EPIC OF SALTPETRE TO GUNPOWDER

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The article provides a very tentative contour of an epic which is yet to be written in completeness, even several details of which may not have been yet discovered. Whereas the development of the nuclear weapons has taken only a few decades of the 20th century, the epic of the development of saltpetre to gunpowder, and the associated knowledge proliferation across many countries, spanned over many centuries, in fact more than a millennium.

The Chinese origin of this epic (with a faint Indian link) is more or less established. The story of guns and other firearms is outside the scope of this article. This dissertation highlights the contributions of eminent scholars like Needham, Sarton, Gode and Iqtidar Alam Khan, and also emphasizes the cross-currents of the progress and clash of civilizations, as the grand saga went on unfolding itself over the ages. History of armament research and development inevitably ushers in the philosophical issue of ends and means in the human civilization.

Key Words: Chinese gunpowder tradition, Firearms, Gunpowder, Indian gunpowder tradition, Pyrotechnics, Saltpetre, Transmission, Technical terms - Arabic, Persian, Sanskrit, Turkish, Urdu.

A PROLOGUE

The spirit of human civilization has never endorsed ‘violence’, and yet has encountered violence from the Nature, the animal world and diverse and hostile human traditions as facts of life, to be resisted by scientific knowledge and technological innovations. The knowledge regarding fire and its applications, some of them catastrophic, cannot be unlearnt, even for the sake of the high ideals of peace and non-violence. The mankind has encountered similar moral dilemma with regard to stones, sticks and swords, then gunpowder and explosives, recently nuclear weapons.

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Referring to the medieval age collapse of the Hindu civilization in India, Swami Vivekananda, the great patriot-saint, wrote in one of his epistles: “The Hindus had been conquered by the Mohammedans due to the Hindus’ ignorance of material civilization, gunpowder and cannon”. The great Swami was by no means an advocate of unbridled violence and senseless application of gunpowder, and yet some of his admirers have attempted to edit and mask his remarks.

Mahatma Gandhi wrote in his Hind Swaraj that: “We have managed with the same kind of plough as existed thousands of years ago... It is not that we did not know how to invent machineries; but our forefathers knew that, if we set our hearts after such things, we would become slaves and lose our moral fibre”

We do not endorse Gandhi’s notion that India’s spiritual culture prohibited or even inhibited the progress of science and technology or the development of armaments. Iron and steel technology was freely used for making swords and war implements in the ancient India, and guns in the medieval India. Even for the Chinese invention of gunpowder, there was an Indian link, as documented by Joseph Needham.

**Saltpetre in the Ancient Civilization**

W.J. Palmer explained for the first time how nitrogenous refuse like urea, ammonia etc. are converted to nitrite and then to nitrate by nitrosifying and nitrifying bacteria respectively, and how potassium - (from plant ash), sodium - and calcium - nitrate layers on the soil were produced near human habitation in the ancient civilizations.

For many centuries the entire world was dependent for the supply of saltpetre, essentially potassium nitrate, also containing some sodium nitrate (Chilean saltpetre) and calcium nitrate (wall saltpetre), on superficial deposits resembling river-bed *natron* (Egyptian Wadi Natrun) and *reh* (Indian Ganga-Yamuna river bed). Whereas formation of non-nitrogenous *reh* has an entirely geological basis, biological factors have played crucial roles in the formation of *sodā* or saltpetre, which is nitrogenous. The formation of saltpetre depended upon natural sources of lime, carbonate, potassium (pot-ash) sodium and other...
ganic nitrogen simultaneously, and such deposits were available all over the tropical countries. Formation of saltpetre deposits was much subdued in the cold countries of Europe.

India distinguished between sārika kṣāra (also known as reh), sodium based alkaline salts of detergent properties, and yava kṣāra plant-based potassium (pot-ash) salts. Yet there was considerable confusion between non-hygroscopic potassium nitrate (KNO₃), the chief constituent of saltpetre and (later) gunpowder, and hygroscopic (hence deleterious) sodium/calcium salts such as sodium sulphate, carbonate etc. China was the first nation to clearly distinguish hsiao (solve) shih (stone), identified by Needham as potassium nitrate, from similar salts of sodium and calcium.

The name hsiao shih appears first in the 4th century BC text Chi Ni Tzu and then again in a 2nd century BC text in a medical and macrobiotic context. The 2nd century AD (Later Han Dynasty) text Lieh Hsien Chuan emphasized the medical property of hsiao shih (imparts immense longevity) and hints at widespread farming of saltpetre deposits. Much later (a text of 973AD) the etymology illustrated the use of saltpetre as a flux: “It was because saltpetre can dissolve (hsiao) and liquefy (hua) minerals, that it was given the name of solve-stone (hsiao shih)”. When heated, saltpetre was known (to decompose and) release energy as heat and ‘turn lead and tin into mercury’. Hot quartz could be melted in its contact. Many minerals such as alum, realgar, cinnabar could be dissolved. The last one could yield mercury.

Needham and his collaborators have provided many details regarding the early Chinese contributions on saltpetre and a soft link with Indian traditions. According to them, the crucial evidence related to the Chinese discovery of the properties of potassium nitrate comes from Thao Hung-Ching’s 492 AD text Pen Tshao Ching Chi Chu, wherein it is written:

“These people formerly obtained a certain substance with a colour and nature more or less similar to that of phu hsiao (identified as sodium sulphate by Needham). That certain substance, now known as genuine hsiao shih, is bright like the light of early dawn and resembling a handful of salt or snow, but not (as hard as) ice. When it is burnt or strongly heated in the fire, a bluish purple flame (tzu chhing yen) arises, and again it turns to a limy ash, not boiling and bubbling like phu hsiao”.

This 492 AD text also described its strong deflagration on hot charcoal and its availability in Lung-hsi (Kansu), Chhinchow in Szechuan, Western Chhiang and in the mountains everywhere (with salty earth) north of Tang-chhang. Similar statements were made by the author in his 510 AD text Ming I Pieh Lu quoting third century AD knowledge. This is the oldest reference to the lilac or bluish purple colour potassium flame in any civilization. After that, there are many references in the Chinese literature to the purple potassium flame, the deflagration, and the properties of flux and solubilisation. The following quotation from the 7th century AD Thang alchemical text about the wandering monks Chin Shih Pu Wu Chiu Shu Chieh (TT900) establishes the fact that Indians were aware of saltpetre and its properties:

“Originally this (saltpetre) was produced in I-chou by the Chiang tribes people, Wu-tu and Lung-hsi, but now that which comes from the Wu-Chhang country (Udyäna: a region of the high Indus valley near Gandhāra and Tokharestan, lies south of the Hindu Kush mountains, on the border of modern Afghanistan and Pakistan, north of the road between Kabul and Peshawar), is also of good quality. In recent times, during the Lin-Te reign period of the Thang, in a chiatzu year (664 A.D.), a certain Indian monk called Chih Fa-Lin (of Yüeh-chih or Saka stock) came to China bringing with him some Sanskrit sutras for translation. When he reached Ling-shih district, he found that the place apparently abounds in saltpetre but the quality is unsuitable. Later he came to Tse-chou with his brother monks, collected the local sample of hsiao shih and found that upon burning, it emitted copious purple flames (like imported thien ming sha, presumably a potassium salt, potash alum). The Indian monk said ‘this marvellous substance can produce changes in the Five Metals, and when the various minerals are brought into contact with it they are completely transmuted into liquid form’. Its properties were indeed the same as those of the material from Wu-Chhang, though the Tse-chou material was a little softer’.4

Quoting the above paragraph, Needham commented that this is not really any evidence for Indian primacy in the stated subject. Yet he conceded that Indians had independent knowledge of saltpetre, and carefully considered the questions of ‘Indian-Chinese chemical contacts during the Thang period and the mutual indebtedness of China and India’. 4 Both the nations were capable of distinguishing yellow brass from gold through flame test and tooking for recipes for immortality.
The Arab alchemists knew saltpetre (occurring in marshy lands of Morocco etc) as *thalj-al-Sin* or the Chinese snow, and in Persian language it was *namak shurâj Chini* or the Chinese salt. Even the Arabic word *bârud* originally stood for saltpetre. Al-Jaubari referred to *bârud-al-thalji* or snowy saltpetre in 1225 AD. Later it meant gunpowder. Needham claimed that there was no word in Classical Sanskrit language for saltpetre, the word *śodaka* ('odd in Hindi, Bengali etc.) being later derived from the Persian *shurâj*. Similarly, *bârud* entered the Indian vocabulary. Thus, ancient India had known (purple flame producing) saltpetre but failed to utilize it for producing gunpowder!

As Needham has explicitly claimed: “It is crystal clear that the methods for the collection and purification of potassium nitrate were steadily developing in China during seven centuries (500-1200 AD), preceding the first knowledge of the salt in Islam or the West; by the beginning of the 8th century, the sulphates of sodium and magnesium had been separated by differential crystallization and were being used in medicine”

Needham quoted one 8th century text claiming: “It is difficult to procure *hsiao shih* (saltpetre) of good quality. Inferior specimens cannot bring realgar and cinnabar into solution. One should first take a piece (of sample for testing) and place it upon burning charcoal. If purple smoke is emitted and the specimen turns to a kind of ash, then it is of good quality, but if it fuses and bubbles for a long time then it is *phu hsiao* (sodium sulphate)”

A very clear statement was provided by Ma Chih in his *Khai - Pao Pen Tshao* dated around 973 AD:

“It was because saltpetre can dissolve (*hsiao*) and liquefy minerals that it was given the name of solve-stone (*hsiao shih*). When it is first boiled and refined, it crystallises in small prickly shapes. Solve-stone is in fact a ground frost, an efflorescence of the soil. It occurs among mountains and marshes, the places where it is produced have an extremely loathsome smell, so that birds cannot fly over them, people sweep it up, collect it, and dissolve it in water, after which they boil to evaporate it, and so it is prepared. The crystals look like the pins of a hair-ornament, as much as five *fen* (about half an inch) in length. Its colour is bluish white”

Proto-gunpowder compositions based upon saltpetre must have been accidentally discovered in China during the 9th century AD or even earlier. During the early part of the millennium, emphasis was laid on dissolving
various minerals to produce ‘alchemical gold’ and ‘elixir for immortality’. Such attempts involving sulphur, charcoal and organic materials must have resulted in pyrotechnic accidents and the discovery of deflagrative compositions. For example, one Taoist literature entitled *Chen Yuan Miao Tao Yao Lüeh* dated approximately 850 AD described a (dangerous) recipe:

> “Some have heated together sulphur, realgar and saltpetre with honey, when smoke and flames resulted, so that their hands and faces have been burnt, and even the whole house (where they were working) burned down”.

Li Fu-Yen, a scholar from Kansu writing around 831 AD described another fateful elixir experiment during which the experimenter ‘saw purple flames bursting forth from the chemical furnace and enveloping the house’.

There were plenty of accounts of alchemical explosions in the 9th-11th century AD Chinese literature, well before the subject was known to the Arab and European alchemists. By 1220 AD, Bokhara and Samarkhand had fallen to the Mongols and the Arab literature (Al-Jaubari) mentions *barūd-al-thalji* or snowy saltpetre in 1225AD.

**Advent of the Age of Gunpowder**

Taylor and Singer have written a very useful note on the ancient combustibles, incendiaries and explosives, and Hall on ancient and medieval pyrotechnics.

The use of fire as a weapon of war is very ancient. The materials whose combustible or combustion properties were used for military purposes were: sulphur, bitumen, resin, tar, volatile petroleum as ‘naphtha’, and then saltpetre. Various tactical methods for exploiting fire were fire-arrow or fire-lance, fire-pot and various projectiles like tubes and rockets.

The improved form of liquid combustible known as ‘Greek Fire’ was apparently devised in the seventh century AD. It was to the expert use of this weapon that the Byzantine Empire owed its survival through the Muslim attacks of 673-78 AD. A tenth century Byzantine manuscript shows that Greek Fires were directed in land-and naval battles from siphons which were bronze force-pumps, from the nozzles of which jets of burning liquid were hurled. The Muslim states learnt Greek Fire technology using petroleum seepages in Iraq and employed fire-pots and projectile-engines like mangonel and trebuchet.
The Chinese took centuries to develop gunpowder. The recipe of Wu Ching Tsung Yao dated 1044 AD had sulphur, saltpetre, charcoal, pitch, tung oil and wax stirred into a paste and wrapped in five layers of paper, tied with thread and covered with wax or pitch. Hydrocarbons formed a considerable part of this substance and the recipe was more suitable as a fiercely burning firework rather than as an explosive 12. Bamboo tubes filled with gunpowder (higher percentage of saltpetre) were soon brought into military service. The Chinese invention of fire-arms with barrels of metal followed naturally from the compression of explosive compositions into hollow cylinders of bamboo or rolled paper along with stones and bullets. The European countries gradually acquired this technology; the oldest surviving example of a metal barrel gun in Europe 13 is dated 1356 AD.

In consultation with Professor J.R. Partington, Needham distinguished between the five evolutionary phenomena in military pyrotechnics: 14.

1. Slow burning of old incendiaries like oils, pitch, sulphur etc.

2. Quick burning of distilled petroleum or naphtha, Greek Fire, hurled in breakable pots.

3. Deflagration of low nitrate (40-60%) powders, burning with a sudden and sparkling combustion, producing the momentum of ‘Roman candles’, fire-lances or rockets.

4. Explosion of mixtures with higher proportions of nitrate, best with sulphur and charcoal as combustibles. Thin walled containers of cast iron or other metal (bombs) can be broken, if the firing is done in a closed space, producing a considerable amount of noise.

5. Detonation of modern-day ‘gunpowder’ with optimal proportion of saltpetre, sulphur and charcoal 75:13:12, a full propellant for projectiles launched from metal-barrel canon or guns with walls of adequate strength. The nitrate, constituting the built-in oxidizing powder for the combustion, produces suddenly 3000 times its bulk of gas (nitrogen, oxides of carbon) and many salts of potassium in particulate form. The temperature reached in the explosion is of the order of 3880°C.
The reactions in burning, deflagration and explosion proceed and propagate because the unreacted material near the reaction zone is heated to above its decomposition temperature by heat conducted from the hot reaction zone. The propagation rates are typically less than 1 mm/sec for burning, and about 1000 m/sec for ‘explosion’. In ‘detonation’, the reaction propagation is brought about more by immensely rapid compression, a shock wave traveling through at the speed of sound; the detonation velocities are in the range of 7000-10000 m/sec. This is a much more violent mechanism. According to modern parlance, gunpowder ‘explodes’, but ‘high explosives’ like nitroglycerine or TNT ‘detonate’.

Needham has documented a continuous increase in the nitrate proportion which took place between the first warlike use of gunpowder in China in the 10th century AD, when the saltpetre hardly exceeded 50%, up to the ‘theoretical’ figure of 75% which was reached on or before the early part of 13th century. In gunpowder, sulphur lowers the ignition temperature to 250°C, increases the speed of combustion raising the temperature to the fusion point of saltpetre (335°C). As for the charcoal, its physical state, grain size, degree of aggregation and surface area are of crucial importance. Quite appropriate is John Bate’s aphorism (1634 AD): “The Saltpeter is the Soule, the Sulphur the Life, and the Coales the Body of it (gunpowder)”.

It is thus evident that alchemical experiments on proto-gunpowder and gunpowder were made for six centuries in China before the West had access to it. Gunpowder technology came to the West in the 13th century AD, as a part of ‘transmission cluster’ along with paper technology, cast iron technology etc. This took place when (and after) the Mongols invaded Eurasia, took control of China, and the Christian traders, monks and technicians had direct access to the Chinese technologies.

**George Sarton on Gunpowder**

George Sarton had written: “It is impossible to say when and where gunpowder was invented, but it is probable that the invention was made in the Latin world or perhaps in Syria in the second half of the thirteenth century. The possibility of a Chinese invention is *not excluded but is unproved*”. The subsequent investigations made by Joseph Needham showed that it was really a Chinese invention.
Sarton rightly pointed out that invention of gunpowder and fire arms involved a slow and ‘long series of smaller revolutions’. The invention of fire-arms was ‘not made before the second quarter of the fourteenth century’.

The discovery of gunpowder hinged on the isolation and purification of non-hygrosopic potassium nitrate, known as ‘saltpetre’, often confused with the associated hygroscopic materials: sodium nitrate (Chile saltpetre), calcium nitrate (wall saltpetre), as well as chlorides and sulphates. The ninth century industry in al-Baṣra (869 AD) probably dealt with alkali salts and not saltpetre. The earliest clear reference in the Muslim literature to real saltpetre is found in the work of Ibn al-Baiṭār, who wrote that ‘bārūd’ is known in Morocco and that the Egyptian physicians called it Chinese snow (thalj al-ṣīnī).

Marc, the Greek, probably flourished in the second half of the thirteenth century. His compilation Liber ignium had recipes of many ages dealing with incendiary and pyrotechnic substances: Greek fire, phosphorescent substances, explosive substances containing saltpetre etc. His Greek text was translated into Arabic, and later from Arabic into Latin. He provided the recipe for gunpowder: one part of sulphur, 2 parts of charcoal and 6 parts of saltpetre, to be very finely powdered upon a marble slab and then mixed together.16

Al-Hasan al-Rammāh (the lancer) was a Muslim writer on military subjects, who lived in Syria and died in his thirties during 1294-1295. His treatise Kitāb al-furūṣiyā dealt with military operations, means of using lances, bows, siege engines; how to fight at sea; how to communicate fire and finally pyrotechnic recipes. Al-Hasan considered saltpetre the fundamental substance of pyrotechnics. He was the first to explain the method of purifying potassium nitrate by repeated crystallization.

Sarton commented that the Greek and the Syrian texts ‘must have been partly derived from the same sources’. Sarton went on to emphasize that ‘it was not enough to discover gunpowder, but it was necessary to apply its explosive force to the propulsion of missiles’. That application, the invention of fire-arms was ‘not made before the second quarter of the fourteenth century’.

Roger Bacon may have known something of gunpowder, and he was certainly acquainted with various inflammable and pyrotechnic substances. ‘In his Opus tertium, Bacon speaks of a powder, the explosive power of which
would be increased if it were enclosed in an instrument of solid material’. Sarton queries: ‘Was this gunpowder,?\textsuperscript{15}

**VIOLENT TRANS - CULTURAL CONTACTS OF THE 13TH CENTURY**

George Sarton failed to trace the origin of the use of gunpowder in human civilization, but mercifully did not deny the possibility of the Chinese origin. We have enough circumstantial evidence to show that a number of Chinese inventions such as those of paper, printing, gunpowder etc. were propagated across Asia and Europe following the violent intrusions of the Mongol army in the 13th century\textsuperscript{17-20}. A bit of narration of the violent trans-cultural contacts of the said period is therefore necessary.

Genghis Khān (1162-1227) belonged to the Shamanite (Buddhist) society of Mongolia and led his world-infamous invasions (1206-1227) of the mainstream Buddhistic China, the Muslim and the Christian worlds of Asia and Europe. These barbaric invasions were continued and further extended by his descendants, during the 13th and even 14th century.

In 1219, the army of Genghis Khān had more than one lakh soldiers, each with several horses: ‘The Mongol pony express, with regular changes of horse and rider at relay stations, could cover 600 kilometres a day, a speed not equalled again until the coming of the railways’. The tradition was nomadic but there was a hard core of newly acquired technologies for war. The sieges of Beijing and other Chinese societies (1214-23) provided the Mongols with the best in siege technology and expertise. Tied onto horses and camels, dragged in wagons or on their own wheels, were battering rams, scaling ladders, four-wheeled mobile shields, trebuchets with their many different types of fire-and smoke bombs, flame-throwing tubes, and the huge double- and triple-bowed siege bows. Four decades later, in 1258, some 1000 Chinese siege-bow crews accompanied the Mongol armies in their assault on Baghdad. ‘This formidable combination of nomadic cavalry and siege weaponry had never been seen before’.

The army of nomadic warriors had become adept at siege warfare, with catapults able to throw gunpowder-filled bombs some 200-300 metres, flame-throwers, multiple bows, and the first true fragmentation bomb, the ‘heaven-
shaking thunder’, which was recorded during the siege of Kaifeng in the northern China in 1232. It consisted of an iron casing filled with gunpowder that exploded so violently that it could be heard several kilometres away; any soldier within 10-12 metres of it was ‘blown to bits, not even a trace being left behind’. This is what Roger Bacon must have referred to, three decades later, in his *Opus tertium* (1266AD).

On the 9th of April 1241, the Christian army of Poland was shattered by the Mongols at Liegnitz. Next day, Subedei, a ferocious general of (now deceased) Genghis Khan, crossed the river Sajo in Hungary, seizing the only bridge with catapults and gunpowder, the first recorded use of this devastating weapon in Europe.

The date of 1232 in Kaifeng, northern China and 1241 in Hungary clearly show that the first recorded use of gunpowder in the medieval world was in the first half of the 13th century, not in the second as stated by Sarton, and this was introduced by the Mongols who had learnt the recipe from the Chinese. The Mongols adapted from the Muslims, superior armour and light-weight swords of Damascene steel. The ‘Greek fire’ or petroleum incendiary was also successfully adapted and used by the Mongols.

The Mongol conquest had religio-cultural overtones. Genghis Khán, a Shamanite, wanted to settle score against the Muslims who had earlier destroyed the beautiful Zoroastrian and Buddhist civilizations in Persia, Afghanistan and Central Asia. Prior to his 1219-1220 AD onslaught on the Muslim empire of Khwarezm (straddling much of present day Uzbekistan, Turkmenistan, northern Iran and Afghanistan), Genghis Khán had uttered: “Let us ride out against the Islamic people, to gain vengeance”. Then again in March 1220, he destroyed the city of Bukhara and lectured to the Muslims in a musalla, a courtyard for prayers: “I am the punishment of God. If you had not committed great sins, God would not have sent a punishment like me upon you”.¹⁸,²⁰

In 1221, the Christian Europe heard of Genghis Khán’s exploits and was delighted to know the fate of the Muslim society suffering at the hands of the Mongols. At that moment, Christianity needed help in their fight against the Muslims in the Fifth Crusade. However the Mongols attacked the Christian nations of Georgia, Poland and Hungary as well. Gradually, the Venetian mer-
chants saw the potential of commercial trade with China and Far East through a modicum of friendship with the Mongols.

For 150 years after Genghis’s death, the Christian Europe continued to benefit through the cultural and trade interactions, advancing in the technologies related to construction of canals and roads, cavalry, silk, porcelain, paper, printing, gunpowder and fire-arms. The Muslims also learnt the secret of gunpowder from the Mongols. Around 1304, the Mongols conducted their last unsuccessful assault on Syria; only two decades earlier, al-Hasan of Syria had compiled his *Kitāb al-fūṣīya* containing recipes for gunpowder and fire-arms of that period.

Genghis Khān’s descendants were the victors in the military domain over a vast expanse of land, but became the victims in the religio-cultural plane succumbing to the deeply entrenched traditions of Taoism and Buddhism in China (Khubilai Khān) and Islam in the Near East and Central Asia. Hulegu’s great-grandson turned Muslim. Amir Temur of the 14th century, also known as Timur-e-lang or Timur the lame, was a Barlas Turk, married a (captured) princess of the house of Genghis Khān. He called himself a ‘gurgan’ or son-in-law of the great Khān and emulated Genghis in conquest, loot, plunder, rapine and unspeakable atrocities. He professed Islam and yet massacred Muslim cities like Bukhara, Baghdad and Damascus. Of him it is said that ‘he used Islam when he needed to justify his most horrific acts, and discarded it when it suited him’\(^2\). The horror of massacre at Delhi (1398 AD) perpetrated by him is well-known.

The design of fire-arms using gunpowder was improved during Timur’s time in the 14th century and we find his descendant Bābūr (calling himself a ‘Mughal’ rather than Mongol) entering in India during the early part of the 16th century with sophisticated cannons.

It is thus seen, as pointed out by Sarton, that the successful use of gunpowder in guns or cannons took several centuries, the steps of which are yet to be fully chronicled through meticulous research on multi-lingual literatures. Gunpowder itself was known to the Chinese long before its knowledge was transmitted by the Mongols to the Muslim and Christian world. The Chinese antiquity of gunpowder has been adequately documented by Joseph Needham and his co-workers.
IN VOLVING GUNPOWDER

In his monumental work on the Chinese contributions to science and civilization, Needham inserted his thoroughly researched treatise on ‘the gunpowder epic’, and proposed his paradigm on the inter-cultural transmissions that took place from China to the rest of the world during the 12th to 14th centuries. There were ‘transmission clusters’ according to him, several important inventions and discoveries moving westwards together: one wave on magnetic compass, the windmill, blast furnace technology for cast iron (first going to the Scandinavian countries); another on mechanical clock, paper-making and printing.

Under the topic of saltpetre to gunpowder and use in cannons, we may consider that there were probably three separate and sequential transmissions:

a) the knowledge of fire-crackers learnt by Europeans of Roger Bacon’s era before 1265 AD.

b) the knowledge of fire-lances, bombs and rockets got into the hands of the Arabs and Europeans by 1280 AD and then incorporated into the literatures of Hasan al-Rammā and Marcus Graecus, and then

c) the knowledge and use of the metal-barrel bombard and hand-gun learnt by the European military around 1300-1315 AD.

It may be carefully noted that the first three items as stated above, namely fire-crackers, fire-lances and bombs had been current in China since 10th century onwards; however rockets were used in China since the second half of the 12th century only, and the evidence of metal-barrel bombard and hand-gun in China comes only from about 1290 AD.

There were many channels through which the knowledge of fire-crackers might have reached Roger Bacon. During the 1240’s, the first few friar monks visited the Mongol court at Karakoron. During the 1250’s Guillaume Boucher, a metal worker and engineer was employed in the same court of the Khans and knew William Ruysbroeck, a Franciscan monk visiting the Mongol court. The latter was personally known to Roger Bacon in Paris.
We have earlier mentioned about the use of gunpowder-filled bombs, thrown by catapults, in the siege of the Kaifeng in northern China in 1232 and during the Hungarian battle over the Sajo river in April 1241 (documented by Prawdin). Needham questions whether the knowledge of gunpowder-filled bombs was transmitted to Europe any time prior to 1260 AD.

However after 1260 AD, transmission of the knowledge of fire-arms related to gunpowder became easier. At that time the Mongols, particularly Khubilai, distrusted Chinese scholars and employed many technically gifted men from Persia, Syria and the Arab lands. During the siege of Hsiangyang (Saian-fu) between 1268 and 1273, great use was made of the counterweighted trebuchets, which Needham proposes to be an Arab invention. The Persian and Syrian experts in Khubilai’s army might have transmitted the knowledge to their homelands.

In this connection it is very instructive, as pointed out by Needham, that ‘the first soldiers anywhere in the world to use metal-barrel hand-guns were the Chinese detachments in the Mongol service a couple of decades after the fall of Hsiangyang, that is to say during the 1290’s. It is quite possible that Khubilai, the Mongol, was instrumental in harnessing the Arab and Chinese talents simultaneously in triggering the new phase of fire-arms. However, we need to undertake deeper research investigations in this area.

Needham has advised us not to overlook the possible continuing roles of the European (and Chinese) ecclesiastics and European merchants in the transmission of knowledge about gunpowder bombs, mines, fire-lances and rocket arrows around 1280 AD. The descendants and followers of Genghis Khan were exercising firm military control all over Asia. The Christian missionaries were regularly sent to Mongol courts as political ambassadors, ‘to seek the help of the Mongols against the Muslims, the traditional foes’. It was a classic case of encircling an enemy with the help of the enemy’s enemy. “The overall strategy of the friars, directed against Islam”, wrote Needham, “succeeded beyond all expectation, apart from the fact that the Mongols did the job for themselves, and made no firm alliances with Christian powers”. Having subdued Persia, the Mongols established their Ilkhânate Empire, centered in Iran, and then invaded Iraq, ruining Baghdad in 1258 AD. At that time, Rabban
Bar Sauma, and his young accomplice, Marqos Bayniel, both Chinese Christian (Nestorian) priests, born and educated in Beijing, visited the Mongol Ilkhâne, and then represented the Mongols at Rome in 1287 AD. Their emissary was partly political, 'to get Western assistance for ousting the Muslims from Jerusalem. They might have been accompanied by a Mongol or Chinese gunner, Chhi Wu Wen, who conveyed the knowledge of gunpowder technology to the Western world (Needham, ref. no.22, p. 575 footnote).

Needham has also hinted at the possible role of the European merchants like Marco Polo in diffusing the gunpowder technology to the West. There was a colony of Italian merchants established at Tabriz in the Ilkhâne, where the Venetian Pietro Vilioni died in 1264. In 1269 Mongol ambassadors from the Ilkhân arrived at Genoa. From 1274 onwards, Buscarello Ghisolfi played a crucially important diplomatic role between the Ilkhâns, the Italian city-states and the Pope and even in England, ‘on the usual ploy of constructing Mongol-Christian alliances against the Muslims’. In the meantime, Marco Polo’s father Niccolo and uncle Maffeo had been to China during 1261 to 1269 AD. Marco himself went with his elders (1271-1295) and served Khubilâi Khan, sometime on secret service missions. The merchants might have played an important role in transmitting the military technology.

Gunpowder weapons had certainly helped to put Khubilâi on the Chinese throne in the 1250’s. The Mongol Yuan dynasty dominated China till the end of the century, but later the Mongols undervalued research and development on gun and gunpowder; the great success of Chu Yuan-Chang during the 1350’s in driving the Mongols out and establishing the Ming dynasty, was partly because he encouraged all efforts to improve artillery and gunpowder weapons. In the mean time, the Christian Europe had started its independent developments in the concerned area of military technology.

Needham speculated that the third stage of transmission i.e. that of the true metal-barrel bombard and hand-gun, reached Europe directly overland, and not through the Arabs at all. There is a persistent Chinese tradition that the Russians were the intermediaries in the travel of gunnery to Europe. The Mongol incursion into Russia had started ever since the fall of Russian Ryazhân in 1237. The Russian word pushka for cannon was probably derived from the
Chinese *phao.* Possibly the Arabs received the bombard from Russia, not directly from China, and that too not before the time of al-Rammāḥ (that is after 1280 AD).

As we have mentioned before, the earliest recorded use of the metal-barrel bombard and hand-gun in the Christian Europe took place around 1300-1315 AD as revealed from the 1326 AD literature of Walter de Milamete. Ever since then, the Western world marched on its own in the unending quest for science, technology and conquest of the nature. As Needham has appropriately concluded:

"By the beginning of the (14th ) century the bell had rung, the curtain had come down (on the gunpowder epic), and the western world was set upon the fateful road to all the techniques of managing explosions: all later small-arms and artillery, but not only that, all heat-engines too, and all space travel."

Many developments on cannons, made of brass, bronze and iron, were executed by not only the Europeans but also the Chinese, Arabs and the successors of the Mongols namely the Mughals, who entered into India.

**Some Additional Notes on the Chinese Contributions**

Apart from Needham’s meticulous research we have had the privilege of important remarks, on the Chinese contributions related to gunpowder and fire-arms, made by Davis and Ware, Goodrich & Feng, and Gode.

During 603-617 AD, Emperor Yang-ti of the Suy dynasty introduced fireworks, probably firecrackers. This tradition went on uninterrupted for centuries. A military handbook dated 1044 AD, firmly refers to the use of a mixture of sulphur, saltpetre, paper, charcoal, tung oil for military purposes. In 1126 fireballs were thrown from catapults against the Kin in defence of K’ai-feng Fu. Six years later i.e. in 1132 AD, Chen Kuei invented long bamboo tubes (precursor of iron firearms) filled with a pyrotechnic composition for routing bandits at Te-an. Before 1164, possibly during 1161-62 AD, Wei Sheng used, against the invading Jurchen and the Kin, fire-stones of gunpowder composition thrown from catapults.

Thus the stage was set for the epic barbarity of Genghiz Khān, the Mongol during, the early 13th century, which went on through his successors
throughout the century. The Tartars, the Mongols and the mainland Chinese people fought against, and simultaneously learning military warfare from, each other before the secrets gradually and inexorably passed on to the other Euro-Asian countries. In 1221 AD, Kin Tartars attacked a Chinese city with gourd-shaped explosive bombs of cast iron, about two inches thick. In 1232, Kin Tartars defending Lo-Yang and K’ai-feng Fu against the Mongols, employed ‘heaven-quaking thunders’ (explosive bombs) and ‘flying fire-spears’ (equipped with fire tubes). In 1259 and again in 1272, the Chinese used long bamboo tubes from which bullets were ejected by sparking off the gunpowder, to halt the advancing Mongols, who were also equipped with fire-weapons such as Mangonel, ‘constructed by two Muslims’. Thus the Mongols were the catalysts in the transmission and diffusion of military knowledge across several Euro-Asian communities.

There is no doubt that the Chinese people must be credited for complete sequential evolution of guns from spouting fire weapons. As early as 1236AD, the Chinese phao was cast from metal. Cast iron and copper cannons dated as early as 1356-1357 AD are displayed in the Chinese museum. However during the period 1290-1330 AD, there were useful contributions from the Muslim and Christian technicians. The Christian nations gradually took over the leadership in the manufacture and use of not only gunpowder and guns but also compass, paper and printing machineries.

The Chinese tradition continued till the 16th-17th century period. Literatures on military pyrotechnics were published. During 1596 AD, Li Shih-Chen distinguished between ‘aquose solve’ (NaNO₃) which dissolves in water and produces cooling, and ‘pyral solve’ (KNO₃) which acts as a pyrometallurgical flux and heats the system. During 1626-1630, the different properties of saltpetre or KNO₃ were articulated: fine, lustrous, insipid in taste, capable of ignition, two crystalline forms, rhombic and needle-like. Purification from impurities, through crystallization using selective coagulants such as turnip slices, glue etc., was described. However by that time saltpetre purification technology was known in many countries including India. As recently as 1676 AD, the traveller Tavernier, observing the fireworks in India and Java (imported from China), acknowledged that ‘the Chinese surpass all the nations of the world in this respect’.
SALTPETRE, GUNPOWDER AND FIRE-ARMS IN INDIA

It is a fact strange but true, that the Indian sub-continent was very slow in acquiring the knowledge of gunpowder and fire-arms. Swami Vivekananda attributed this fact to be one of the causes (apart from pernicious casteism) for the medieval collapse of the Hindu civilization in India.

We have cited before, the 664 AD reference indicating the knowledge of saltpetre possessed by an Indian monk visiting China, but neither Needham nor any other scholar has been able to throw more light on this subject. Needham had high expectations regarding the proven phenomenon of ‘Indian-Chinese Chemical contacts during the Thang period and the mutual indebtedness of China and India’, and therefore we may be able to discover in the future more facts in this regard.

Around 910 AD, al-Rāzi of the Arab world mentioned about an Indian salt, ‘black, friable with very little glitter’, and a Chinese salt ‘white, hard, smell like that of boiled eggs’. The latter could have been saltpetre. In 1225, Al-Jaubari mentioned bārūḏ-al-thalji or ‘snowy saltpetre’ and in 1240, Ibn al Baiţār was the first in the Arabic world to write on saltpetre or bārūḏ (which later meant gunpowder) or tals al-Ṣīni (‘Chinese snow’), available also in Morocco. Thus, there was little possibility of India learning about the subject through the Muslim invaders before 1240 AD. Around 1280 AD Saadi’s Gulistan described a Hindu (slave?) throwing burning naft, naphtha or gunpowder?

From that time, many Arabic-Persian-Turkish words entered into Urdu literature of India and then to other Indian languages:

bārūḏ, dāru (gunpowder), tope (cannon in Turkish), topci, topkhānā, shodaka or soḍā from Persian shurāj, hawai (rocket,) ātashbājī (pyrotechnics), banduk (musket or match-lock) etc.

The Arabic/Persian terminologies were learnt not only from the Chinese, Arabs and Turks but also the Europeans. The Arabic word banduk for example was possibly derived from the German venedig or the Venice-based filberts.

We are primarily concerned with the unknown chronology, route and mechanism of transmission regarding the knowledge of pyrotechnic, gunpow-
der and fire-arms in India. P.K. Gode raised these questions in his wonderful set of papers 25a,b,c and urged other scholars to direct their research for the period prior to 1400 AD; he provided some information only after this date.

**P.K. Gode’s Findings**

It seems that ‘guns’ were available in Bengal around 1406 AD, as reported by Mahaun, a Chinese visitor 30 who accompanied a big emissary of the Emperor. It is not clear whether the ‘guns’ were made of metal or these were bamboos filled with explosives, as described one century later (vams‘anāla, vēmānāla) in the Sanskrit literature Kautukacintāmaṇi of Orissa. Mahaun also found paper in Bengal, a commodity which the Arabs had picked up from the Chinese in the 8th century AD and introduced in India during the 12th century.

Abdur Razzaq, the ambassador from the Court of Sultan Shāh Rukh of Persia stayed in Vijayanagar during April to December in 1443 (reign of Devaraya II) and reported pyrotechny fireworks during the Mahānāvami festival (October 1443); gunpowder was possibly used. Eventually, nālikāstra or gun was also procured at Vijaynagar as revealed in the Sanskrit literature Ākāṣabhairava-tantra and used prior to the collapse of the empire in 1550 AD. Vijayanagar army was weak in artilllery, which comprised of a corps of musketeers and several cannons. The Muslims made use of artillery fully, with the help of Turkish gunners trained in European wars.31

Ram Chandra Kak, while recording the political history of Kashmir during the reign of Zain-ul-Abidin (1421-1472 AD), wrote that the king composed a treatise Manufacture of Fire-works in Persian and even introduced the use of firearms in Kashmir during 1466 AD.32

In 1472 Mahmud Gawan used mines in his campaign against Rai in Belgā(u)m; ‘the laying of mines was entirely a new thing in the Deccan’ (common in north India then?) and Prof. Gode commented: “The use of mines presupposes the importation of gunpowder or its manufacture in India”33.

Ten years later, in 1482, Mahmud Begurra (Begda), the well-known king of Gujarat fought against the pirates of Bulsar using a force consisting of musketeers and gunners34. He also cannonaded the city of Champaner and the palace of Raja Beni Rai34. Referring to the use of musketeers in the siege of Champaner, Briggs made some significant observations:
“This is the first mention of artillery and musketry in the Gujarat history. They were probably introduced by the Arabs and Turks from the Red Sea and Gulf of Persia... The use of ‘hukka’ or shells at this early period is remarkable, although it is mentioned that the Muslims employed grenades in their ships at the time the Portuguese reached India”\(^\text{35}\).

It is evident that before the Portuguese landed in India, and nearly half a century before Bābūr’s army invaded India with cannons (1528), the then rulers in India had some knowledge of gunpowder and fire-arms. Yet, that knowledge was not adequate, and there was positively a technology gap, which resulted in fresh political collapse in the country at the hands of the Mughals and then the Europeans.

The Hindu rulers (of Vijayanagar, Orissa etc.) around 1500 AD had poorer contact with the outside world (compared to the Muslim rulers in India) and were thus one additional step behind in the technology race. They were conversant with gunpowder, but not the intricacies of the rapidly developing fire-arms. Verthema certified that around 1500 AD, Vijayanagar exhibited widespread use of pyrotechny.

Gode has made detailed observations\(^\text{36}\) on the Sanskrit work \emph{Kautukacintāmaṇi} by Gajapati Prataparudradeva of Orissa (1497-1532 AD) (son of Purushottamadeva) patron of Viswanatha Sen. The latter was probably a Bengali and the real author of the said works. Prataparudradeva was a contemporary of the famous Bengali saint, Lord Caitanya (1485-1533 AD).

The cited Sanskrit literature lists sulphur, charcoal and saltpetre as important constituents of pyrotechny compositions and gunpowder. The word for saltpetre used was \textit{yavakṣāra}, the classical Sanskrit word for plant ash alkali containing potassium carbonate, and not \textit{sodaka} or \textit{sodi} derived from the Persian word \textit{shurāj}. The diffusion of knowledge on saltpetre in Bengal and Orissa was probably through the north-eastern India, directly from the Chinese. The cited Sanskrit literature listed \textit{vēṇunāla} or \textit{vamsanāla}, hollow piece of bamboo filled with gunpowder, which as we have mentioned earlier, was used by Chen Kuei in China in 1132 AD. The word \textit{nālikā} was used in Sanskrit literatures of Orissa as well as Vijayanagar to indicate ‘gun’ during the first few decades of the 16th century. One or two centuries later, the Marathi literature gradually
and partially switched over to the Arabic-Persian-Turkish terminologies related to gunpowder and fire-arms.

The diffusion of Chinese knowledge through north-eastern India is manifest through the use of paper and silk during early sixteenth century and also the manufacture of cast iron in north-eastern India using air blast in the furnace.

In the western Indian scenario, Barbosa indicated in his Travels (1515-1518 AD) that fireworks (mainly for celebration) were manufactured on a large scale in Gujarat. He also referred to riders of elephants with bows, arrows and handguns. But we have no hard evidence of cannons being used in India prior to 1526; in that year, on 01 November to be precise, Bābur the invading Mughal, a descendent of Timur, supervised the casting of a gun by Ustad Ali Kuli.

FINDINGS OF IQTIDAR ALAM KHAN

In his recently published meticulous research on medieval India, Khan has deliberated more on firearms, which are not discussed in this article, and much less on saltpetre and gunpowder. Yet some of his critical observations on the Persian literature deserve full consideration along with those made earlier by P.K. Gode. The knowledge of the Chinese inventions of huo pao (a catapult throwing projectiles containing gunpowder), huo ch’iang (a bamboo tube used for throwing fire by igniting gunpowder), and pao chang (gunpowder-based crackers) might have reached India through the Mongols in the thirteenth century itself. Hulegu utilised the expertise of captured (earlier in 1253) Chinese engineers during his onslaught in Iran (1256). When his envoy was received in the Delhi Court of Nasir al-Dīn Mahmud in 1258, there was the large scale display of pyrotechnics atishbāzī based on saltpetre; this is one of the earliest references for the subject. The secrets of the gunpowder and firearms were however not divulged in 1258. In an eulogy honouring Jālāl al-Dīn Firoz Khalji (1290-95), Āmir ‘Khusrau mentioned hāwai (rocket) and other pyrotechnics based on naft which definitely meant bārūd or gunpowder and not naphtha. Earlier, we referred to Saadi using the same word naft in his Gulistan of the 13th century.
By 1299-1300 there was definitely some armament technology transfer to India. Āmīr Khusrau mentioned Ālāl al-Dīn Khalji’s forces using maghribi (a missile throwing device) and even the Hindus, besieged in the fort of Ranthambhor, returning in kind. The Hindus had in their ranks many Mongol deserters, considered experts of fireworks and firearms such as huo ch’iang. Āmīr Khusrau wrote: “A few neo-Muslims from amongst the ill-fated Mongols turned their faces from the Sun of Islam and joined the Hindus”.

During the 14th century, there was some use of pyrotechny (1351-57) and rocket or hāwai in the Delhi Sultanate and not much of firearms. India was falling behind in the technology race and the Christian West was rapidly advancing, excelling over even the Mongols, the Chinese and the Turks. By 1375 there were large guns of the bombard type in Europe. Some scholars have suggested the advent of firearms in the Hindu Vijaynagara - during 1356-77 but these must have been imported. During 1366-67 the Bahmani Muslim kingdom acquired for the first time karkhānā-i atishbāzī which ‘before this date was not known among Muslims in the Deccan’. Many Fīrangis (Europeans) and Rumīs (Turks) were employed in the Bahmani state at that time.

The 1398 invasion of Timur, the Mughal, was a turning point in the history of India, when the Sultanate in Delhi faced the superior firepower, better firearms and the mine-laying expertise (in Bhatnair and Meerut) of Timur’s army. During the early period of the new (15th) century there was some slow progress in the Indian scenario, and a bit of technology transfer.

In 1419 Chinese bombardes were imported in Calicut and such import of technology was perceptible in Assam and Bengal. The earliest reference to saltpetre as a component of gunpowder appeared in the Persian dictionary Adat ul - fuzala compiled in Jaunpur during 1419-20, in which the term shurāj/ shurā/shodā (saltpetre) was explained: “salt derived from earth which is at times used for throwing nafi”. It may be noted that the term nafi was converted much later to bārūd. Some forty years later, another text Sharfnāma-i Ahmad Munairi, compiled in Bengal (1457-64), explained the ‘saline earth from which salt (shodā) is separated for the use of nafi-specialists in atishbāzī’. It further stated: ‘that stone which they propel with the energy (created) by combustible substances, (and is) known in India as golā or kashkanjīr’.
The above useful citations rendered by Iqtidar Alam Khan along with the studies of P.K. Gode quoted earlier give us a tentative picture of the status of the technology in the Bengal-Bihar-Orissa region during the latter half of the 15th century. Bengal had acquired ‘bān’, a variety of Chinese invention: ‘an iron tube of about one foot long and an inch in diameter, fixed to a bamboo rod 10-12 ft long) the tube filled with combustible composition’. The Purhias or the ‘technicians of the East’ processed saltpetre from the Patna-Bhojpur-Purnea region and used the ‘Bengali’ guns (or rather hāns) even against Bābūr during 1529.

During 1442-43, Rana Kumbha supplied to one of his allies two cannons cast in an alloy of copper. This was known as kaman-i-rad. Such weaponries were also used by Sultan Mahmud Khalji of Malwa (1456), by Mahmud Gawan leading Bahmani army during the siege of Belgaum (1473), and by Sultan Mahmud Begarha in his naval expedition against the pirates in the Gulf of Cambay (1484-85) etc.

Iqtidar Alam Khan did not find any concrete proof that there was any ‘cannon’ type equipment in India before Timur, although there was the knowledge and use of other devices’ using gunpowder. Even the superior fire-power of the Moghuls like Timur (1398) and Bābūr (1526) was partly borrowed from the Turks and Europeans.

India after Bābūr

The specialised topic of guns and firearms in India since the era of Bābūr is outside the scope of this article; besides, this subject has been covered elsewhere. We would however make some general remarks specially about saltpetre, gunpowder and technology gap in India, the last named topic first.

After Bābūr, his descendants like Akbar considered artillery as, ‘locks and keys of the empire’. Yet, it is doubtful whether research and development in this regard were adequate to match with the European standards.

A gunner from Milan who died in Lahore in 1597 left all his books to the Jesuit father in the Moghul court, including some technical works on the founding of cannon and on siege operations. Jehāngīr employed three or four Christians in 1632, including one Venetian Angelo Gradenigo, as maker of
artillery. Jehāṅgīr appreciated fancy goods more: musket barrels wrought in
gold and set with agates of various colours were brought to him in 1625 AD by
some Venetians. Niccolao Manucci, the famous Venetian reached India in 1656
and entered services as an artillery man under Dārā Shukoh. In 1672 a big gun
cast by a native of Rome was mounted on the gate wall of Bijapur. All these
facts show heavy dependence of the Indian rulers on the Europeans.

Bernier in his Travels (1656 AD) recorded about the artillery of
Aurangzeb and commented: “Formerly when the Mughals were little skilled in
the management of artillery, the pay of the Europeans was more liberal, and
there are still some remaining who receive high salary. Now the king admits
them with difficulty”. As a matter of fact, during the 17th century, England
prohibited its citizens to part with the armament secrets for any Indian benefit.
During the end of the 18th century the Peshwas continued to purchase canions
from the English, and Tipu Sultan switched over from purchase to manufacture
of guns. Bernier had aptly observed that in the event of European onslaufths
(which eventually abounded in the 18th century) Indian armies had no ability
to resist and counter.

Just as Śivājī, heralded an era of national resurgence in the 17th cen-
tury, the Marathi literature brought about a transition of technical terms related
to gunpowder and fire-arms, from the Sanskritic words such as:

Yantraśāla, nālikā (gun), sugolakatati udgātā (cannon balls emanating
from gun) āyasagolakaihū (iron cannon balls), āgneyauśadha (gunpowder),
bahnicūrṇā (gunpowder), bhusāṇḍī (musket or a small portable piece of can-
non), golikā (bullet) later converted to guli, golīyā (bullet), bāṇa or bānnes of
Tavernier (a sort of grenade attached to a stick to be thrown at the enemy),
cherks or carki (from cakra, a disc-typed rotating pyrotechny to scare the el-
ephants) etc.

The more common and extant Arabic/PersiansTurkish words such as: banduk (musket), barakandāj (musketeer), karol (mounted musketeer), hoke
or hukkah (vessels filled with gunpowder or shell or bombs), dāru (gunpow-
der), dārughānā (godown or storage for gunpowder), bhānda (cannons), bhā
ndiacā mār (naval cannon), golandāj (artillery man), dārugola (bullet with
gunpowder or musket), tope (Turkish word for gun or cannon), topci (gunner),
tope-\textit{khan}u (Turko-Persian, cannon department), \textit{darog}u (chief of the artillery), \textit{haw}u (air pyrotechny or rocket) etc.

Raghun\u0161\u0161a Pa\u00f6n\u0161ita in his \textit{R\u00e1j\u0161y\u0161vah\u0161rakois\u0161a} (1676 A.D.) explained the non-Sanskrit terms to the Maratha King \Siv\u017aj\u0161i: \textit{banduka} is \textit{nala}, \textit{barakandaj} is \textit{n\u0161ika}, \textit{daru} is \textit{agnicurna}, \textit{jabarjang} and \textit{jambur\u0161} are the names of \textit{laghu\_yantra}, musket or small gun etc.\textsuperscript{40}

The Maratha resurgence in the Indian scenario was brought about by the valour of \Siv\u017aj\u0161i and his mentor, the great patriot-saint R\u00e1mad\u0161\u00e1 (1608-1682 AD), who strongly exhorted his disciple on \textit{k\u0175atra\_dharma}, the duty of a patriot-warrior:

\begin{center}
\textit{jais\u0161a bh\textit{\u0161\u0161dy\textit{\u0161}mc\u0161 galol\u0161 / nirbhaya bh\textit{\u0161r\textit{\u0161}madhye padil\u0161 / tais\u0161a k\textit{\u0161}atra ricav\u0161al\u0161 / parasainamadhye // 6 //}
\end{center}

\textquote{impinge on the enemy-rank like the gunball from the cannon}\textsuperscript{41}.

R\u00e1macandrapant Am\u00e1tya (1650-1733 AD), who had an intimate knowledge of the Maratha administration under \Siv\u017aj\u0161i and his descendants, compiled an official manual \textit{Aj\n\textit{n\u00e1patra} on Maratha polity, published on 21 November 1716. Apart from the compiled technical terms, some of which have been already cited in this article, the official manual contained many significant guidelines,\textsuperscript{42} such as:

a) the gunpowder arsenal should be kept away from residential quarters;

b) the gunpowder and armaments should be dried in the sun once every fortnight (as the English saying goes: \textquote{keep the powder dry});

c) the navy should be provided with brave men and firearms;

d) the enemy should be kept under naval fire and their ships should be destroyed by naval cannonading, etc.

Quoting the above, Gode wondered whether the Marhatas imported or manufactured the cannons and paid any personal attention to the manufacture of fire-arms as the emperor \textemdash{}\textsuperscript{\textit{A}k\textit{bar} had done\textsuperscript{42}. The attention paid to the importance of navy, sadly ignored even by \textit{A}k\textit{bar} and his descendants, was scanty and much belated in the Indian scenario.
MORE DETAILS ON SALT PETRE IN INDIA AND ITS USES

As Professor Gode has suggested, there should be intensive research on the questions: how, when and by whom the use of saltpetre was started in India before or around 1400 AD. Our knowledge about the isolation and use of this commodity in India even for the period of 1400-1600 AD, till the writings of Ābul Fazl, is scanty.

Regarding the manufacture and use of saltpetre in pre-modern India, some coherent accounts have been provided by Ābul Fazl, Moreland and the present author. Information on this subject provided by Iqtidar Alam Khan has been scanty (much more was expected from him) and quoted earlier in this article.

Ābul Fazl wrote very significantly: “Saltpetre is a saline earth. They fill with it a perforated vessel, and pour some water over it, and collecting what drops through, they boil it, clean it, and let it crystallize. Saltpetre, which in gunpowder produces the explosive heat, is used by his Majesty (Ākbar) as a means for cooling water, and is thus a source of joy for great and small.”

The facts that saltpetre has been used in India in pyrotechny, for gunpowder explosives (to generate heat), and also as coolant (paradoxically) for drinks and producing ice, have been overlooked by most scholars for no good reason. The present author has provided the thermodynamic framework for the apparently paradoxical (exothermic and endothermic) behaviour of saltpetre. The nitrates in the saltpetre have constitutional oxygen and release energy (when heated) in an explosive fashion. However the hygroscopic nature of calcium and sodium nitrate render them almost useless in humid atmosphere. The non-hygroscopic potassium nitrate is thus the only useful constituent for gunpowder technology and this component had to be isolated by repeated fractional crystallization.

As a contrast, the heats of dissolution (ΔH) in water of most of the constituents of saltpetre are endothermic (abstract heat and therefore cool). The thermodynamic values of ΔH in kilo-calorie/g. mol. of the solutes (some seven constituents in saltpetre) range from 4.11 (CaCl₂, 6H₂O) to 18.74 (Na₂SO₄, 10H₂O). It is noteworthy that dissolution of anhydrous CaCl₂, Na₂SO₄ etc. is
exothermic, but the dissolution of hydrated salts (and also of non-hygroscopic KNO₃) is endothermic. Thus, hygroscopicity of some of the constituents of saltpetre, hindering the efficacy of gunpowder, actually aid in its cooling property: ‘aquose solve’ of the Chinese (1596).

The present author made thermodynamic calculations using the negative ΔH value, heat of dissolution in water, for KNO₃ 8.633 K.cal/g.mol of solute and Abul Fazl’s recipe (50g saltpetre in 100 g. water, nearly the solubility limit of KNO₃ in water at 35°C) to show that water-bath temperature could be reduced by 20-25 degrees centigrade. This cooling process could have been repeated through successive stages of cooling. At 0°C, solubility of KNO₃ in water is 13.3 g/100 g and it was shown by our calculation that one kg of saltpetre should abstract heat, equivalent to freezing of one kg of water at 0°C to ice⁴⁵. Dharmpal has quoted one 1775 AD paper written by Sir Robert Barker who witnessed ‘the process of making ice’ at Allahabad (cold December night) using saltpetre.

Reverting back to the topic of saltpetre to gunpowder, we notice Moreland’s landmark contribution on saltpetre in India during the period of Akbar to Aurangzeb⁴⁴. Very significantly, he linked the 17th century saltpetre export trade from India to the ‘military history of Europe after the defeat of the Spanish Armada in 1588’. Then he went on to comment: “By the beginning of the 17th century, the progress of war was outrunning the European supplies of saltpetre, and the discovery that practically unlimited quantities of saltpetre were available in India, was a very great advantage to those belligerent nations which were in a position to obtain it by the ocean route”.

Aurangzeb was afraid that gunpowder made from Indian saltpetre might be used against some Muslim power’. His efforts for preventing the Portuguese, the Dutch, the French and the British from production and export/smuggling of Indian saltpetre were unsuccessful. Even he was unaware of the full might of the newly arising European science and technology and (in the words of J.D.Bernal) ‘the scientific consequences of gunpowder’: “Gunpowder and the cannon not only blew up the medieval world economically and politically; they were major forces in destroying the systems of ideas”. It started with the discoveries of selective crystallization and ballistics, and after four centuries of alchemical experiments, it led to the discovery of oxygen and the whole of
modem chemistry\textsuperscript{47}. Use of saltpetre led alchemists to the doorstep of nitric acid.

Moreland's account\textsuperscript{44} of the Dutch and British endeavours during the 17th century to exploit, refine and export Indian saltpetre and gunpowder has been summarised by the present author\textsuperscript{45}. Saltpetre used to be obtained from various parts of India such as the Coromandal coast, Gujarat, Agra, Konkan, Orissa etc., but the most voluminous product came from Bihar, around the Patna region\textsuperscript{48}. The total output in the Patna area around 1688 came to $2.26 \times 10^5$ maunds raw and $1.27 \times 10^5$ maunds refined.

The larger output as well as better quality of the Patna saltpetre was due to the Dutch involvement in the technology since 1621. We do not have any substantial account of the indigenous efforts of refining Indian saltpetre during the 15th and 16th centuries. During the early part of the 17th century, the indigenous technology of munias, extant in the Patna-Chapra region was found to be primitive and backdated. The Dutch imported better equipment around 1640-41. British machineries came to India during 1740-1754. Ever since the middle of the 18th century, the East India Company of England enjoyed the monopoly of Indian saltpetre, a very powerful ammunition targeted against the land which produced it!

Valentine Ball reported in 1881 that during the preceding period of five years (1876-1880) more than 1.67 million cwt (hundred weights) of saltpetre valued at nearly 1.37 million pounds sterling had been exported from Calcutta\textsuperscript{49}, presumably for the upkeep and further expansion of the British empire such as in Myanmar! Two-thirds of export through Calcutta came from the districts of Tirhut, Saran and Champaran, the rest from Kanpur, Ghazipur, Allahabad and Varanasi in the Uttar Pradesh. Buchanan's \textit{Patna-Gaya-Report} published by the Behar Research Society, Patna, Volume II, pp.625-626, recording observations about the manufacturers of fireworks in Bihar around 1811 AD, illustrates the mind-set of the then subjugated Indians. Buchanan has been quoted by P.K.Gode:

"Those who make fireworks (in 1811) are not superior to the \textit{Atushbāz} usual in Bengal. The fireworks are chiefly employed at marriages. At other seasons the same people make gunpowder of which a good deal is used. The
nations seem to delight in the noise of firearms and fire powder merely for pastime.

"Many people in this district are constantly provided with arms and ammunition, as a defence against robbers or rather from family habits, considering themselves as born soldiers. They do not, however, parade in arms and few of them now appear in public with even swords".50

Buchanan might have thought that the Indians would remain non-violent and docile for ever. Forty-six years later, the Nation which had produced Śivājī and Tipu Sultan, used gunpowder against the British during its first struggle for independence. At that time the Indians resolved never again to ignore modern education, science and technology, gunpowder and firearms, not even for the sake of the principle of non-violence.

CONCLUDING REMARKS: AN EPILOGUE

The topic of saltpetre to gunpowder and firearms is of epic proportion; its evolutionary history in different centuries and countries needs to be further investigated in depth. History of armament research and development inevitably ushers in the philosophical issues of ends and means in the human civilization.

New discoveries related to violence have always shocked the mankind. Needham quoted Robert Boyle the great chemist writing in 1664 how the red Indians in the American continent felt dazed when the Spaniards used gunpowder against them:

"The poor Indians lookt upon the Spaniards as more than Men, because the knowledge they had of the Properties of Nitre, Sulphur and Charcoale duly mixt, enabled them to Thunder and Lighten so fatally, when they pleased".51

The Japanese were similarly shocked when the nuclear bombs were dropped on Hiroshima and Nagasaki. Needham has rightly observed that science and technology have provided Man 'mastery over the sub-atomic processes of suns, sources of inextinguishable energy, a mastery which has outstripped his ethical and moral maturity; yet, mastery over Nature remains the second grandest of ideals'.51
The ethical/moral ideal of non-violence and love, the dictum of ‘live and let live’ is definitely the grandest of ideals. But what alternative do we have when our adversary gathers the knowledge of fire, gunpowder and nuclear bomb. Acquiring the like mastery over Nature seems to be the only alternative, ‘the second grandest of ideals’. India could not gather the knowledge of manufacture and use of gunpowder in good time, and therefore suffered for many centuries. The five underground nuclear test explosions in India on 11 and 13 May, 1998, were heralded as the ‘Smile of Buddha’. As indicated in the beginning of this article, the two great savants of India, namely Swami Vivekananda and Mahatma Gandhi, have expressed philosophical views on this issue which are not identical. The author of this article supports the former.

**References**


4. Reference no. 3, Volume 5, Part 3, p.139


   a) Use of Guns and Gunpowder in India, From AD 1400 Onwards, pp.1-9.
   
   b) The Manufacture and Use of Fire-arms in India Between AD 1450 and 1850, pp.1 0-30.
   
   c) The History of Fireworks in India Between AD 1400 and 1900, pp.31-56.


31. Reference No.25a, pp.3-8 and 25c, p41.


33. Reference No.25a, pp.5-7.


36. Reference No.25c, pp 42-44.


40. P.K.Gode has beautifully explained these terminologies appearing in different languages used in India during 16th to 18th centuries. Ref.No.25a, pp.3-7; 25b, pp.11-12,17-20,28-29; 25c, pp 40, 47-50.


50. Reference no. 25c, pp.53-54.

51. Reference no. 3, Volume 5, Part 7, p.5