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METALLURGY IN MEDIEVAL INDIA

The metallurgy had gone through a long process of evolution and innovation. It is the spirit of human endeavour which allowed man to innovate, improvise and master technology through experimentation. The main reason for the technological development was the establishment of the Delhi Sultanate and later the Mughal empire, witnessed an increase in the degree of centralization, buraecuratization and urbanization in the regions it controlled.¹ The technique for production of metallic goods were so developed and as the historian K.N. Chaudhuri has documented, specialized metal goods like swords, armor, guns and ornamental metalware were being exported to number of West Asian countries in the medieval period.² Although the techniques for smelting and producing copper bronze, and later iron were present in a number of civilizations, the method of producing crucible cast steel was discovered and perfected in India.

Iron and Steel

India enjoys a reputation of being one of the ancient civilizations which was familiar with the art of making and use of iron. According to recent ¹⁴C ³

³. It is also called Radio-carbon Dating. It is a method of measuring in dead organic matter. The radio-active isotope C-14 which disappears at a known and calculable rate.
On the basis of the researches in this field, it may be asserted that the advent of iron was not via any external source but was an indigenous development within the subcontinent. Evidences show that the earliest iron known to prehistoric man was meteoric iron and it is the purest form of iron in the native state. The first reference of iron mention in ancient India text is *Rigveda*. Iron is described in this sacred writings as *ayas*. Ayas is said to be hard, tough, strong, tenacious, ductile and malleable. The metallurgy of iron slowly evolved over the centuries from slagrich simple wrought iron to steel and later to good quality of wootz steel.

**Ores**

The study of iron manufacture should start with required primary material like iron ore, flux and fuel. Iron ores are more abundant and more widespread than any other ores. Not less than 4.2% of our earth is formed by iron or its compounds. India has very large deposits of high grade iron ores (hematite) scattered in the hilly region beginning with Gwalior and extending to the tip of southern India. Iron mining area can also be identified on the basis of the *Ain-i-

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Akbari and other seventeenth century sources. These places are Kalinger, Burhanpur (in central India), Kumaon, Gwalior, Bazuha (in Bengal) and Indur and Nirmal (south India).

There are many literary sources of this period which provides great details on iron and steel and also its metallurgical uses in different fields. The Geniza records of the eleventh and twelfth centuries bear testimony to the export of Deccan iron and steel to the Middle East. The Romans also imported the very superior ‘Seric’ iron from the east, believing it to come from China but Forbes claims that it was of Indian origin coming from the famous smelting centre of Hyderabad. This Seric iron was known in china as bin iron (high carbon steel), Hinduwani in Arab countries, pulad (faulad) in Persia and finally Europeans pronounced it Wootz probably a corruption of the word ‘ukku’ in Telgu.

Process of making Wootz Steel

Wootz steel was made by a method resembling the modern cementation process or crucible process. The artisan placed small pieces of wrought iron in contact with wood and leaves of soecific plants (Cassia auriculata) and then

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9. Ibid., p. 442.
10. Ibid., p. 391.
11. Ibid., p. 478.
heated the lot in sealed clay crucibles at temperatures too low to cause complete liquification. Nonetheless, the iron crucibles were heated in a current of air till the iron became red-hot and plastic. It was then allowed to cool very slowly until it absorbed a fixed amount of carbon (1.5 to 2%) to make it into wootz steel.\textsuperscript{16} This wood steel on cooling, usually formed itself into round discs of 5” in diameter and $\frac{1}{2}$ in thick, weighing about 2 lb. These cakes were exported to Damascus in Syria for making sword-blades, which were appreciated for their sharp edges and beautiful, flowing water patterns on them.\textsuperscript{17} The manual of war was called \textit{Adabu’l harb wa’sh shuja’at} written by Fakhr-i Mudabbir during Iltutmish reign (A.D. 1210-36). He thought the Indian swords (swords of \textit{korij} in Cutch which was made of steel) to be the best, and writes that the Damascened sword (\textit{maujdarya}) was the rarest and fetched the highest price.\textsuperscript{18} Umari praised that iron ore of an exceptionally high grade was mined in India and was used to produce damascened steel which had a worldwide reputation.\textsuperscript{19} Nizami has also given a vivid poetic picture of the Indian swords of the solders of Gwalior. “That sword was coloured of cerulean blue, which from its blazing luster resembled a hundred thousand venues and it was well tempered horse shoe of five which with its wound exhibited the peculiarity of lightening and thunder; and in the perfect weapon the extreme of sharpness lay hid; like (poison in) in fangs of serpent and (the water of blade)

\begin{itemize}
  \item \textsuperscript{16} Mahmud, J.S., \textit{Metal Technology in Medieval India}, Daya Publication, Delhi, 1998, p. 42.
  \item \textsuperscript{17} Forbes in Singer (ed.), op.cit., p. 57.
  \item \textsuperscript{18} \textit{Adabu’l Harb Wa’sh Shuja’at}, ed. Ahmad Suhaili Khvansari, Tehran, A.H.S., 1346, pp. 258-60.
  \item \textsuperscript{19} \textit{Masalik al-Absar fi Mamalik al-Ansar}, Shihab al-Din al-Umari (Eng. Tr.) I.H. Siddiqi and Q.M. Ahmad, A Fourteenth Century Arab Account of India, etc. Aligarh, 1971, p. 61.
\end{itemize}
looked like ants creeping on the surface of diamond”.

According to Sarngadhara who flourished in the 13th or 14th century the reputed centers of swords manufacture were Khatikhatra, Risi, Vanga, Surparaka, Videha, Anga, Madhayamagrama, Vedidesa, Sahagrama and Kalinger. Among these places Anga swords became famous for their strength, sharpness and excellent handle. The colours of swords, according to him, depended on the types of iron that was used in their manufacture.

**Types**

Al-Biruni has mentioned about the two types of iron. One variety which is soft is called *narhaman*. This is a word of feminine gender. The second variety which is called *shabargan* and entitled as masculine as it is hard. It is malleable, but refuses to be folded. The *narhaman* kind is divided into two sub species. The first is the *narhaman* kind proper; the other kind is the water from it when it is melted and separated from the stones. The second sub-species is called *dawsa*, and in Persian *astah*.

Swords in Rome, Russia and Saqalibah are made from *sharbarqan*. They are occasionally called iqala, fatha and *jazm* i.e. the orthographical sign for remaining silent. Therefore, the *qala* sword possesses clangour, whereas the non *qala* sword possesses an irritating sound. When a particular class of swords is attributed to it, the class is collectively called *qalaiyyah*. Some people tend

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20. Elliot and Dawson, *The History of India as Told by its owns historians*, II, p. 227.
believe that these swords bear relationship to specific places, e.g. Hindiyyah
(Hindsutan), Yamaniyyah and Mashrafiyah.

The *Rasa Ratna Samuccaya* a compilation of the 13th or 14th century text
on alchemy. The chapter five, verses 69 through 96 give the information related
to metallurgical perspective. But these indigenous Sanskrit sources are not
very much helpful in understanding the techniques of production. It has
classified iron into three broad categories *munda* (wrought iron) *tiksana* (cast
iron, steel) and *kanta* (magnetic iron).

(i) *Munda loha* is of three types: *mrdu*, *kuntha* and *kadara*.

(a) *mrdu* – that which melts quickly on heating, does not break on beating,
which is soft and slimy. It is the best of all the three varieties of *munda*.

(b) *Kuntha* is one which spreads with difficulty on beating. This is of medium
type of qualitative grade.

(c) *Kadara* is inferior loha (iron) which breaks on hammering and looks
black.

(ii) *Tikshana loha* or steel which is made from cast iron/pig iron after removing
some of the impurities. *Tikshana loha* are of six types: *khara*, *Sara*, *pograra*,
*vajira* and *kalayasas*.

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23. Ibid., p. 60.
“Carburisation of Iron in Ancient India, *IJHS*, 29(3): 1994, pp. 358-359, has given different
shades of opinion with regard to antiquity of wootz in Ancient India.
(a) *khara* is hard, without *pogaras* (free from fibres), breaks on bending and shines like mercury on fracture.

(b) *Sara* – whose edges can be destroyed quickly and easily which is obtained from the pale earth.

(c) *Hrnnala*, which looks whitish black, contains *pogaras* like that of concubiji (castor seeds) and is hard to be pierced.

(d) *Pograra-Anga, Chaya* and *Vanga* are the three synonymous of *pograra*. The structure of iron which looks like hair follicles and which is brittle.

(e) *Vajira* is solid and very hard like *vajra* (diamond), it has minute likes and pogara is black in colour.

(f) *Kalayasa*, which is bluish black in colour, deme smooth, heavy and bright in appearance and whose sharpened edges do not get spoiled even by hammering with iron articles.

(iii) *Kanta loha*\(^\text{27}\) – This is obtained from magnetic iron ore. It is the best of all the three varieties of iron. *Kanta loha* is of five types, *bhramaka, cumbaka, karsaka, dravaka* and *romaka*. In the classification *bhramaka* is inferior, *cumbaka* is medium, *karsaka* is good and *dravaka* is the best of all.

Such types of iron classification we do not find in any Persian sources of medieval Indian history.

\(^{27}\) Ibid., verse 71, p. 193.
Large sized structures of iron like pillars, beams etc. used in monumental buildings are found in several parts of the country. The famous wrought pillar of Delhi (nearly seven tons) of the 5th century A.D., the huge iron beams at Puri (12th century A.D.) the ornamental gates of somnath and 43 ft. Dhar pillar in Malwa constitute elements of the historical legacy of metallurgical skill of Indian craftsmanship.

With growing emphasis on arms and armours, there also the requirements of iron for their production on a much large scale. For this purpose Shahi Karkhanas became busier for making cannons, guns and different kinds of swords. The emperors themselves look personal interest in their design and manufacture. The manual of war was called Adabu’l harb wa’sh Shuja’at, written by Fakhr-i Mudabbir has emphasise that the Indians had superior techniques or material for the manufacture of the sword. Swords of different kinds are quoted in this text, namely Cini, Rusi, Khazari, Rumi, Firangi, Yamani, Bilamani (red saylamani), Shahi, Sai, Hindi and Kashmiri.28

An important Sanskrit source of the fourteenth century A.D. (or 16th C.) is Sarangadhars by the Alchemist Saragadhara describes the technique of manufacturing swords. He mentions several important centres of sword making. He also given a detailed account of the quality of iron that was to be used for the manufacture of the different types of swords.

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Tuzuk-i Jahangiri, mentions the Meteoric iron which fell as meteors and it was used for making swords, though much earlier Ibn-Sina in his book *Kitab al Shifa*[^29] mentioned the fall of a meteor iron. Jahangir writes, “one of the strange events of this time was on 30 Fawardin (10 April 1621) in the present year, in a certain village of the pargana of Jalandhar; in the morning a terrible noise arose from the East. Such that its inhabitants, from fright at that terror increasing sound, nearly deserted their bodies. Whilst this noise and disturbance were going on, a light fell from above on the ground, and the people thought that fire was running down from heaven. After a moment, when that noise ceased, and their troubled hearts recovered from their bewilderment and terror, they sent a quick runner to the collector (amil) Muhammad Saed, and informed him of what had occurred. He immediately rode there himself, and went to look at the spot. For ten or twelve yards in length and breadth, the land was so burnt that no trace of any grass or green was left, and there were still signs of heat and burning. He ordered them to dig up the soil, and the more they dug the greater the heat appeared to be, till they came to a place where a piece of heated iron appeared. It was so hot as if it had been taken out of a furnace. After a while it became cold, and taking it up, he conveyed it to his house, and placing it in a Kharita (cover) which he sealed, he sent it to court. I ordered them to weigh it in my presence, and it came to 160 tolas. I ordered Master (ustad) Daud to make a sword, a dagger and a knife of it, and bring them to me. He represented that it would not stand below the hammer and fall

to pieces. I told him in that case to mix it with other iron and make use of it. As I had told him, he mixed three parts of lighting iron and one part of other iron, and having made two swords, one dagger and one knife, brought them to me. From the mixing of other iron, he had brought out its quality (watering). According to the manner of the excellent swords of Yaman, and the South, it could be bent, and became straight again. I ordered them to test it in my presence. It cut very well, equal to true swords".  

30. Khulasah-i Mufid-ul Insan (17th or 18th C).  

31. Persian source which describe the different chemical technology which were prominent in medieval time, gives the informations of polishing of western swords (Teqh-i Firangi). During the same period Mir Yahya in his book Majma’atu’s Sanai (cir. 1624) also give the information in making the European swords and sharping of the weapons like the swords.  

It is believed that the first cannons roared in India during the battle of Panipat in 1526. Moghuls were the major users of cannons and continued to manufacture them for centuries. Baburnama described the metal (for making cannon) was not melted in one furnace but in eight small furnaces from which the metal was designed to now together into the mould.  

32. The Ain-i Akbari, give the clear description of cannon manufacture. The barrel was made up of disks of wrough iron through which holes had been punched using hammers and chisels. These perforated discs were joined together by forge welding and
the joints were reinforced by slipping red hot iron rings into there joints so that on cooling these rings contracted tightly into the joints. This lent also describes methods of making the hard gun barrels which would now be made by a diagonal rolling of sheets of iron. Earlier strips of iron were rolled around an iron bar and the edges would be joined together by welding. This could lead to burst barrels or leakage of propulsion power. The new method provided barrels sacral folds thick and hence greater fire power.

Apart from its use in artillery iron found limited applicability in agricultural implements such as hoes, sickles, ploughsharcs, axes, etc. as well as in the making of house hold utensils. The curiosity of the nobility toward acquiring new information on production technique was largely nonexistent till the close of the 18th century and use of iron became limited.

Gold and Silver

The history of gold is the history of civilization. The first grains of this metal fell into the hands of humans several thousands years ago and almost immediately came to be considered precious. In ancient times Egypt was believed to be the richest country in gold.

Gold and silver are the noble metal. Its vessel, golden tray, colored dishes, gobblets, lota (water-pot), spoon and earthen pots, have been mentioned as articles of utensils throughout in the medieval period. The Tabaqat-i-Nasari

35. Ibid.
also refers to gold and silver dishes in the palace of Laksmanasena of Bengal.\(^{38}\)

It were also used for making coins, jewellery for adoration and other decorative items like flower vase etc. The *Ain-i-Akbari* describe the details of the working of the mint, describes methods for testing the purity of the precious metals, separating the two precious metals from each other and from other ingredients. The *sarafiss* (gold smith) were expert in handling these metals and made use of all the known physical and chemical processes involved in their working.\(^{39}\)

**Ores:** According to *Rasa Ratna Samuccaya* gold and silver were obtained from the mines or available as deposits on the Himalaya group of mountain.\(^{40}\)

*Tabkat-i Baburi* mentions that the silver was collected from Siwalik Mountain.\(^{41}\)

Thakkura Pheru (Royal treasury officer of Allaudin Khalji in his book *Dhatupatti* has stated that gold and silver particles are obtained from alluvial washings and in mountain rocks\(^{42}\) but he does not give the exact places of mines while *Ain* mention names of certain gold and silver mines which were kumaon\(^{43}\) (gold bearing sand used to collected), Guge in Tibet\(^{44}\) (gold mine), Punjab\(^{45}\) (collected from river sand), Tipara\(^{46}\) (gold mine) and Bhutant\(^{47}\) (small

\(^{38}\) Elliot and Dowson, *The History of India as told by its Own Historians*, ii, p. 309.

\(^{39}\) *Ain-i Akbari* tr. Blochmann, p. 16, 18, 28-32.

\(^{40}\) *Rasa Ratna Samuccaya*, tr. Dr. Damodar Joshi, *IJHS*, INSA, p. 186.

\(^{41}\) *Tabqat-i Baburi* of Zain Khan, tr. Hasan Askari, p. 110.


\(^{44}\) Ibid., p. 365.


\(^{46}\) *Ain-i Akbari*, op.cit. II, p. 132.

\(^{47}\) Alamgir Nama, Muhammad Kazim (ed) Khadim Hussain and Abdul Hai, Bib. Ind. Calcutta, 1865-73, p. 690.
amount collected from sand washing) in Bengal. *Mirat-i-Ahamadi* state that
gold was collected from the sands of *sonrekha* river (a stream flowing between
Girnar Hills and Junagarh) of Gujrat.48 The alluvial gold was collected by
spreading goat or sheep-skin49 when the gold particles carried by the river
which got caught in the hair of goat skin and were then shaken out and
collected. This collected reef gold were merged into small ingots in clay
crucible over charcoal fire. For this, temperature of 1063°C would have been
necessary. The existence of silver mines at Punjab (mines in the Northern Mts.
In Lahoresubha), Rajasthan (Sojhat and Jaitaram pargana), Kumaun, Bhutant
(Bengal), Assam (in the Mts. North of Uttar Kul), Guge in Tibet.50

The Method of purification of gold and silver:

The numerous purification and assaying processes found in literary
sources of medieval India like *Rasaratna samuccaya* and *Ain-i Akbari*. *Rasa
Ratna Samuccaya* states that take one karsa of gold plate and enclose it inside a
pair of earthen dishes along with salt(probably saltpeter) and red ochre and
apply heat for half an hour in the midst of burning charcoal .By this method its
ture colours will come out51

Tarnished gold + salt (prob. Saltpeter) +Backed soil powder  ————> Bright gold

Then the heated metal should be dipped seven times each in oil, butter, cow's
urine, and acidic liquid. This was the common method for the purification of

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gold.\textsuperscript{52}

The \textit{Ain} seven of \textit{Ain-i Akbari} give the most comprehensive and systematic process for purification and separation of gold and silver obtained after the smelting of gold/silver ores. Every hundred Jalali (or hundred tolas of) gold requires four sers of saltpeter and four sers of brick dust of unburnt bricks.\textsuperscript{53}

The gold plate was washed with clean water and then stratified the above mentioned mixture and put one on top of the other. This whole mound was covered with cow dung known in Hindi as \textit{upla} then were blazed it and allowed to burn gently until they were reduced to an ash. This ash was kept aside and fresh \textit{upla} were kept around the gold plates and ignited. This process was carried out three times after which the gold plates were called as \textit{sitai}. By this process, the impurities were absorbed in the brick dust and dry cowdung. This operation must be repeated till six mixtures but only eighteen such fires was the gold considered pure.\textsuperscript{54} The ash obtained from this process was known as \textit{khak-i-khalis} in Persian and \textit{saloni} in Hindi.\textsuperscript{55}

If on breaking the gold plate a soft sound originate the gold was considered pure. If the sound was harsh, the plates of gold were going through to three more fires. The method of assaying was as follows. From each of the gold plates one \textit{masha} was taken away of which aggregate a plate was made which was tested on the touchstone and if required one or two more fires were applied. In most cases, however, the desired effect was obtained by three or four fires. Yet another method of

\textsuperscript{52} Ibid., p. 211.
\textsuperscript{53} Ibid. (ed. N. Kishore), pp. 15-16; Ain, tr. Blochmann, pp. 21-23.
\textsuperscript{54} Ibid. (ed. N. Kishore), p. 23.
\textsuperscript{55} Ibid., p. 21.
assaying was also used that was as follows: Two tolas of pure gold were taken along with two tolas of the gold which passed through the fire and made into twenty small plates each of equal weight. These plates were then stratified with the above mentioned mixture (of saltpeter and brick dust) and (after wrapping with upla) the heaps were ignited. After this both kinds of gold plates were found in equal weight it was a proof of their purity.\textsuperscript{56} The gold which was red on heating, white on cutting, yellow on rubbing, shining bright was considered pure.\textsuperscript{46}

For the purification of silver\textsuperscript{57} a hole was dug in a ground and sprayed into it a small quantity of cow dung then it was filled with the ashes of mughilan\textsuperscript{58} wood. These ashes were moistened and the dig work as a crucible. Impure silver was placed into this hole along with one-fourth its weight of lead on the top of the silver, covered the whole with coals and blow the fire with the help of bellow until both the metals were reduce to a molten state (boiling point of silver 1063C). This operation of heating and melting was generally repeated four times. The indications of purity were a lightning-like brightness, and the molten silver beginning to harden at the sick. As soon as it would begin to harden at the middle, it was sprinkled with water which cause flame issued from it resembled in shape the “horn of wild goat”. It then formed itself into a disc of perfectly refined. If this disc was melted again half a surkh in every tola will burn away or 6 masha and 2 surkh in 100 tolas. The ashes of the disc

\textsuperscript{56} Ain, tr. Blochmann, vol. 1, p. 22.
\textsuperscript{58} Ibid., op.cit., p. 23.
which was mixed with silver and lead formed a kind of litharge, called kharal in Hindi and *khushta* in Persian. The Hindu text *Rasa Ratna Samuccaya* also give the purification method of silver\(^{59}\) which is somewhat related with the Abul Fazl’s technique.

Take an earthen dish and sprinkled a mixture of lime and ashes in a circular row and placed in it impure silver with its equal weight of lead and also sprayed borex (\(\text{Na}_2\text{B}_4\text{O}_7.10\text{H}_2\text{O}\)). Now covered the whole with charcoals and blow the fire till the lead was consumed. Repeated this process for three times and the silver would purify.

The silver which was compact, heavy, clear, bright, soft, white in colours, free from fissures, and white on cutting and heating was considered to be superior quality.\(^{60}\) And the inferior quality of silver exhibited red, yellow, or black in colours on heating, rough, full of fissure, light, and hard to touch and was not recommend for use.\(^{61}\)

The *khak-i-khalis* was collected by Niyariya\(^{62}\) who first washed it in a vessel whatever gold particles contain in *khak* would settle down at the bottom of the vessel due to its weigh and thus be collected. The remaining ash (still contain gold), known as *kukhra* in Hindi, was rubbed with quicksilver so that the gold inside the ash to form an amalgam which was kept over the fire in a retort would lead to an easy evaporation of the mercury/ quicksilver and the

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\(^{59}\) *Rasa Ratna Samuccaya*, op.cit., p. 189.
\(^{60}\) Ibid., p. 187.
\(^{61}\) Ibid.
\(^{62}\) Ibid., p. 24.
separation of the remaining gold. The amalgamation process was known to the Romans and Pliny describes the way in which mercury is used to recover gold as the above process was executed.\textsuperscript{63}

The rest of the ash (\textit{kukhra}) which still contained some gold and silver, for the recovery of this precious metals the well-known technique of cupellation was applied. This process is probably the oldest and most efficient way of separating the precious metals from the baser ones. Its principle is alloying the gold with lead or copper in a special pot or crucible and oxidizing the product by means of heating the precious metal in a strong current of air so that the base metals are oxidized and absorbed by the wall of porous containers. (As we have seen in all the above purification process that the cupel which was the pit lined with ash in the case of silver and the clay brick dust in the case of gold).\textsuperscript{64} The \textit{Ain-i-Akbari} gives the clear description of the method of cupellation.\textsuperscript{65} (Though Jabir Ibn Hayyan (Geber) the Arab chemist of the 9\textsuperscript{th} century, gives a clear description of the determination of noble metals by cupellation).

The rest of the ash was mixed with lead powder called \textit{Punhar}.\textsuperscript{66} This

\textsuperscript{64}. Ibid., p. 177.
\textsuperscript{65}. \textit{Ain-i-Akbari}, op.cit. p. 24. Cupellation: Method of the separation of silver, gold and other nobles metals from impurities which are oxidized by hot air. The impure metal is placed in a cupel (a flat dish made up of porous refractory material) and a blast of hot air is directed upon it in a special furnace. The impurities are oxidized by the air and are partly swept away by the blast and partly absorbed by the cupel.
\textsuperscript{66}. \textit{Punhar} was prepared by heating lead in the presence of carbon ashes (especial ashes of Babul-wood) until it melt. The coals were removed, the bellows inlet closed, and the lead allowed to cool in the absence of oxygen. This lead to the formation of lead granules absorbed in ash. This mixture was known as \textit{Punhar}. 
Punhar was mixed with a mild acid known as *rasi* (it was made from *ashkhar* or *sajji* or potassium hydroxide and saltpeter) and rolled into balls weighting 2 *sers* each. These balls were dried in the presence of sun. Now take a vessel of one and a half yards (4.5ft.) in length consisted of a clay vessel, narrow at the both ends, and wide in the middle which was the ingenious design. With a hole at the bottom and filled the vessel with coals within four fingers of the top then placed it over a pit dug in the earth and blow the fire with two bellows after that dried ash balls were broked into pieces and now throw them into the fire and melt them. The lead was thus reduced and was the first to fall through into the pit and was thus separated from gold, silver, copper alloy called *burgrawati*\(^{67}\) the other impurities were blown away as oxides.

The process of remaining alloy of gold, silver and copper was as follows. A pit was dug in the ground and filled with the ashes of *babul-wood* (half a ser for every 100 *tolas* of *bugrawati*) shaped into a dish. The pit was covered with coals and were ignited till this alloys became molten after which they were removed and replaced by babul wood and heated once again. The copper, along with traces of lead, was absorbed by the ashes leaving the silver and gold in an alloy form.

**The method of separating the silver from the gold**

The composition of remaining two metals, the silver and gold alloy was melted six times: thrice times with copper and thrice times with sulphur called in Hindi *chhachhiya*.\(^{68}\) For every tola of the alloy, one *masha* of copper and

\(^{67}\) *Ain-i-Akbari*, op.cit.,p. 25.

\(^{68}\) Ibid (ed.) N. Kishore, I, p. 26. Abul Fazl probably meant some special type of sulphur. He wrote *Gugard-i-Chhachiya*. 
two *masha*, two *surkh* of sulphur. The mixture of gold and silver is burnt first with copper and next with sulphur. And if in all, 100 *tolas* of the mixture was present, 100 mash as of copper was used in following manner. First 50 mashas was mixed and melted with the alloy and then the remaining half was used in two equal proportions. The sulphur was also used in similar manner. (Thus if 2 masha and 2 surkh of sulphur is to be used per tola of the alloy. then for 100 tola as 225 masha will be used, first 112.5 masha and then the remaining half in two equal proportions).\(^6\) Therefore, initially the mixture of gold and silver was broken into small bits and melted with 50 masha of copper in a crucible. A vessel full of cold water, covered by a meshing of hay (*khas*) was kept close at hand. The molten mass was then poured through this meshing and the water stirred continuously so that the pieces do not form into mass. These granules were again melted twice with the remaining copper (in two equal portions) and thrice with the sulphur in similar proportions. After the mixture was allowed to cool after the final melting with sulphur, a white ash appears on the surface of the molten mass. This ash was a form of silver. This silver was purified by the process described earlier i.e. heating with lead in a bone ash' crucible.

The above process is a rather interesting example of the application of the application of 'beading' or breaking up of molten mass into small pieces so as to provide a larger surface area for reaction.\(^7\)

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\(^7\). See textbook on Chemistry, for this information.
Thus the alloy was melted three times with sulphur and three times with copper and then allowed to cool. After the final cooling, a white ash appeared on the surface of the mass. This ash was a form of silver which was purified by heating in a bone-ash crucible. The remaining mass containing gold is called *kail* in Punjabi and *pinjar* around Delhi. The gold revocable is of low quality. The process of mixing this gold with purer gold in the ratio 1:8 and purification according to *aloni* or *saloni* may be undertaken. This process involved the making of an oxygen-rich paste of 2 parts of cow-dung and 1 part of saltpeter which was rubbed on the surface of the crude gold ingots (already smeared with sesame oil) on heating these ingots, a considerable degree of purity was attained.\textsuperscript{71}

Even the ash left after this process was not wasted. The *Paniwar* adds 1.1/2 sers of borex (*tanger*) to every man of *kharal* (ash) along with 3 sers of natural sodium carbonate (*naturun*) and kneads them together. This mixture is then put ser by ser into the furnace described previously (the *tanur*) when lead, mixed with silver, collects in the pit (at the bottom of the furnace).\textsuperscript{72} This mixture was separated in accordance with the method of purification silver. This lead thus attained may be used to prepare the *Punhar* for the earlier stage of the reclamation process already described.\textsuperscript{73}

Other process for the purification of gold wire using cow-dung, rock salt

\textsuperscript{71} Ain-i-Akbari, op.cit., p. 26.
\textsuperscript{72} Ibid., p. 27.
\textsuperscript{73} Ibid.
and washings with lime juice was also known.\(^{74}\) *Rasarnavakalpa* and *Rasa Ratna samuccaya* also gives the method of killing gold and silver.\(^{75}\)

**Zinc**: India was the one of the ancient civilization which was familiar with the art of making, brass and use of zinc in it, but zinc as a separate metal became known much later.

Zinc was not found in native form but was obtained almost from minerals. Calamine or zinc carbonate was the main ore of zinc which forms heavy crusts of crystals, usually colored green, and blue, yellow, gray or brown by impurities\(^{76}\). *Rasaka* or *Kharpard*\(^{77}\) was the name generally applied to the mineral calamine in sanskrit.

*Rasarnava*\(^{78}\) the twelfth century text, mentioned the process for zinc extraction from calamine as follow: “*Rasaka* (calamine) mixed with wool, lac, *Terminalia chebula*, and borex and in a covered crucible, yields and essence of the appearance of zinc”.

Although the earliest Indian reference to the production of zinc as metal was given in the *Rasaratnakara*\(^{79}\) of Nagarjuna. He mentions that copper could be converted into brass by heating it with calamine and organic matters but it did not bear a separate name it was referred to as a metal of the appearance of tin.

\(^{74}\) *Ain-i Akbari* (tr. Jarett) iii, p. 314, Cf. I.G. Khan, ‘Metallurgy in medieval India’ in ed. Anirudh Ray & S.K. Bagchi, Technology in Ancient and Medieval India, Delhi, Sandeep Prakashan, p. 84.


\(^{77}\) *Rasa Ratna Samuccaya*, op.cit., verse 149, p. 49.


\(^{79}\) P. Ray, op.cit., p. 130.
Mukamusagatam dhamatam tankanena samanvitam

satvam kutilasamkasam patate natrasasayah.

This verse state that zinc are digested repeatedly with fermented paddy-water, natorn and clarified butter, and mixed with wool, lac, Terminalia chebula and borex and roasted in a covered crucible.

The next important alchemical text is Dhatumanjari\textsuperscript{80} that was complied during 13\textsuperscript{th} or 14\textsuperscript{th} centuries A.D. Jasatava, yasadayaka, rupyablrzrata (lit. broher to silver) and charmaka were the synonyms to zinc as given by this text but it was not clearly mentioned as the metals. Greeks use the word cadneia, The Arabs use the term tutiya or totia\textsuperscript{81} and in Persian Ain-i-Akbari given the name to zinc as Ruh-i-tutiya.

Yasada or zinc is not described in Rasa Ratna Samuccaya as it was not known as specific metal but Forbes accepted that zinc was prepared by Indian (Hindu) chemists through distillation process since the twelfth century.\textsuperscript{82}

The apparatus used for producing zinc by distillation method were similar to Kosthi\textsuperscript{83} described in the Rasa Ratna Samuccaya, recently discovered at zawar near Udaipur.\textsuperscript{84} (Fig. A)

\textsuperscript{80} Ibid., p. 197.
\textsuperscript{81} Forbes, R.J., Studies in Ancient Technology, Vol. viii, p. 269.
\textsuperscript{82} Ibid., p. 281.
\textsuperscript{83} Rasa Ratna Samuccaya, op.cit. vol. 26, Chapter IX, verse 46, IJHS, July 91, No. 3, p. 344.
\textsuperscript{84} Rina Shrivastava, Mining and Metallurgy in Ancient India, p. 183.
Figure A : Kosthi Yantram (Apparatus)
[This apparatus used by the Hindu metallurgist for the manufacture of zinc]

Calamine is to be powdered with lac, treacle, white mustard, the myrobalans, natron and borax, and the mixture boiled with milk and clarified butter and made into balls. These are to be enclose in a crucible and strongly heated. The contents are then poured on a slab of stone -the essence of calamine of the beautiful appearance of tin (thus obtained) is to be used.
Or a vessel filled with water is to be placed inside a koshi apparatus and a perforated cup or saucer placed over it; a crucible charged as above is to be fixed in an inverted position over the saucer and strongly heated by means of the fire of jujube (Zizyphus jujube) charcoal; the essence which drops into the water should be applied in medicine.

*Rasaparakasasudhakara* of Yasodhara has given almost identical process with that described in the above mentioned text. Irfan Habib argue that zinc separation through distillation, first achieved in China in tenth century then arrived in India by the fourteenth century on the other hand Forbes’ grudging remark that “Zinc was prepared by Indian chemists since the twelfth century but that this remained a laboratory experiment and never was applied to industrial product”. Yasada (jasta) as a specific metal became known to Indians from the fifteenth century A.D. Bhavamisra mentioned zinc in his work *Bhavaparakasa*, as the saptadhatu (seven metals), whereas the Persian text, *Haft Ahbab* of twelfth century Persian text clearly states about the seven metals and considered zinc as a metal, represented by the sign of the planet, Mercury (Utarid).

Archeological evidence suggests that the mining of zinc ore and smelting industry at zawar (Rajasthan) began in the mid centuries of the first

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86. Irfan Habib, *The Economic History of Medieval India*, Tukika publication, p. 5.
87. Forbes, R.J., op.cit., p. 280.
88. *Haft Ahbab*, Ms. No. 77, CAS, Department of History Library, A.M.U., Aligarh, folio no. 4.
millennium B.C.\textsuperscript{89} The \textit{Ain-i-Akbari} is the first Persian source which give the clear evidence of zinc mine in zawar. Abul Fazal give the description of zinc (jast), which according to the opinions of some, is \textit{Ruh-i-tutiya} and resembles led, is nowhere mentioned in Philosophical books, but there is a mine of it in Hindustan in the territory of jalor\textsuperscript{90} which is a dependency of the subha of Ajmer.\textsuperscript{91} The Sanskrit text, \textit{Dhatukriya} or \textit{Dhatumanjari also} mentioned the location of zinc: kambhoja, Ruma (Istambul), Balkh\textsuperscript{92}, etc. but these area were out of the boundries of India during medieval period.

The \textit{Ain} describe the three verities of brass that were made from copper and zinc oxide (\textit{ruh-i-tutiya}) which contain 28\%, 33\%, and 42\% zinc. The last verities being so hard and brittle that it could only be cast.\textsuperscript{93}

In the seventeen century, China exported zinc to Europe under the name of ‘\textit{totamu}’ or tutenag. The term tutenag may derived from the south Indian term “\textit{tuttanga}”.\textsuperscript{94} The Persian writer Ibn-i-Hawqal (950 A.D.) states that zinc was come from Sardan and Inclia.\textsuperscript{95} Marco polo also mentioned the deposits of zinc mines in Sindh and India.\textsuperscript{96}

\textsuperscript{90} Jalor is an obvious misreading of Zawar. It was one of the dependencies of Gogunda. Cf. Irfan Habib \textit{Mughal Atlas}, p. 20.
\textsuperscript{91} \textit{Ain-i-Akbari} (S.S.) p. 28; (N.K.), I, p. 37; tr. Blochmann, p. 42.
\textsuperscript{92} Ray, P., op.cit., p. 198.
\textsuperscript{93} \textit{Ain-i-Akbari}, op.cit., p. 42.
\textsuperscript{94} Vijaya Jayant Deshpande, \textit{History of Chemistry and Alchemy in India from pre-Modern Times}, p. 140.
\textsuperscript{95} Forbes, op.cit., p. 280.
\textsuperscript{96} Ibid., p. 269.
**Copper:** According to the definition of Jabir copper is “Metallick Body, livid, partaking of a dusky redness, ignoble (or sustaining ignition), fusible, extensible under the Hammer but refusing the cupel and cement”. In Greek alchemy copper is represented by the sign of the planet venus. According to Rasakamdhhenu, in India, copper is said to have originated from surya (sun). In Rome it is known as khalque, in Syria it is nusahaan, in Arabic nuhas, mis and qitr. In Sanskrit it is called tamra while in Persian it is known as nahari. Copper is a soft, red colored metal and possessing metallic lustre. It is very widely distributed in nature and is found in soil, water and ores. The Atlas of Irfan Habib has facilitated the location of the important medival ore-sites.

The important mines of copper were at Singhana, Udaipur, Babi, Kotputli, and Cainapur in Rajasthan and Kumaun in suba Awadh. The ores obtained from these places were quite rich in copper. The kotputli mine of copper was so rich that one man of ore (khak) yielded 35 sers of copper. The Rasa Ratna Samuccaya has described the two verities of copper on the basis of the place of origin. The one brought from Nepal was considered of superior quality while the other was Mleccha an obscure origin, was considered impure.

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97. Ibid., p. 1.
101. Ibid., ii, 285.
The early medieval texts describe the smelting processes which was prevalent in the contemporary society. Rasarnava and Rasaratnasamuccaya describe extraction of copper from Makshika or pyrite as:

“Makshika, repeatedly in honey, oil of seeds of ricinus communis, urine of cow, clarified butter and the extract of bulbous root of musa supieutum when gently rosted in a crucible yields an essence in the shape of copper”.103

The method for the extraction of copper from Vimala or Iron pyrite is given in Rasaratnakara, Rasarnava and Rasaratnasamuccaya as:

“Vimala digested with alum, green vitriol, borex and watery liquid extracted from moringapter, musa sapientum and finally roasted in covered crucible in combination with the ashes of Schrebera swiet, yields and essence in shape of Chandraka (Moon)”.104

By the some recent evidence which gives glimpses of the possible technique employed by the early metal-workers for extracting copper from its ores and this technique was perhaps continued in medieval period also. Since copper is found in the form of sulphides, oxides, and carbonates being to undergo reduction at around 750°C, a small pit in the ground surrounded by removable fire clay rings to enforce a good draught of air (enhanced by bellows) with an opening for extracting the molten copper105 (Fig. B)

103 . Rasarnava, vi, verses, 12-13 and Rasaratnasamuccaya, ii, verses, 89-90.
104 . Ibid., 103-04.
105 . Bose et al., Concise History of Science in India, p. 300.
Figure B: A native copper smelting furnace at Singhara near Khetri in Rajasthan\textsuperscript{106}

\begin{itemize}
\item[a] Three separate annular parts made of fire-clay and placed one upon the other firmly
\item[b] Chamber for burning some quantity of charcoal.
\item[c] Openings for poking the fire form time to time.
\end{itemize}

The ore is crushed to a powder, mixed with cow-dung, made into balls (pindi) and roasted. The charge consisted of roasted ore, charcoal and Iron slag (acting as flux). The slag is first drawn off, and the smelted copper which accumulated at the bottom of the furnace is removed the following day. This mass is again melted, refined in an open furnace using a strong blast from below, and finally cast into bars.\textsuperscript{107}

The \textit{Rasaratnasamuccaya} also gives the four methods for the purification\textsuperscript{108} \textit{tamra} (copper) that was as follow:

(1) Melt copper foils in presence of Alma (acid), add gairika to it and pour

\textsuperscript{106} Bose, D.M., Sen, S.N. and Subbarayappa, B.V., \textit{A Conise of History of Science in India}, INSA Publication, 1971, p. 300
\textsuperscript{107} Negoi, \textit{Copper in Ancient india}, Calcutta, 1918, p. 63-4.
\textsuperscript{108} Ibid., verses, 49-52.
the whole into butter milk and dung-juice of buffalo, seven times, in each liquid. By doing so tamra gets rid of dosas (bad effects).

(2) Well cleaned plates of copper should be anointed with *saindhava lavana* (rock salt) mixed with lemon juice. These then be heated strongly and dipped in sauviraka (acidic liquid). This process is repeated eight times to make tamra purified.

(3) Anoint copper plate with acid and rock salt paste, heat strongly and dip in nirgundi juice eight times. By this method also tamra plate get purified.

(4) Boil the plates of copper in cow’s urine for one yama on strong heat. By doing so tamra definitely gets purified.

Copper comes to be utilized more commonly during the subsequent ages for minting coins. With the dawn or the 16th century, copper was acquiring monetary importance due to the continuous debasement of the silver *tanka* introduced by the Delhi Sultan in which copper later came to predominate. Its role was increased in A.D 1540 when Sher Shah and then Akbar established a pure and uniform tri-metallic currency in India.109 Akbar introduced different types of copper coins during his reign like *Dam, Adhela, Paola,* and *Damri* but the *Dam* was the most prominent.110


Uses of copper for the construction of guns and cannons (most of cannons were cast in bronze, mostly copper containing and 20% tin) occupied an important place in Mughal rule. Babur, the first Mughal Emperor, who first introduced guns in India, has given an account of the casting of a Copper gun in his well known memoirs. Babur writes: “Around the mould they erected eight furnaces for melting the metal (copper). From the foot of each started a channel which ended in the mould. The fused metal rushed into the mould through these channels like boiling water, till the mould was filled up. A day or two afterwards when the mould had cooled down, it was opened. The bore of the piece had no fault and a chamber could easily be made in it. The body of canon was then uncovered, and a certain number of artificers were set to finish it”.

The application of ‘tinning’ (qalai) of copper utensils are also found from the Persian sources of medieval India. The history of this process in India (qaliai) has already been examined by the P.K. Gode\textsuperscript{112} who, apart from citing the literary evidence in the Ain also cites archeological evidence such as a copper bowl with tin plating on the interior as well as the exterior, belonging to the Bhamani Period (1347-1550 A.D). The Ain-i-Akbari clearly mentions the tinning of copper utensils in the royal kitchen twice every month for the emperor and once a month for the princes and others in the royal family.\textsuperscript{113}

The tinning (qalai) process was very much the same as at present. A low

\textsuperscript{111} Baburnama (Cf. Beveridge) II, 536-7.
\textsuperscript{112} Gode, Studies in Indian Culture, Poona (1976) iii, pp. 116-117.
\textsuperscript{113} Ain-i-Akbari (ed.) N. Kishore, I, p. 57.
melting tin soldier (232°C) is applied to the red hot copper utensils. The tin due to the high temperature melts and can be rubbed into the hot copper surface. This plating is saved from oxidation and 'peeling' by immediately plunging the utensil into water.\textsuperscript{114} The Mughals were therefore aware of the corrosive effect of organic acids on copper and plated it with the relatively unreactive tin. Surface colouration of metals was an established art in Mughal India and Badauni writes about an alchemist who "turned copper utensils in gold".\textsuperscript{115}

**ALLOYS:**

A metal-like substance that is a mixture of two or more metal. Alloying was developed because it changed the physical and chemical characteristic of materials according to requirement. Alloys can be classified by the number of their constituents. An alloy with two components is called a binary alloy; one with three is a ternary alloy, and so forth.

**Brass:**

Pittal/Brass is an alloy containing copper and zinc in the ratio 2:1 is described in \textit{Rasa Ratna Samuccaya}.\textsuperscript{116} \textit{The Ain-i-Akbari} (1590), the magnum opus of Abul Fazed described three types of brass\textsuperscript{117} follows:

(a) Having 2½ sers of copper (72%) and 1 ser ruh-i-tutiya or zinc (28%), this type of brass was said to be malleable even when cold.

\begin{itemize}
\item \textsuperscript{114} The Tin solidifies and contracts into continuous plating on the hot copper surface, whose melting point is much higher (1035oC).
\item \textsuperscript{115} \textit{Muntakhab-ut-Twarikh}, Badauni (tr.) George S.A. Ranking, vol. III, reprinted, 1990, pp. 161-162.
\item \textsuperscript{116} \textit{Rasa Ratna Samuccaya}, op.cit., p. 228.
\item \textsuperscript{117} \textit{Ain-i-Akbari}, ed. Sir Syed, p. 28, Ain, tr. Blochmann, . 42.
\end{itemize}
(b) This brass had copper 67% and zinc 33%, which was malleable when heated.

(c) Alloy of 58% copper and 42% zinc and could only be worked by casting. Vagabhatta described two varieties of Pitted, namely ritika and kakatundi. Of these the ritika was considered as superior because which was heavy, soft, smooth, yellow, shining, clean, malleable, ductile and cool to touch was considered to be of superior quality. The best example of the notable brass gun of Mughal time is “Great gun of Agra” which had enormous of 14 ft. in length and 221/2 inch in bore, into which a man could easily enter in a crouching position. Its weight was 53 tons.\textsuperscript{118}

**Bronze:**

It is an alloy made by mixing "eight parts of copper with two parts of tin."\textsuperscript{119} The Kansaya/bronze made in Saurastra was considered the best.\textsuperscript{120} Two type of bronze were discussed in *Ain-i Akbari*.

\textbf{(a)} Safiduri (white bronze): This was known as kansi in Hindi and it was the mixture of copper and tin in the ratio 4: 1 (80% copper and 20% tin).\textsuperscript{121} This bronze must have been very hard and brittle as the percentage of tin in bronze must not normally exceed 14% (or correctly 8-12%).\textsuperscript{122}

\textbf{(b)} Rui (black bronze): another type of bronze containing copper and lead in the ratio 8:3 (or 27% lead) are also described in the *Ain*. This alloy was called

\textsuperscript{118} Bose et al., *Concise History of Science in India*, p. 341.
\textsuperscript{119} Ibid., p. 229.
\textsuperscript{120} Ibid.
\textsuperscript{122} Subbarayappa, B.V., ‘Chemical practices and alchemy’, op.cit., p. 281.
by Hindustani people as *bhangar* while the Persians called as *Rui*.\(^{123}\) Bronze which produce intense sound, soft, white in colours and turns red on heating was known as superior quality.\(^{124}\) The most important gun of the Mughal time is the famous *Malik-i-Maidan* (lit. monarch of the plain), made of bronze.

The material of the gun on analysis revealed the following composition: Copper, 80.4%, tin, 19.59% (extract 4:1 ratio) length, 14.3”; diameter, 4’10” at mouth; 2’4½” at bore; probably cast in Ahmadabad in 1549 during the reign of Sultan Burhan Nizam Shah, and now in Bijapur. According to Fergusson and others it formed the largest piece of ordinance in the world at their time.\(^{125}\)

**Sim-i-sukhta (burnt silver)**: It was the composition of lead, silver and bronze and was used in painting.\(^{126}\)

**Kaulpatr**: According to Abul Fazal this alloy was the invention of Akbar. It contained 2sers of Safidru (bronze) and 1 ser of copper. It was colored and looked well.\(^{127}\)

**Bist biswa**: This was the discovery of an alloy in silver. Silver was alloyed with lead, tin and copper. In Iran and Turan it was called the highest degree of fineness of silver *dahdah*, while in Hindustan; *Sarraf* used for it the term *bist biswa*. According to the quantity of the alloy, it descends in degree; but it is not made less than five, and no one would care for silver baser than ten degrees. Practical men can discover from the colour of the compound, which

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\(^{123}\) *Ain-i-Akbari*, op.cit., p. 42.  
\(^{124}\) *Rasa Ratna Samuccaya*, op.cit., p. 229.  
\(^{125}\) Neogi, op.cit., pp. 32-38.  
\(^{126}\) *Ain-i Akbari*, tr. Blochmann, p. 42.  
\(^{127}\) Ibid.
of the alloys is prevailing, whilst by filing and boring it, the quality of the inside is ascertained. They also try it by beating it when hot, and then throwing it into water, when blackness denotes lead, redness copper, a white grayish colour tin, and whiteness a large proportion of silver.\textsuperscript{128}

**Vamloha**: copper (tamra) mixed with steel (tiksna loha) was melt and the melted powder in lakuca juice associated with sulphur for a number of times converted itself into an alloy and that was known as varaloha.\textsuperscript{129}

**Chandrarka**: Sixteen parts of silver was mixed with twelve parts of copper and melted together. The material thus obtained was called Chandrarka.\textsuperscript{130}

**Ghosakrista Tamra**: When molten bell metal (Kansaya) mixed with a little talaka (orpiment) and subjected to tadana (blowing) through vankanala (bent tube) liberate tin from it and leaves pure copper then that was known as ghosakrista tamra.\textsuperscript{131}

**Vartaloha**: It was also an alloy made by mixing five metals, bronze, copper, brass, iron, and lead in equal proportion. It was also known as panchaloha or Vartaloha.\textsuperscript{132}

**Haft-josh**: According to Abul Fazal Haft-josh, like kharsini, is nowhere to be found. Some call it taliqun while other gives this name to common copper. It is consist of six metals, probably, gold, silver, copper, tin, iron, and lead.\textsuperscript{133} The

\textsuperscript{128} Ibid., p. 23.
\textsuperscript{129} *Rasa Ratna Samuccaya*, op.cit. chapter 8, verse, 12, p. 304.
\textsuperscript{130} Ibid. (8:23).
\textsuperscript{131} Ibid. (8:38).
\textsuperscript{132} Ibid. (5:212).
\textsuperscript{133} *Ain-i Akbari*, tr. Blochmann, p. 42, Ain, ed. Sir Syed Ahmad, I, p. 28.
Jawaharnama\textsuperscript{134} of Mohd. Asharaf bin Asad Rustamdari who compiled this treats on mineralogy for Babur (compiled 1530 A.D). He state that it is an alloy but not mentioned the metals from which it is made. It is used for making utensils. \textit{Farhang-i-Anand Raj}\textsuperscript{135} (c. 1650 A.D.) of Anand Raj also mention about the “Haft josh” he says it is an alloy whose Turkish term is taligun. It is made of gold, silver, copper, tin, iron, and Zinc. It is poisonous and has a mirror surface used for making tweezers, arrowheads, lanceheads. Ibn Batuta’s \textit{Rehla}\textsuperscript{136} (C.1330 A.D) also informed that the iron pillar at Mehrauli was made of Haft josh around Delhi.

\textbf{Ashtdhatu:} Abul Fazal describes the chemical relationship between \textit{Hafi josh} and \textit{Asstdhatu} by saying that it is a compound of eight metals. The six of the \textit{haft-josh} plus \textit{ruh-i-tutiya} (zinc) and \textit{Kansaya} (bronze). It is also made of seven compounds.\textsuperscript{137}

Thus, it is evident from the foregoing pages endeavour enabled development and progress in the field of metallurgy. The establishment of the Delhi sultanate fostered technological development. The iron and steel industry flourished in India since ancient times. The various sources of medieval period describe different types of iron and their ores, method of purification of gold and silver, separating silver from gold, smelting process, detail discussion on alloys such as brass, bronze and \textit{haft josh}, etc.

\textsuperscript{135} Farhang-i-Anandraj, Tehran A.H. (1336), p.
\textsuperscript{137} Ain-i-Akbari, op.cit., p. 42.