excellent piping material. Lead pipes bearing the insignia of Roman emperors can still be found.

The ability of lead to flow and collect at the bottom of the campfire is an important concept in process metallurgy as reduction reactions to be useful must cause a phase separation between the metal and the gangue. Also, the phase separation should also enable the metal to be cast into a desired shape once concentrated.

Mercury

Mercury was also known to the ancients and has been found in tombs in Egypt dating back to 1500 and 1600 BC. Pliny, the Roman chronicler, outlined purification techniques by squeezing it through leather and also noted that it was poisonous. Mercury, also known as quicksilver, is the only metal which is liquid at room temperature. Although it can be found in its native state, it is more commonly found in such ores as calomel, livingstonite, cordierite and its sulfide cinnabar. Extraction is most simply carried out by distillation as mercury compounds decompose at moderate temperatures and volatilize. Mercury was widely used because of its ability to dissolve silver and gold (amalgamation) and was the basis of many plating technologies. There is also indications that it was prized and perhaps worshipped by the Egyptians.

In 315 BC, Dioscorides mentions recovery of quicksilver (which he called hydrargyros, liquid silver) by distillation, stating *"An iron bowl containing cinnabar is put into an earthenware container and sealed with clay. It is then set on a fire and the soot which sticks to the cover is quicksilver"*. Methods changed little until the eighteenth century.

14.2 HISTORICAL EVOLUTION OF METALS

We give here a brief account of the use of metals in different regions of the world and follow it up with details regarding the use of metals in India in the historical context.

14.2.1 In World

The Sumerian city-states are considered as the first major metal-using civilization. They navigated the Euphrates river for commerce, including the transportation of copper from Armenia to the north. At Gerza on the Nile river just south of the modern site of Cairo, the Gerzeans developed a civilization based on the metallurgy of copper which they had learnt from Mesopotamia, in about 3200 BC.

The pyramids and other great buildings of the Egyptian civilization were built of stones that had been quarried and shaped using copper tools. While the rock used in the buildings was found nearby, the Eygptians mined copper in the Sinai Peninsula. The scale of copper mining in the Sinai reached a size that made it the first real industry of the ancient world. The Egyptians mined deposits of the green copper mineral **malachite**. Malachite, a copper carbonate, was prized because it was the easiest copper mineral to reduce to copper metal. The closely related blue copper carbonate mineral **azurite** also was discovered. Near these two copper ore minerals, the early prospectors often found another copper mineral, blue-green turquoise. Turquoise is still prized around the world as a gem stone. Ruins of the old mines, the miners' huts, and inscriptions to the Goddess Hathor, the Lady of the Turquoise, can be found to this day in the Sinai.

Copper reached the island of Crete from Egypt. A copper axe from about 3000 BC was found on the floor of the ruins of a house. Egyptian barges carried copper to the western coast of Asia Minor, where they traded for the famous cedar wood from what is now Lebanon. Ruins of the Cretan civilization hold artifacts with Egyptian influence, such as fresco painting, pottery, and stone statuettes. However, the form of the metal objects is more like that from Asia Minor.

Metallurgy from Asia Minor reached Cyprus about 2600 BC. Egyptians traded fabrics and gold for copper from Cyprus. Myceneans settled near the copper deposit sites in Cyprus.

Early metal-smiths of Sumer, Babylon, and Egypt were highly prized members of their society. Often they were not free, owing their obedience and livelihood to temple priests and authorities. They were so valuable that invading armies made a special effort to carry them off in captivity. Metalsmiths transmitted their secrets to their children. Their guilds may have been the first trade unions in history.

Bronze, came into use at about the same time in Asia. Bronze artifacts dated at 3600 BC have been found in Thailand. Copper is found scattered around East Asia. Tin is found in the peninsula of Malaysia. Chinese written records date the first copper mining at about 2600 BC. and the first casting of copper vessels at about 2200 BC. The Shang dynasty's capital of Anyang in northern China had a bronze-casting industry in 1400 BC.

14.2.2 In India

India witnessed a long sequence of cultures using both stone and copper tools known as Chalcolithic cultures. The innovation in the Chalcolithic cultures was the use of the new technology of smelting and crafting bronze artefacts. The most prominent has been Harappan culture also termed as Bronze Age culture. We shall take up discussion on the use of metals in the historical sequence in which some of the early metals were used by the people.

Copper/Bronze

The copper workings in India have an antiquity dating back to the second millennium BC. They are reported from Barudih in Singhbhum. We alsohave a small finger ring discovered at Babri, Birbhum, West Bengal which has been formed from the chalcolithic levels and is dateable to about 1000 BC. It seems the copper mines at Chhotanagpur plateau were in use at that point of time and tin as an alloy was being used to obtain bronze.

In the Harappan culture copper tools were used to help cut stone tools in a more fine manner. The Harappans practiced alloying of copper and tin so that a more strong metal, bronze would be available. "Whereas 70 percent of analysed copper artefacts from Mohenjodaro and Harappa have been found to contain one percent tin (probably the same as found in the natural ore), the remaining 30 per cent had tin ranging from

8 to 12 per cent, which indicates that tin was here deliberately mixed with copper. The proportion of bronze within copper artefacts increases significantly with time at Mohenjodaro, and this was probably the case in the Indus civilization generally. Nickel, arsenic and lead were also used as copper alloys (Irfan Habib, *The Indus Civilization, A People's History of India 2*, New Delhi, 2002, p. 29).

The ore for smelting copper in the Harappan culture was most likely obtained from Rajasthan and Baluchistan, though Afghanistan and Persian sources too would have made the supply (Cf. D.P. Aggarwal, 'Archaeometallurgical Studies in India: A Review' in *Archaeology and Interactive Disciplines*, ed. S. Settar, Ravi Kovisettar, New Delhi, 2002, p. 426). "Copper was smelted in brick-lined pits, and wax-and-clay moulds were probably used to cast whole or parts of copper and bronze artefacts. These included tools such as razors, knives, chisels, hooks, sickles, saws and axes... Smaller copper tools include awls, nails, needles and tubular drills.... A considerable number of copper and bronze utensils (pots and pans) suggests that at least richer households could now use metal ware in addition to the breakable pottery" (Irfan Habib, *op. cit*, pp. 29-30).

The Chalcolithic cultures, other than the Harappans, also used copper for making different artefacts. A content analysis of these artefacts reveals that the chalcolithic metallurgical traditions and the Harappan tradition had distinct identities and the probability of any direct transmission is precluded (Cf. D.P. Agarwal, *op. cit*, p. 431).

Iron

The studies focusing on the history of introduction of iron in India had earlier believed that iron was introduced between 600 and 700 BC (cf.D. H. Gordon, *Prehistoric Background of Indian Culture*, Bombay, 1950). But the discoveries made at Painted Greyware (PGW) sites has now settled this date around 1000 BC. D.K. Chakrabarti has written a comprehensive work dealing with the discovery and use of iron in India (*The Early Use of Iron in India*, Bombay, 1992). Some of his main findings may be given here to understand the use pattern of iron:

- The probable date of production of iron in India is c 800 BC;
- The use of iron in India is earliest reported from Central India and South India;
- These production centres were located close to the areas from where ore was found;
- There was a continuity in tradition of iron metallurgy up to the preindustrial period; and
- Any correspondence between the Indian iron tools of the earliest period and the West Asian tools was lacking (Also see D.P. Agarwal, *op. cit.* p. 433).

Zinc

India provides the earliest evidence of metallic zinc. "There are references to burning a metal, *rasa*, to produce an eye salve, which should refer to zinc, placing it use in the last centuries of the first millennium BC. The *Rasaratnakara*, ascribed to Nagarjuna, the great Indian scientist who lived in the fourth century AD, describes both the production of brass by the familiar cementation process, and of metallic zinc. Furnaces (*Koshthi*) have been found at the ancient mines of Zawar in Rajasthan (D.P. Agarwal, *op. cit*, pp. 434-35).

The Zawar mines from where zinc was extracted are located at about 35 kms. to the south of Udaipur in Rajasthan. The ore is mainly a mixture of zinc and lead and is obtained in dolomite formations. Agarwal suggests that "zinc and some lead was being mined between the sixth and first centuries BC" (*op. cit*, p. 435). This trend then continued further and as we come to medieval India we find evidence of zinc distillation process on a fairly elaborate scale. P.T. Craddock (*The Early History of Zinc*, 1987) specializes in the study. We give an extract from him explaining the process (as quoted in Aggarwal) : "at first glance the Zawar industry is the most unusual phenomena, a fully fledged technology with neither antecedents nor successors—and apparently no contemporaries either, for even within India it seems unique.... Zinc required a much higher temperature and the total exclusion of air. The form of the Kosthi furnace for holding the retorts seems to have been inspired by the common spottery kiln. The arrangement is of course totally different, instead of a fire beneath to heat the pots stacked above through the perforated floor, in the Kosthi, the fire and retorts were in the upper chamber and the zinc was collected beneath… the Zawar process was certainly one of the most sophisticated and technically exacting process developed in the mediaeval world, one hesitates to use the term 'pre-industrial', for surely this process, with its appreciation of scientific techniques and learning towards mass production, should properly be considered as an early example of an industrial process in the modern sense'' (p. 435).

It is evident from the description given above that metals as a resource had come to grip the society firmly by the time state formation in India began. Thereafter, it was a question of controlling the resources. It is not without reason that the Magadhan state grew in and around Rajgrih which area was a significant iron ore area.

14.3 MINERAL RESOURCES

To be classified as a "true" mineral, a substance must be a solid and have a crystal structure. It must also be an inorganic, naturally-occurring, homogenous substance with a defined chemical composition. Mineral-like substances that do not strictly meet the definition are sometimes classified as mineraloids. A crystal structure refers to the orderly geometric spatial arrangement of atoms in the internal structure of a mineral. This crystal structure is based on regular internal atomic or ionic arrangement that is often visible as the mineral form. Even when the mineral grains are too small to see or are irregularly shaped the crystal structure can be determined by x-ray analysis and/or optical microscopy.

Chemistry and crystal structure define together a mineral. In fact, two or more minerals may have the same chemical composition, but differ in crystal structure (these are known as *polymorphs*). Similarly, some minerals have different chemical compositions, but the same crystal structure. Crystal structure greatly influences a mineral's physical properties. For example, though diamond and graphite have the same composition as both are pure carbon, but graphite is very soft, while diamond is the hardest of all known minerals.

A mineral is a naturally occurring, inorganic substance with a definite chemical composition and a crystalline structure. A rock is an aggregate of two or more minerals. (A rock may also include organic remains). The specific minerals in a rock can vary a lot. Some minerals, like quartz, mica or feldspar are common, while others have been found in only one or two locations worldwide. Over half of the mineral spices known are so rare that they have only been found in a handful of samples, and many are known from only one or two small grains.

There are currently just over 4,000 known minerals. according to the International Mineralogical Association, which is responsible for the approval of and naming of new mineral spices found in nature.

Minerals may be classified according to their composition. The list below is an approximate order of their abundance in the earth's crust.

- *Silicate Class* – the feldspars, quartz, olivines, pyroxenes, amphiboles, garnets, and micas;
- *Carbonate Class* – lime, dolomite, stalactites, and stalagmites;
- Sulfates – anhydrite (calcium sulfate), celestite (strontium sulfate), barite (barium sulfate), and gypsum (hydrated calcium sulfate). The sulfate class also includes the chromate, molybdate, selenate, sulfite, tellurate, and tungstate minerals;
- *Halide Class* – The fluoride, chloride, and iodide minerals;
- *Oxide Class* – hematite, magnetite, chromite, rutile, and ice;
- *Sulfide Class* – selenides, tellurides, arsenides, antimonides, bismuthinides, and sulfosalts;
- *Phosphate Class* – phosphate, arsenate, vanadate, and antimonite minerals.

One of the common use of minerals by humans has been in dietary form. They are inorganic compounds necessary for life and good nutrition. Some of these are minerals such as salt; others are potassium, calcium, iron, zinc, magnesium, and copper. These can be naturally occurring in food or added in elemental or mineral form. For a considerably long period the minerals in dietary form were used by man through experience.

14.4 SUMMARY

The inclusion of metal technology introduced some complexities into the patterns of living, for instance determining who was to control the new technology, since those who were producing the artefacts were not necessarily the same as those in authority. In most of the cultures bronze technology was accompanied by the script, beginning a new chapter in the process of historical evolution. If bronze marks the beginning of the new chapter in the social relations/stratification, then introduction of iron provided tools to colonise the newer terrain, not inhabitable until then. The process of expansion of agriculture received a new and potent tool. It provided tools to not only clear the forest tract but also to exploit the hidden potential of land other than the river denuded ones. Similarly minerals played an important role – as dietary supplement and in jewellery.

14.5 EXERCISES

1) The introduction of metals changed the life-style of man in a major way. Comment.

2) Discuss the introduction of bronze in Indian history and assess the significance of this process.

3) Compare the changes introduced in Indian history by bronze and iron.

4) Write a short note on minerals as a resource.

14.6 SUGGESTED READING

Bridget and Raymond Allchin, *The Birth of Indian Civilisation*, India and Pakistan before 500 BC, Penguin, 1968

Alan W. Cramb, *Short History of Metals*, Department of Materials Science and Engineering, Carnegie Mellon University