HISTORY OF SCIENCES IN INDIA: PALI SOURCES

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The history of science in India should, of necessity, encompass the varied source materials in different languages of this culture-area which has nurtured and evolved a number of rich languages over a long stretch of time. Over the last one hundred years, the more important sources of scientific value in Sanskrit, the celebrated classical language of India, have merited the attention of scholars who endeavoured to delineate the history of science in India particularly in the ancient period. But the other sources in ancient languages like Pāli and Prākṛt which were admittedly the vehicles of thought of a great number of common people for centuries have, for one reason or the other, not come yet into the purview of historians of Indian science. In particular, Pāli was indeed effective in disseminating Buddhistic thought and practice for at least a thousand years in the ancient period. Hence the Pāli works deserve to be identified and studied from the point of view of the history of Indian science and technology. As a step in this direction, a preliminary bibliographic work is in progress. Based on the information collected so far, the paper attempts to give a brief account of some of the known Pāli sources and their scientific contents in a perspective.

The term Pāli seems to be the abbreviated form of *Pālibhāṣā* which, in common parlance, means 'the language of the canon.[1] Pāli language is considered to have been based on what the linguists choose to call a middle Indo-Aryan dialect which, in turn, came into vogue as a result of modification here and there of the old forms of the antiquated Indo-Aryan dialects. In effect, then, Pāli is not an unmixed language. It would seem that in its evolution, this language was subject to not a few of the historical influences including the spread of Buddhism over a vast area comprising different types of people whose dialects varied from place to place. The wandering preachers of Buddhism and, in fact, the Buddha himself, with a zeal to propagate the new religion of compassion and right conduct, contributed a great deal to the formulation and evolution of the Pāli language and literature.

The extant, rather old, literature in the Pāli language has been arranged as the *Tipiṭika Pāli*[2] which forms the canon of the Theravāda or Sthaviravāda,[3] one of the Hinayāna schools of Buddhism. There is a view that the Pāli canon represents the thoughts and practices primarily of the people of the middle Ganges basin and of the Magadhan Empire. The early period ascribed to the effervescence of the Pāli literature of this type ranges from the sixth to

fourth centuries B.C. It is reasonable to assume that in course of time the Pāli language might have been influenced by the literary forms in vogue in some of the western regions, particularly Taxila, which received the impact of Buddhism. Be that as it may, there is no denying that the Pāli language began to spread far and wide, to South India, Ceylon, Thailand, Cambodia, Laos, Vietnam and even Indonesia. In its spread, as could be expected, Pāli was prone to absorb some of the literary expressions of the regions concerned.

Of great significance as a primary Pāli source is the *Tipitika* which literally means the 'threefold basket'. This huge treatise is arranged in three parts, viz. *Vinayapiṭaka*[4] (containing 227 rules of the Buddhist monastic discipline and a record of events pertaining to the Buddha), *Sutta-Piṭaka*[5] (an account of the doctrines of the Buddha in the form of dialogues, stories and poems) and *Abhidhamma-piṭaka*[6] (an elaboration of Buddhist philosophy in consonance with the Theravāda teaching). Of the three, the *Sutta* is by far the largest and the most informative. Apart from the *Tipitika*, the other most important Pāli works include *Abhidharmakośa* of Vasubandhu,[7] *Visuddhimagga*[8] of Buddhaghosa, *Visuddhimagga-tikā* of Dhammapala,[9] *Vinayamukha* of Sammanna,[10] *Attasālini*[11] and other commentaries on the *Tipitika*.

There is no gainsaying that a systematic study of the Pāli sources is still a desideratum from the point of view of the history of science in India. As the history of science of a culture-area admittedly impinges upon its religio-philosophical climate from time to time, the importance of the study of the Pāli sources can hardly be overemphasized; for, such a study would doubtless result in gaining the much needed insight into one of the most encompassing religio-philosophies of the ancient period, viz. the Buddhism. A cursory study of some of the Buddhist sources like the *Jātakas* and their commentaries known as *Aṭṭakathas* indicates that they contain not a few scientific idea as well as technological practices which, if critically studied, might throw ample light on the general level of science and technology during that period. It is refreshing to note that there are a number of repositories of Pāli sources in and outside India deserving a scholastic attention.

Like all the other ancient renowned religions, Buddhism was deeply concerned with the physical world-view, origin and evolution of life and living processes. Further, the abiding human compassion, which formed the core, as it were, of Buddhism and the consequent attempts at alleviating human suffering, was responsible to a great extent for promoting medicine as a healing art. No wonder then that in the Pāli texts we come across considerable details regarding medical code as well as practices adopted by the followers of Buddhism. The following is but a brief account of the scientific ideas and technological practices as found in some of the Pāli works.

Atomism

Of the Buddhist concepts concerning the physical world-view, the atomic theory of the Theravāda school is of special significance. There are some noticeable differences between the atomic views found in the Pāli canonical works of the Theravāda school and those in the Sanskrit works of the other Buddhist schools, like the Vaibhāṣikas and the Sautrāntikas. For example, the Theravādins have postulated relatively a large number of material elements in exposition of their well-known *rūpa-kalāpa* (or *kalpā*)[12] theory. In the later works of the Theravādins, the term kalāpa connotes the smallest unit of matter which, in turn, is regarded as a collection of material elements. The *kalāpa* thus corresponds to the *saṃghata-paramāṇu*[13] of the Vaibhāṣikas. It may be noted that the Vaibhāṣikas postulate two kinds of *paramāṇus*, viz. the *dravya-paramāṇu* (unitary atom) and the *saṃghāta-paramāṇu* (the aggregate atom). The *dravya-paramāṇu* is considered as the smallest unit of matter, subtle (*sarvasukṣma*), partless (*niravayāvat*) and without spatial dimensions (*dik-bhāgabhedatya*).[14] As this smallest unit cannot, by nature, exist in isolation, it enters into combination and forms the aggregate, i.e. the *saṃghāta-paramāṇu*. A fact of significance from the point of view of Indian atomism is that the smallest of the phenomenal aggregate is presumed to be an octad, i.e. of eight atoms consisting of four atoms of the primary elements (*pathavī, āp, tejas* and *vāyu*) and four of the secondary elements (*rūpa, gandha, rasa* and *sparśa*).[15] Such a view is not shared by either the Nyāya-Vaiśeṣikas or the Jainas whose atomic theories are well known.

Buddhaghoṣa (*c.* fifth century A.D.) in his work *Viśuddhimagga* has discussed in considerable detail the implications of the Theravāda atomic theory. It would seem that the Theravādins regarded that the ultimate unit of matter as an aggregate which, though composed of a number of atoms, forms a unity by itself inasmuch as it has a simultaneous origination (*ekuppada*) and cessation (*eknirvādha*).[16] The *Visuddhimagga*,[17] in recognition of the unitary characteristic of such an aggregate, calls this ultimate unit of matter the *cuṇṇa* or *paramāṇu*. However, in the subsequent Theravāda works, the word *kalāpa* is used to denote the aggregate in its plurality of different elements. The *Abhidhammamattha Samgha* even uses the word *pindi*[18] (literally means a state of aggregation), to indicate the collection of atoms. The main reason for postulating a plural percept in terms of a unitary conception seems to be that each element is in reality a group or plural composition of infinitesimally small material entities. Perhaps, the nearest term of the Theravādins corresponding to the Vaibhāṣika *dravya-paramāṇu* is *kalpāṅga* which has the connotation of limb or part of the collection. It must, nevertheless, be emphasized that the *kalpāṅgas* are more in the nature of a logical postulate than recognized material entities comprising the bigger *kalpā* with which they are, according to the Theravāda, inseparably associated. It is even argued that the colour

(*rūpa*) of mango, for instance, cannot be separated from its quality of hardness or solidity (*pathavī*: Sans: *Pṛthvī*) or from its taste (*rasa*). In brief, the *kalpāṅgas* are what the Theravādins describe as *sabbapariyantuma* and not spatially (*padesato*)[19] separate or distinctly separate entities from the same *kalāpa*. This conception of Theravādins seems to have been shared by the Sautrāntikas in contradistinction to the Vaibhāṣikas.

The *Vibhaṅgattakatha*[20] gives an account of even the size of the kalāpa in relation to *aṅgula* (finger-breadth) as follows:—

36 *paramāṇus*	1 *aṇu*
36 *aṇus*	1 *tajjari*
36 *tajjaris*	1 *rathareṇu*[21]
36 *thareṇus*	1 *likhā*[22]
7 *likhās*	1 *ukā*[23]
7 *ukās*	1 *dhannamāsa*[24]
7 *dhannamāsas*	1 *aṅgula*

If computed, this would mean that the size of the *paramāṇu* is equal to 1/581/147/136 of an inch. As it is rather difficult to explain as to why the numbers 36 and 7 have been chosen for purposes of equation of one another, it is perhaps best to describe it as an attempt to emphasize the infinitesimally small size of the *paramāṇu*. The *Visuddhimagga-tīka* even goes to the extent of saying that the *paramāṇu* is so minute that it can be perceived only by the divine eye (*dibbacakkhū*: Sans: *divyacakṣu*).[25] In this respect the Theravādins are similar to the followers of the Jaina atomic school, who regard the *paramāṇu* as capable of being perceived only by the *kevalins* (liberated souls).

It should be pointed out that the physical world-view of the Theravādins is to a great extent dependent upon their concept of *rūpa-dhammas* or the ultimate irreducible entities. For, each *rūpa-dhamma*, it is pointed out, is inexorably associated with a set of other *rūpa-dhammas*. As a result, no distinction is sought to be made between substance and quality. According to the Theravādins, there are as many as twenty-eight *rūpa-dhammas*,[26] viz. the four elements (*pathavī*, *āpo*, *teja* and *vāyo*); five sense organs (*cakkhū*, *sōta*, *ghāna*, *jivhā* and *gandha*) and three faculties of life (masculine, feminine and material), food (*āhāra*), physical basis of mental activity (*hadaya-vatthū*), two modes of expression, three characteristics of matter (*lahuta*, *maduta* and *kammanata*), four phases of matter and *ākāśa*. Of the above, the first four are recognized as primary elements, the next fourteen secondary elements and the remaining ten as nominal entities.

It is perhaps desirable at this stage to make special mention of the Theravāda conception of the first four primary elements. Interesting it is indeed to note that the doctrine of elements is one of the dominant features of the

physical world-view of different culture-areas in the ancient and the early medieval periods. In India, Upaniṣadic in origin, the conception of elements became integrated not only with orthodox systems but also the Buddhist, Jaina and the Cārvāka schools. While the former recognized the five elements including *ākāśa*, the latter generally accepted the important role of four elements in the origin, evolution and disolution of the physical world. As to the Buddhist schools, the Theravādins, the Vaibhāṣikas and the Sautrāntikas lent weight to the conception of four elements within their respective religio-philosophical dispositions.[27] According to the conception of the Theravādins, the four primary elements in their atomic state constitute what is called the *suddhatthaka*[28] (octuple or octad) and also function as common support (*eka-nisaya*) in respect of the four secondary elements (which in the Nyāya-Vaiśeṣika system correspond to the qualities). The Buddhist schools in general do not admit of the duality between the atomic matter and the supposed qualities determined by the sense organs. The Theravādins postulate that each sense organ is a decad (*dasakā*)[29] consisting of the octuple, a material faculty of life (*rūpa-jivitindriya*)[30] and the sense organ itself. In this way the Pāli sources offer an insight into the physical world-view encompassing the material and the sensorial.

Medicine

The Pāli works are also sources of information concerning the medical practices in vogue then. In this respect the *Dīgha* and the *Saṃyutta Nikāyas*, as also the *Vinayapiṭaka* are particularly valuable. The *Saṃyutta* gives also an account of the surgical practices. It may be mentioned that Jīvaka Kumārabhacca was a renowned surgeon and, as the *Vinayapiṭaka* mentions,[31] he learnt the art of surgery from the reputed teacher, Punarvasu Ātreya for seven years, thus pointing to the fact that the Āyurvedic surgical tradition was followed by him. There is also an account of Jīvaka performing a surgical operation on the son of a well-known merchant in order to cure him of the *antagantha bādha* (intestinal strangulation), and also how he removed the worms which caused disease in head. Jīvaka was even supposed to be an expert in ophthalmic surgery.

The *Mahāvagga* has a chapter on medicine (*bheṣajja khanearca*). The *bhikkus* were expected to have an adequate knowledge of the use of certain substances for curing diseases. The substances included tallows, roots, turmeric, ginger, garlic, certain astringent decoctions, rice-gruel, leaves, fruits, pepper, resinous material, and several types of salt compositions. Eye-ointments were known, and they went under the appellation of *kalānjana, rasānjana, sotānjana, gerukam* and *kappalam* (generally collyriums).[32] *Kabālika*[33] was a sort of medicinal paste. *Sattir sitaloli*,[34] probably a drink having as one of its ingredients the mud adhering to the ploughshare, was in use for curing food-poisoning or incompatibility. *Cuṇṇa-bheṣajja*,[35] which

denoted the use of finely powdered material (*cuṇṇa*) as medicine, was widely practised in the cure of itches (*kaṇḍu*), pimples (*pīḷaka*), weeping wounds (*āsava*) and the like. Several oils which were employed for medication purposes included those of *tila* (sesame), *madhukā* (seeds of *Bassia latifolia*) and castor. The *Mahāvagga* refers to the application of a special type of medicine through the nose by means of a pipe (*Nātthukarani*).[36] The *Samanta pāsādika* gives an interesting account of the treatment of gout by sweating the body profusely. It was one of the injunctions of the Buddha that the monks should carry with them five kinds of materials to be used as medicine, but store them for seven days only.[37] These included *sappi* (a kind of ghee), *navanīta* (butter), *tela* (oil), *madhu* (honey) and *phaṇita* (molasses). In addition, they were also expected to acquire the necessary medical knowledge and have in their possession certain roots, herbs, myrobalans and the like for use in times of emergency.

The Pāli sources are not devoid of information concerning the anatomical knowledge. The *Visuddhimagga* says that there are 64 bones in the hand and a like number in the feet. The other types of bones mentioned include those of the ankle, hip, spine, ribs, breast, collar and jaw, and the total number of bones thus enumerated is around 300.[38] This text also gives an account of the shape and colour of the bones as well as their position or placement in the body. In addition, it describes in a concise manner the types of flesh, marrow, hairs, teeth and nails on the one hand and spleen, heart, bowels, and brain on the other. As to blood, two kinds, viz. stored and mobile, are described. Stored blood is stated to have the colour of cooked and thickened lac, while mobile blood is of the colour of the clear molten lac itself. It must, nevertheless, be emphasized that the Pāli sources do not appear to contain any theoretical information of the type found in the well-known Āyurvedic texts.

Astronomical Ideas

A study of the extant Pāli works reveals that there is rather a considerable account of astronomical ideas. In the Indian culture-area, like the other ancient ones, astronomy in its beginnings was an inevitable part of the sacerdotal texts dealing with the sacrifices and the like, followed by the priestly order. As Buddhism did not recognize the importance of sacrifices and their performance at the so-called auspices times in relation to the positions of heavenly bodies, there was little or no attempt to codify the astronomical knowledge from that point of view. However, the *Vinayamukhā* in its section devoted to time-measurement speaks in no unmistakable terms about the practical aspects of astronomy. The standard of measurement was one rotation of the earth around the sun, called the day, which was counted from the time or observing the faint reddening of the sky (dawn). The fortnight

(15 or 14 days) was referred to as *pakkha*[40] (Sans: *pakṣa*), and two fortnights constituted a month. The fortnight of the waning moon was followed by that of the waxing moon. Only three seasons (*utu*),[41] (*hemanta*, *gimma* and *vassana* of four months each) were recognized. They commenced from *Māgasira*, *Citta* and *Sāvana* respectively. The month had 30 and 29 days, with the result the average lunar month was recognized as of 29½ days. However, it is not stated in the Pāli texts as to which month has thirty or twenty-nine days. Each month was named after the stars or asterisms being in conjunction with the moon on the full moon midnight. The year began with Māgasirmāsa (approximately November–December).

In course of time, particularly during the time of the *Attakathas*, the year was divided into two periods of six months, in one of which each month was reckoned as being composed of thirty days and in the other only twenty-nine. As to the month itself, a change came about at this time inasmuch as the fortnight of the waxing moon was adopted as the first half of the month in contradistinction to the earlier practice.

The *Vinayamukhā* informs that no implicit reliance could be placed on the moon's motion only for reckoning time, and hence the necessity for luni-solar adjustments. While the solar year was known to be equal to 365 days and six hours, the ordinary year, as computed on the basis of 12 months of 29½ lunar days each, was 354 days. The difference of more than eleven days between the solar and the ordinary year was sought to be adjusted every three years by adding about 33 days. Sometimes luni-solar adjustments were also made once in two years. The Pāli texts refer to the additional month as *adhikamāsa*, similar to the Vedic tradition. The general practice followed was to intercalate as many as seven months in a cycle of 19 years. The Pāli works, nevertheless, do not appear to recognize a fixed or a properly computed cycle of years. In other words, no uniform calendrical formulation seems to have been attempted. It is even pointed out that in this respect the *bhikkus* should be given the necessary freedom to make luni-solar adjustments, bestowing attention on the observed rainy months during which time the wandering monks had perforce to take shelter in the places concerned. Probably, such a flexible injunction was meant for introducing the four rainy months in a year in an appropriate manner after the necessary intercalation once in two years or so.

Measurements

A study of the extant Pāli texts reveals rather an extraordinary attention paid to determine physical standards for the linear capacity and weight measurements. The linear measurement which was intended to determine distance, height, size of the body and the like was admittedly practical in its

application, comprising as it did the unitary lengths of rice grains, which were computed to bigger lengths as follows:[42]

7 rice grains	1 finger-breadth
12 finger-breadths	1 hand-span
8 hand-spans	1 *wat* (about 2·19 yards)
25 *wats*	1 *usabhā* (54·2 yds.)
80 *usabhās*	1 *gavutā* (2·48 miles or 4 km.)
4 *gavutās*	1 *yojana* (9·92 or 16 km.)

In practice, it would appear that six unhusked grains of the then available brownish glutinous rice, or seven of white rice, were considered to be equal to one finger-breadth (generally that of a carpenter). As regards the capacity measurements for liquids as well as grains, the general standard adopted was the fistful or handful. A small bowl was also in use for small measurements and a vessel or a pot which went under the appellation *alahaka* (Sans: *āḍhaka*) for relatively larger measurements. The weight measurement, *masakā* (black-gram grain) was taken to be the standard, and it was related to the small rice grain as well as *kunjā* as follows:

4 rice grains	1 *kunjā*
2 *kunjās*	1 *masakā*
5 *masakās*	2 *akkhā*
8 *akkhās*	1 *dhārāna*
10 *dhārānas*	1 *palā*
100 *palās*	1 *tulā*
10 *tulās*	1 *bhāra*

The noble metals, gold and silver, were weighed in terms of standard rice grains, *kunjā*, *masakā* and *dhārāna*. 5 *dhārānas* were considered to be equal to one *suvanna* (Sans: *suvarṇa*), 5 *suvannas* being equal to 1 *nikkha* (Sans: *nikṣa*). There was also a special measurement which went under the name of *sugata-pamana* (Sans: *sugatapramāṇa*), the exact weight of which was equivalent to three handspans or 16 finger-breadths. It may be noted that the *bhikkus* used to be given instructions in the practice as well as computation of measurements as they had to go from one place to another, and this enabled them to overcome the possible difficulties which they would encounter, evidently as a result of inadequate knowledge of the measurement practices of the regions concerned.

Dyeing Methods

In some of the Pāli sources, we come across details relating to the methods of dyeing. It may be noted that the *bhikkus* had to wear dyed robes as per

the specific requirements of the monastic order. The ancient practice to dye the robes using yellow-mud (*pāndumattika*) or an extract of cow-dung (*cakhana*) did not receive the approval of the Buddha who, in turn, prescribed six kinds of materials for dyeing purposes, viz. the extracts of roots, stem, bark, leaves, flowers and fruits of certain plants.[43] The colour desired was a combination of red and blue (*majjetha*), or black or red.[44] The dye was called *kasāva* which also was the name applicable to the dyed robes. The colour obtained by using the root of the jack-fruit tree became the standard in Ceylon.[45] The *Mahāvagga* gives an account of the dyeing process in terms of the oven (*culli*), pot, ladle (*raja-nuluka*), trough (*rajenadoni*), a bomboo or string (*cīvaramsa*).[46] The two important dyes frequently alluded to in the Pāli works are *tagarajana* and *pattarajana*.[47] In the preparation of dyes, there were certain injunctions concerning the use of certain plant products, a knowledge of which was considered as essential for the *bhikkus*. Turmeric (*haldi*), *manjettha tungahāra, doddam, kaṇḍula, alli, nilli, kimsuka* and *kusumbha* were forbidden as the ingredients for preparing the dyestuffs, according to the *Samanta-Pāsādika*.[48]

Architectural

The same text contains descriptions of the ordinary houses as well as palatial buildings, the latter being of different types like the *vihāra, pāsāda, hammiya, kathima* and *sāla*.[49] While the *vihara* meant a dwelling-place for monks, *pāsāda* and *hammiya* were attractive buildings with storeys. It would seem that the height of a storey was a little more than an ordinary man's height. In this text, there is also an account of *udosika*[50] (a garage to accommodate a chariot or any other vehicle) and *attha* (watch-tower). Exact measurements and details of construction as well as the associated engineering skills have, however, not been found in this source, although it is reasonable to suppose that construction of the imposing structures might have been accomplished with skill and accuracy during that time. For example, the famous monastery at Nalanda, the most remarkable one for its grandeur and height, as the Chinese pilgrim Hieun Tsang observed, was a three-storeyed structure which was built essentially using brick, mortar and cement. The main block was an (oblong) rectangle having eight distinct halls where the devoted would stay. A long veranda was also provided all round. The terrace as well as the floor was covered with durable concrete cement compositions which, after finishing, would impart lustre to the surface. The dimensions of halls and storeys, each storey being 10 ft. in height, and the provision of eaves unmistakably point out that the engineering skill was of a high order.[51]

As noted already, the Pāli language was an important vehicle of the Buddhist thought over a vast stretch of the country and even beyond. Though the scientific ideas and technical practices, as found in the Pāli texts, owe their

origin, by and large, to those of the Sanskrit tradition, it would appear that they were suitably modified or presented in such forms as would appeal to a large section of the common people, thus rendering possible a dissemination of the Indian scientific ideas and practices far and wide.

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14 *Abhidhamsa Kasaviya Khga*, Tokyo, p. 85.
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16 *Abhidhammamatha Samgha*, p. 29.
17 *Visuddhimagga*, p. 58.
18 *Abhidhammamatha Samgha*, p. 28.
19 *Attasālini* (2), p. 311.
20 *Abhidhammapadadipika*, Ed. Subhuti, Colombo, 1938, p. 138.
21 Mote of dust; size of the particle of dust raised by the chariot wheel.
22 *Sans*: *likṣā*; a kind of vermin of small size.
23 *Sans*: *ukā*; a louse.
24 Grain; bean.
25 Essentials of Buddhist Philosophy, Honolulu, 1947, p. 286.
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