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ARTICLE

Nation-building in the laboratory: Science, state, and the postcolonial genesis of India's National Chemical Laboratory

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Abstract
Conceived during the final years of British colonial rule, the CSIR–National Chemical Laboratory was the first of the *"Bhatnagar Eleven"* national laboratories established by the Council of Scientific and Industrial Research. This article situates the founding and growth of CSIR–NCL within the broader trajectory of postcolonial nation-building, scientific modernism, and techno-nationalist ambition in independent India. Drawing on archival materials, oral histories, and institutional records, it examines how the laboratory's creation reflected shifting intellectual, political, and economic priorities—from colonial science policy frameworks to indigenous developmental goals. The study further explores how NCL sought to balance basic research with applied industrial innovation, while positioning itself within a global scientific and technological landscape. By tracing the laboratory's contributions in chemistry, chemical engineering, materials science, and biochemical sciences, this article offers insight into the evolving relationship among science, the state, and society in twentieth-century India.

Keywords CSIR-National Chemical Laboratory · Indian scientific institutions · Industrial research in India · Science policy and innovation · History of science in India

1 Introduction

In 2025, the CSIR–National Chemical Laboratory (CSIR-NCL), popularly known as NCL, celebrated its seventy-fifth anniversary. Established amidst the political uncertainties of late colonial India and inaugurated shortly after independence by Prime Minister Jawaharlal Nehru, NCL was envisioned not merely as a center of chemical research but as a cornerstone of a broader project: to mobilize science and technology for national reconstruction and industrial self-reliance. This article investigates the scientific, institutional, and socio-political imperatives that underpinned the creation of India's first national laboratory, tracing its transformation into a premier center of scientific and technological innovation in the postcolonial era.

2 Early foundations

The emergence of NCL cannot be fully understood without situating it within the broader historical context of science in India. By the end of the nineteenth century, India witnessed significant advancements in fundamental scientific research, particularly in university laboratories and endowed research institutions. However, applied science research and technological training received insufficient attention, largely due to the absence of a clear policy from the government at both the central and provincial levels. During British rule, Indian entrepreneurship was not encouraged, a trend that continued until the *Swadeshi* (self-reliance) movement gained momentum in 1905, led by early nationalists in response to the partition of Bengal. Later, Mahatma Gandhi further strengthened the call for self-reliance through his advocacy of indigenous industry. However, even as some industries began to emerge, larger ones continued to rely on a flawed strategy,

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depending on tariff protection, abundant raw materials, cheap labor, and a ready domestic market, as highlighted by the Indian Industrial Commission Report (1916–1918).[1] Many emerging industries struggled to withstand foreign competition, and even those that survived remained largely dependent on imported machinery and technology.

The British Government in India established the Industrial Intelligence and Research Bureau in Kolkata on March 1, 1935, based on the recommendations of the Indian Industrial Commission and the Indian Tariff Board's reports, to support more than 300 industrial establishments across the country.[2] The Bureau was reformed with a broader scope and objectives as the Board of Scientific and Industrial Research (BSIR), attached to the Department of Commerce, Government of India, on April 1, 1940.[3] The focus on solving problems directly related to the Second World War limited the broader expansion of research topics within the BSIR. As the country was drawn into the War and became a primary supply base for the Allied Forces in the Middle and Far East, the strategic role, coupled with the disruptions in supply chains, compelled manufacturers to turn to indigenous technologies and expertise to meet critical demands. Moreover, the suboptimal level of investment and the absence of clear, realistic goals from the government for advancing scientific work constrained the scope of BSIR's activities.

3 CSIR and the chain of research laboratories

To level the playing field for indigenous industries, it became increasingly clear that coordinated industrial research, with a comprehensive scope and broad distribution across the country was essential.[4] Accordingly, this realization led to the establishment of the Council of Scientific and Industrial Research (CSIR) in India, in 1942, marking a new era in bridging the gap between science and its application to human welfare.[5] The organization's motto was to expand the country's industrial infrastructure, which had hitherto been largely untapped, and to foster innovations for the benefit of its people. During the initial years, CSIR focused on addressing urgent challenges, particularly those arising from the requirements of the Second World War (Krishna, 2011). One of its key achievements in the foundational decade was establishing a chain of research laboratories to advance research across all major scientific disciplines (Jacob and Bandyopadhyay, 2025). These laboratories represented a consolidation of an organization for the application of scientific knowledge to industry, backed by a definite government policy and continuous financial support. The large-scale expenditure for the establishment of these permanent laboratories were generously supported by industries and private benefactors. The science created in the national laboratories, both fundamental and applied, not only discovered new sources of wealth but also ensured that India remained competitive with the best nations in the world (Anderson, 2010). Collectively, the CSIR national laboratories represent a vital intellectual asset that has significantly contributed to India's progress and prosperity for over 75 years.

The establishment of the first eleven in the chain of research laboratories, often called as the *"Bhatnagar Eleven",* was the result of two-fold policy adopted by the British Government in India (Rajagopal et al., 1991). After the Second World War, numerous research projects were undertaken at the five main universities; Calcutta, Madras, Bombay, Punjab, and Allahabad, as well as in various specialized institutes, with funding provided by the Government through the CSIR.[6] However, it became clear that, despite their value, the facilities at these research institutes and universities were insufficient to meet the growing needs of the country. Scientific work in these institutions centered on individual workers, each isolated in their own labs and pursuing their preferred areas. But knowledge had grown to such an extent, and the different methods of tackling a problem had become so interrelated, that solitary workers could no longer be expected to make notable contributions to the advancement of science on their own. Research aimed at national interests requires well-directed teamwork. The second part of the policy was the establishment of national laboratories in each well-defined branches of science which has the potential to generate unparalleled wealth. Modern scientific research demands substantial investment, but it promises to repay this investment many times over. With their resources and equipment, these labs today undertake expensive research projects that extend beyond the capabilities of existing institutions. The concept of such national laboratories was planned in consonance with the research enterprises in other countries, which have played a significant role in advancing science and revitalizing industries. Research expenditure assumed a significant proportion of the national expenditure in those countries (Bhatnagar, 1947).

The CSIR owes its establishment to the steadfast leadership of the Honourable Sir Arcot Ramasamy Mudaliar, a Member of the Council of His Excellency the

[1] Indian Industrial Commission Report, Superintendent Government Printing, Calcutta (1918).

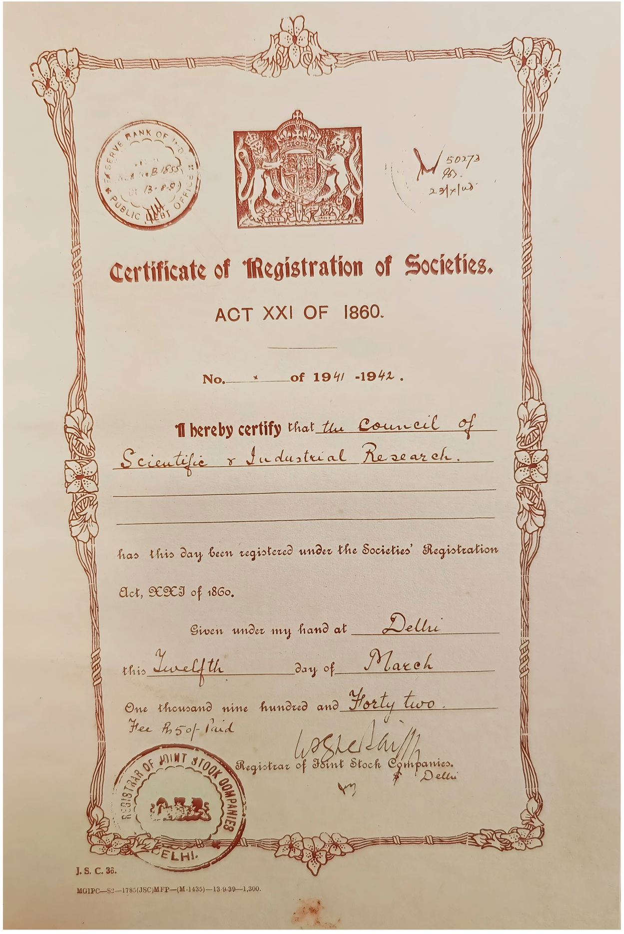
[2] Industrial Research Bureau, *Current Science,* vol. 5, no. 2, p. 55–57 (1936).

[3] The Constitution of the Board of Scientific and Industrial Research, Home Department, Government of India (1940).

[4] Scientific and Industrial Research in India, *Nature,* 151, 329 (1943).

[5] Department of Commerce Resolution, Government of India, New Delhi (1942).

[6] BSIR Review Report, CSIR, New Delhi (1954).


Certificate of Registration of Societies.

ACT XXI OF 1860.

No. ____ of 1941 -1942.

I hereby certify that the Council of Scientific & Industrial Research.

has this day been registered under the Societies' Registration Act, XXI of 1860.

Given under my hand at Delhi

this Twelfth day of March

One thousand nine hundred and Forty two.

Fee Rs 50/- Paid

Registrar of Joint Stock Companies, Delhi

REGISTRAR OF JOINT STOCK COMPANIES DELHI

J. S. C. 36.

Fig. 1 The CSIR Certificate of Registration, Registrar of Joint Stock Companies, Delhi (1942) Courtesy: CSIR-NCL Archives

Governor-General, and Sir Shanti Swarup Bhatnagar, Director of Scientific and Industrial Research. In November 1941, Sir Mudaliar moved the Industrial Research Fund Bill in the Legislative Assembly:

> This Assembly recommends to the Governor-General in Council that a fund called the Industrial Research Fund be constituted for the purpose of fostering industrial development in this country, and that provision be made in the Budget for an annual grant of Rs. 10 lakhs to the Fund for a period of five years.[7]

This resolution was passed by the Legislative Assembly and accepted by the Government of India, and it was then decided to set up CSIR as an autonomous body to implement and give effect to the resolution creating the Industrial Research Fund. Mudaliar's continued involvement demonstrated remarkable foresight in securing government support aligned with national priorities. Complementing this, Sir S. S. Bhatnagar is widely regarded as the architect of CSIR. After Independence, the *"Nehru–Bhatnagar effect"* further accelerated the Council's activities, enabling it to become the innovation engine of India (Fig. 1).

4 Proposal for the National Chemical Laboratory

The founding of the National Chemical Laboratory (NCL) marked a pivotal moment in India's scientific awakening, a nation long suppressed began to give voice to its aspirations of harnessing science and technology for the betterment of its people. When Sir S. S. Bhatnagar assumed office as the Scientific Advisor to the Government of India and Director of the BSIR in August 1940, he envisioned the creation of a network of national laboratories across the country. Driven by this conviction, Bhatnagar undertook the formidable task of establishing eleven national laboratories (Doraiswamy, 2011). On September 2, 1941, he formally proposed to the Government of India the establishment of the National Physical Laboratory and the National Chemical Laboratory:

> The present laboratory, which has been placed at the disposal of the Director, Scientific & Industrial Research, deals with physico-chemical investigations on industrial subjects and is extremely unsatisfactory from the point of view of both equipment and staff. I am definitely of the opinion that, as time rolls by, we shall have to expand these activities considerably, and these laboratories will have to be strengthened and developed on the same lines as in England. All the laboratories will be under independent Directors of Research, and the coordinating authority for all scientific work under the Board should be the Director, Scientific & Industrial Research. If that happens, it would be advantageous to divide the laboratories into (a) the National Chemical Laboratory and (b) the National Physical Laboratory, under two separate Directors of Research. I have therefore thought of a plan by which the contemplated project can be given effect to gradually.[8]

This proposal was accepted by Honourable Sir A. R. Mudaliar. Bhatnagar, in his initial note, strongly urged that a comprehensive plan for the laboratories could only be developed by a properly constituted planning committee, which would study matters such as location, equipment, staffing, and costs. The constitution of such a committee ensured that any information they supplied would be a well-balanced statement of the position viewed from all aspects.

[7] CSIR Review Report, CSIR, New Delhi (1948).

[8] CSIR Review Report, CSIR, New Delhi (1954).

At the 10th meeting of the BSIR on July 12, 1943, the formation of such a committee was recommended. The Governing Body of the CSIR, at its 4th meeting held on July 14, 1943, approved the BSIR's recommendation and constituted the NCL planning committee. Honourable Sir Ardeshir Dalal (Director, Tata Iron and Steel Works, Bombay) was nominated as the chairman of the committee to oversee the plan and modus operandi. The first meeting of the committee was held on January 20, 1944, at the office of Sir Dalal at Bombay House, Bombay. Meanwhile, it became necessary to recruit a full-time officer to oversee the laboratory's planning and development and serve as the secretary to the committee. In June 1944, Bashir Ahmad (Assistant Director, CSIR) was deputed to this position. Later, in October 1944, after Sir Dalal joined the Government of India as Member for Planning and Development, Sir John Matthai (Director, Tata Sons Ltd., Bombay) succeeded him as the chairman. Other illustrious members of the planning committee were Sir J. C. Ghosh (Director, Indian Institute of Science, Bangalore), Prof. J. N. Mukherjee (Science College, Calcutta), Prof. K. Venkataraman (University of Bombay), Prof. M. D. Qureshi (Osmania University, Hyderabad), Mr. M. D. Parekh (Chief Chemical Engineer, Delhi Cloth and General Mills Co., Ltd., Delhi), and Prof. P. Carter Speers (University of Punjab). In drawing up the plans, the objective of providing modern buildings with the latest designs and equipped with the most up-to-date apparatus was prominently kept in view. The committee conducted formal case studies and visited the Chemical Research Laboratory, Teddington; Mellon Institute of Industrial Research, Pittsburgh; Massachusetts Institute of Technology, Cambridge and General Motors Corporation, Detroit. Subsequently, a detailed plan was developed, following more or less the lines of the brethren abroad but customized to address India's unique needs.[9] This plan was then widely circulated to various scientific organizations and distinguished individuals, both within India and abroad, for feedback.[10] The proposal roused considerable interest among the enlightened section of the Indian community. The final plan, revised based on the received feedbacks was then submitted to the Government of India in 1945.[11] The committee noted the objective of the new laboratory as:

> The work of the National Chemical Laboratory would be largely of a fundamental, basic and applied character, along lines likely to promote research in industrial chemistry and the chemical utilization of the raw material resources so as to help the development of the country and its industries. The development of new processes evolved at the laboratory will, wherever considered desirable, be carried out up to the pilot plant stage so that the chemical and other industries requiring the aid of chemical research in general will benefit from the investigations carried out at the laboratory.[12]

4.1 Funding allocations and location for the new laboratory

The Second World War ended. CSIR's proposal was then approved by the Government of India, and sanctioned with a grant of Rs. 1 crore in 1944–45 for the construction and equipment of a chain of research institutions, of which Rs. 25 lakhs were designated for the NCL.[13] The planning committee identified non-recurring expenses including estimates of costs for land, building, equipment etc. of Rs. 35 lakhs and an average recurring expenses for salaries of the staff, cost of chemicals, and utilities etc. of Rs. 11.6 lakhs. Under the direction of CSIR, all the proposed new laboratories were allowed to derive funding from private benefactors and industries, either directly or indirectly, through contributions and special grants. Additionally, money spent on this by industries and benefactors was exempt from income tax assessment. Thereafter, in response to Sir A. R. Mudaliar's appeal to industrialists and Sir Dalal's written request to Mr. J. R. D. Tata, the Tata organization generously contributed a donation of Rs. 8.31 lakhs to NCL. Besides providing financial assistance, the Tata organization took a special interest in the establishment of the new laboratory. CSIR also decided to amalgamate the chemical section of its headquarters (Delhi University) with the NCL. Thus, it was decided to transfer all equipment, chemicals, apparatus, and the library from New Delhi, with an estimated value of Rs. 5.6 lakhs at pre-war rates. Therefore, the total funds available for the NCL amounted to Rs. 38.9 lakhs combining both financial support and equipment.

While giving their generous grant, the Tata Trust expressed their interest that the new laboratory should be located in either Bombay or a place in close proximity to the industrial activities of the Presidency. After long and careful consideration, CSIR selected Poona, a city long renowned for its culture, situated on the foothills of the Sahyadri mountain range (Western Ghats of the Indian Peninsula), as the most advantageous site for the NCL. Poona was favoured for its proximity to Bombay, its closeness to various industries and factories involved in the production of chemicals and explosives, and its nearness to numerous educational institutions. The city is home to the largest command of

[9] Tentative Proposals by the National Chemical Laboratory Committee, CSIR, New Delhi (1944).

[10] A National Chemical Laboratory for India, *Science,* vol. 100, p. 163 (1944).

[11] The Proposed Plan of the National Chemical Laboratory, CSIR, New Delhi (1945).

[12] Proposal for National Chemical Laboratory in India, National Archives of India, New Delhi (1946).

[13] CSIR Review Report, CSIR, New Delhi (1954).

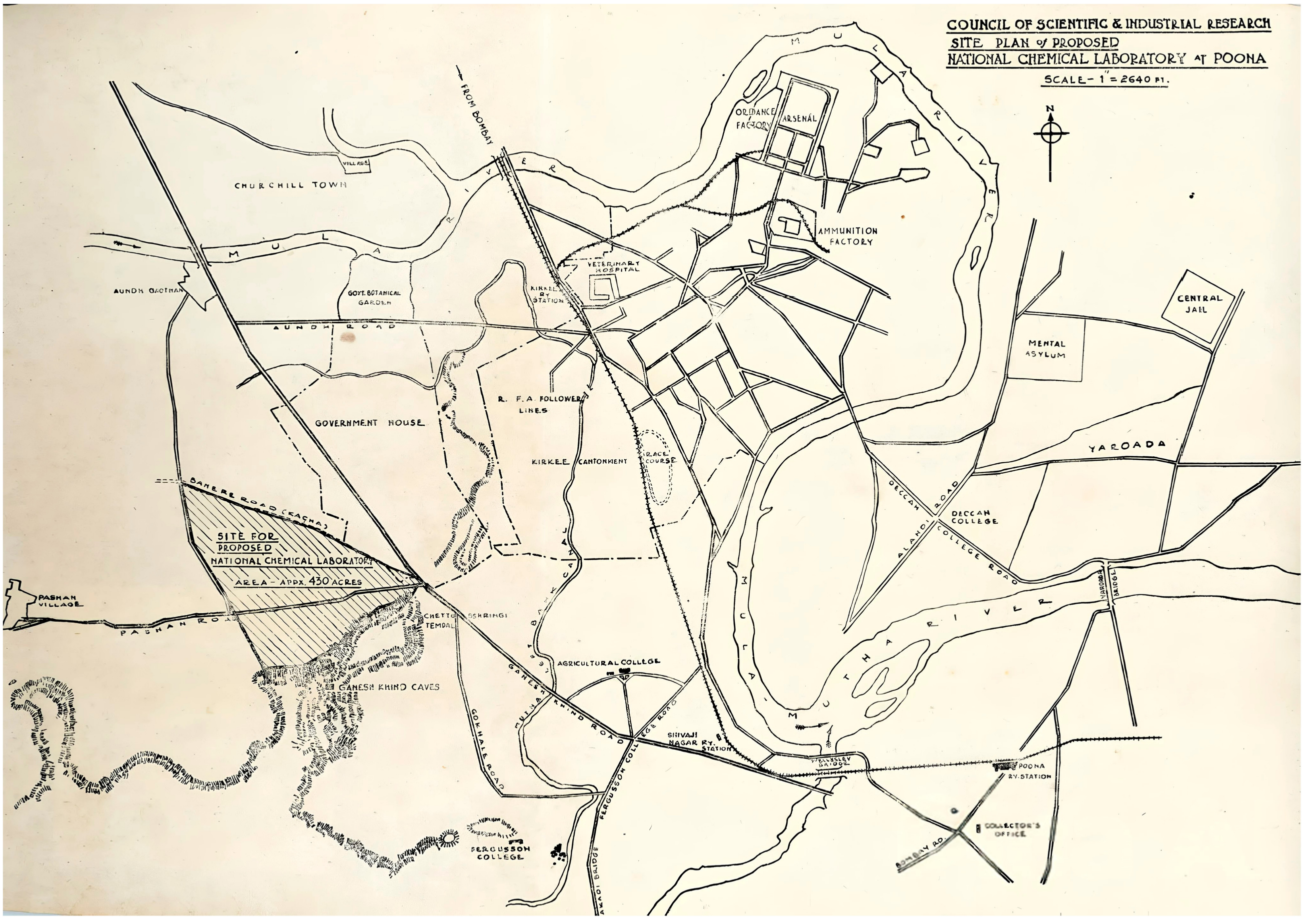


Fig. 2 The Layout Map of Site Proposed for NCL. Courtesy: CSIR-NCL Archives

the Indian Army and hosts several defence establishments. Poona also enjoys a moderate climate throughout the year and is blessed with picturesque natural surroundings. Seven potential sites within the city were identified by the committee, out of which three were then shortlisted based on factors such as available area and cost. The CSIR's initial choice for the site was located across from the Governor's mansion in Poona (the present-day campus of the Pune University). However, this proposal was rejected by the Government of Bombay due to objections from Governor Sir John Colville's office, who stated that:

> The unpleasant odours and fumes from the chemical laboratory could not be allowed to pollute the pleasant surroundings of Governor's residence.[14]

Thereafter, a 435-acre army camp known as *Pashan* (meaning 'rock' in Sanskrit), located about four miles from the city, was identified, and the land was acquired by the CSIR from the Bombay Government.[15] At the committee's request, Shri Morarji Desai, then Home Minister of the Bombay Presidency and later Prime Minister of India, proactively negotiated with Mr. Hirubhai M. Patel, Defence Secretary, and Sardar Baldev Singh of the Ministry of Defence to secure land from the Army. The Government of Bombay recognized the importance of such a research institution and deemed it appropriate to lend their support and encouragement to the cause. This area, finally selected between hills and clear skies, offered a scenic, breezy plateau located close to prominent institutions such as the Agricultural College, the Law College, and the College of Engineering.

A local planning committee, chaired by Prof. D. G. Karve of Brihan Maharashtra College of Commerce, Poona, was formed to secure local support for essential services, including electricity, water, transport, civil works, and others. Other committee members, mostly principals of nearby colleges and schools, who came forward enthusiastically, included Prof. G. R. Paranjpe, Honorary Secretary, Maharashtra Association for the Cultivation of Science; Mr. D. D. Karve, Principal, Fergusson College, Pune; Mr. Jivraj Mehta; Mr. J. A. Taraporewala, and Mr. H. K. Ambler. The team leased a spacious building owned by Brigadier Mohite,

[14] The National Chemical Laboratory of India, CSIR, Poona (1947).

[15] CSIR: A Review, CSIR, New Delhi (1948).

a retired Indian Army officer, and set it up as their operational base for the construction of the lab (presently Reserve Bank of India College of Agricultural Banking, Pune). NCL benefited significantly from the honorary services of these individuals, whose wise counsel and support guided it through its formative years (Ahmed, 1947) (Fig. 2).

4.2 Foundation stone laying ceremony

On Sunday, April 06, 1947, Honorable Mr. B. G. Kher, Prime Minister and Minister for Education of the Government of Bombay laid the cornerstone of the new laboratory (Fig. 3). The ceremony was presided over by Honorable Shri C. Rajagopalachari, Member for Industries and Supplies, Government of India, and President of the CSIR. A large gathering of over 2,000 from different parts of the country attended the function. The people of the nearby Pashan village greeted the guests with garlands, symbolizing their goodwill and welcoming the new laboratory to their neighborhood. Bhatnagar, in his opening address, said the scope and work of the NCL:

> The subject of chemistry occupies a unique position in the field of industrial development. There is hardly any finalized industrial product, raw material or process in which chemistry does not play a part. It is obvious that no single laboratory could hope to accomplish everything needed for industrial research in this field and specific problems will have to be solved and fundamental work carried out in numerous other laboratories in the provinces and the universities and in the laboratories of private industries. At the present stage of our country's development, we do, however, need an outstanding laboratory in India which will offer facilities for research work in the more important fields of chemistry.

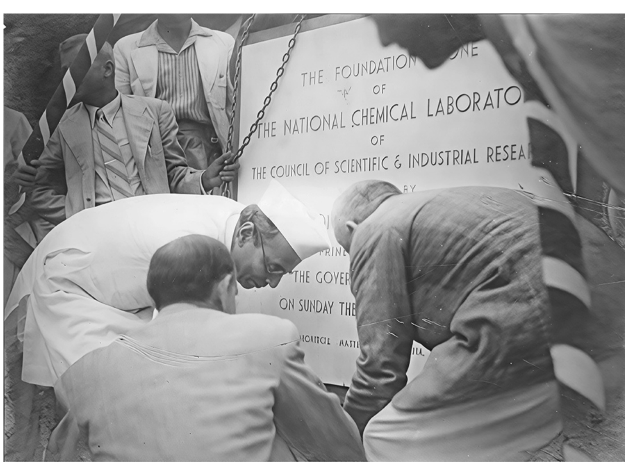


Fig. 3 Shri B. G. Kher, Honorable Prime Minister of Bombay State, laying the Foundation Stone on April 06, 1947. Courtesy: CSIR-NCL Archives

The silver trowel, hammer, and bowl used by the Honorable Minister to lay the foundation stone were offered to him as a gift by CSIR. However, the Minister expressed that it was his principle not to accept such presents. As a result, the items were auctioned to the public on behalf of the laboratory. Mr. M. L. Dahanukar, a philanthropic industrialist of Bombay, purchased them for Rs. 5,000/-. In a generous gesture, he then donated them back to the NCL to be preserved in its museum as a memento of this historic occasion.[16]

4.3 Construction of the laboratory

Messrs. Master, Sathe, and Bhuta, an architectural firm from Bombay, were appointed by CSIR as the chief architects for the laboratory. Renowned for their contributions to many iconic modern Indian buildings, the trio embraced and interpreted *Swadeshi* arts, seamlessly integrating these elements into their designs to create a harmonious visual language known as *Indo Deco.* Alongside them, Messrs. Achyut Kanvinde and Shaukat Rai, as well as Messrs. Gannon Dunkerley and Co., Ltd., Bombay, were entrusted with minor assignments. Notably, one of the chief architects had already been deputed by CSIR to visit laboratories in the UK and the US, gaining valuable insights to inform their work. Construction work began in February 1948. Proactive discussions were also held with eminent chemical engineers and industrialists, leveraging their scientific expertise in construction to benefit the broader chemical community. To oversee the progress of construction, Bhatnagar used to visit the site every week, accompanied occasionally by Prof. Homi J. Bhabha FRS (Director, Tata Institute of Fundamental Research, Bombay) and Mr. K. A. Hamied (Founder, Chemical Industrial and Pharmaceutical Laboratories, Bombay). The 'E' shaped main building was modelled in line with the Chemical Research Laboratory in Teddington and *Sarasvati* building of the Law College, Poona, which could be expanded for future extensions without impairing the architectural harmony of the structure. This building, which measured 640 feet in length and 200 feet in width, contained 250 rooms of various sizes, stood as an impressive sight set in a natural amphitheater surrounded by hills. When completed, it featured a basement, ground floor, first, and second floors covering a floor space of 1.5 lakh square feet. The floors and stairs of the entrance hall are made of gray Italian marble, and the pillars extending to the second floor are painted a soft vista blue. A feature of interest is that the basement is a dug-out tunnel from which the service mains for water, gas, electricity, and steam have been brought up

[16] The National Chemical Laboratory of India, CSIR, Poona (1947).

Fig. 4 General View of the Chemical Research Laboratory, Teddington (1940s). Courtesy: CSIR-NCL Archives

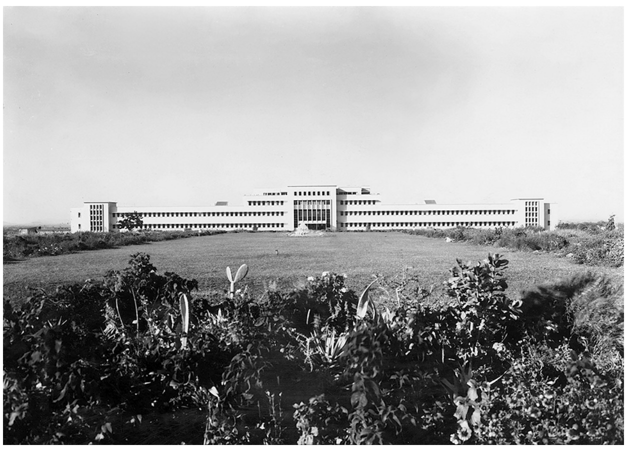


Fig. 5 General View of the Main Building of NCL, Pune (1950s). Courtesy: CSIR-NCL Archives

vertically. This provides an efficient distribution of services with minimal expenditure. The main building included an auditorium, library, museum, visitor room, lecture hall, offices for administration, and sectional laboratories. In front of the main building, a large eighty-foot water fountain was constructed, accompanied by a series of water pools. These were surrounded by ornamental trees that extended up to the main gate. The design reflected Indian traditions and the belief in bringing prosperity and good fortune to the laboratory while enhancing its aesthetic appeal. Along with the main building, the construction of auxiliary buildings to accommodate pilot plants and workshops was also commenced. Residential quarters for the staff were built, and a hostel was provided, surrounded by extensive lawns, gardens, and tree-lined avenues. Although the entire project was expected to take a long time, CSIR prioritized the construction of the main building, as the inauguration date, set in consultation with the Honorable Prime Minister, was scheduled for the first week of January 1950 (Figs. 4 & 5).[17]

[17] The NCL of India, CSIR, Poona (1950).

4.4 Appointment of the director and staff

Initially, CSIR planned to appoint Salimuzzaman Siddiqui, a renowned organic chemist and head of the chemical section at its New Delhi headquarters, as Director of the new laboratory, a position he was already holding in an acting capacity.[18] He also led the NCL's Organic Chemistry Division and served as its first Chair. As these developments coincided with the partition of India, Pakistan's Prime Minister, Liaquat Ali Khan, requested that India's Prime Minister, Jawaharlal Nehru, relieve Siddiqui so that he could help establish scientific infrastructure in Pakistan. Siddiqui accepted the request and emigrated to Pakistan in 1951, later becoming the founding Director of the Pakistan Council of Scientific and Industrial Research (PCSIR). Historical accounts describe him as a reluctant emigrant who had served India and its scientific institutions with great distinction. One of his notable contributions during his tenure in India was the development of indelible ink, which was used in independent India's first general elections (Muhammad, 1996).

Consequently, Bhatnagar was tasked by Prime Minister Nehru with finding a new Director for NCL. As an accomplished colloid chemist, Bhatnagar likely recommended to the Prime Minister the name of Professor James William McBain, FRS, Emeritus Professor of Physical Chemistry at Stanford University. Professor McBain had served as Vice-President of the Faraday Society, Chairman of the Colloid Division of the American Chemical Society, and was a Fellow of the Royal Society.[19] Prof. George S. Parks, former head of the department of chemistry at Stanford and one of Prof. McBain's colleagues, reminisced him in his memorial resolution:

> Prof. McBain's work at the National Chemical Laboratory sprang from his deep willingness to serve his fellow man wherever and however he could. At an age when most men would turn without reluctance to a period of restful retirement, McBain never hesitated to accept the challenge of laying the firm foundations for the widespread development of industrial chemistry in India, and he brought to the task all his missionary zeal and energy.[20]

The R&D work at the lab began in March 1949, covering both pure and applied fields across seven divisions with their respective chiefs: Inorganic and Analytical Chemistry (J. Gupta), Organic Chemistry (S. Siddiqui), Biochemistry (M. Damodaran), Physical and Electrochemistry (S. S. Marsden), Chemical Engineering (J. H. Truttwin), Plastics

[18] CSIR: A Review, CSIR, New Delhi (1948).

[19] National Chemical Laboratory of India, *Nature,* vol. 163, p. 595 (1949).

[20] G. S. Parks, Memorial Resolution of Prof. J. W. Mcbain (1953).

and High Polymers (S. L. Kapur), and Survey and Information (K. G. Mathur). Prof. B. D. Laroia, former head of the Department of Chemistry at the University of Delhi, joined as the head of administration for the laboratory. Out of the proposed 320 scientific, technical, and administrative positions, 150 were filled with permanent personnel.

4.5 The opening ceremony

On the morning of January 03, 1950, the Honourable Prime Minister, Pandit Jawaharlal Nehru, dedicated the National Chemical Laboratory to the nation, marking it as the first in the series of the *"Bhatnagar Eleven."* This important and auspicious occasion coincided with the celebration of the thirty-seventh session of the Indian Science Congress Association, so that many distinguished Indian and foreign scientists were assembled.[21] The ceremony was presided over by His Excellency Raja Maharaj Singh, the Governor of Bombay. The ceremony was attended by representatives from all elements of the scientific community, including Syama Prasad Mukherjee, Minister of Industry and Supply, and Vice-President of CSIR; S. S. Bhatnagar, FRS, Director of CSIR; and several distinguished scientists, including Nobel laureates. Among them were Sir Robert Robinson, President of the Royal Society accompanied by Lady Robinson, who was also a very distinguished chemist; Chancellor A. H. Compton, the discoverer of the Compton Effect and a renowned physicist and Mrs. Compton; Prof. Madame Joliot-Curie, Nobel laureate and Director of the Institute de Radium Laboratory in Paris; Sir C. V. Raman, India's Nobel Laureate; Sir P. Auger, Nobel laureate and Director of Science at UNESCO in Paris; Prof. O. E. H. Rydbeck, Nobel laureate and Director of Research at Chalmers Institute of Technology in Gothenburg; Prof. J. D. Bernal of University of London; Prof. E. U. Condon, Director of the National Bureau of Standards in Washington; and Prof. Herman Mark, of the Polymer Research Institute in Brooklyn. Around five thousand people attended the colourful ceremony.[22] In his address, Bhatnagar expressed his immense satisfaction and joy at the successful completion of his venture:

> In that hour when I decided to take up office of the Director, BSIR, I dreamt of a chain of National Laboratories, of large teams of scientists working for the development of India and the creation of a scientific outlook on life among India's masses. Those who consider that India's ills can be cured by increasing productivity must realize that this can be achieved only by the application of science to its agriculture. I have struggled through the years to fulfill that dream, and it seems that it may now come true. Of the eleven National Laboratories we have been planning, equipping, and executing, seven will be opened this year. The remaining four will soon materialize. It is a day of real thanksgiving for me, and I feel I must pay my homage of thanks to all those who have helped me to realize my dream.[23]

Syama Prasad Mukherjee, Minister of Industry and Supply, assured that the new laboratory would not be run as a government department but would be granted sufficient scientific autonomy and flexibility in administration, ensuring that its activities would not be hindered. Prof. J. W. McBain, the Director, proclaimed the visionary statement: *"The purpose of this laboratory is to advance knowledge and to apply chemical science for the good of the people,"* thereby establishing the laboratory's distinctive and valuable identity. This statement, which remains unchanged and is beautifully inscribed in the foyer of the NCL main building, aligns with the fundamental purpose of Britain's oldest and most exclusive scientific society, the Royal Society, as outlined in its founding charters of the 1660s: *"The purpose is to recognize, promote, and support excellence in science, and to encourage the development and use of science for the benefit of humanity."* Both statements share a common theme: the advancement of science for the well-being of society.

The foundation and inauguration of NCL were closely linked to India's independence and the proclamation of the Republic, making the lab nearly as old as the nation itself. Its establishment symbolized a new India, embracing scientific progress and self-reliance. The relentless efforts of the committee and the workers from July 1943 to December 1950 transformed the concept of NCL into a tangible reality. The journey, from the initial proposal in 1941 to the foundation stone ceremony in 1947, and official opening in 1950, was delayed by the upheaval of the Second World War. The Government of Bombay rejected the initial proposed site, and the military were initially reluctant to vacate the new site. Despite these setbacks, the committee's unwavering spirit of idealism and teamwork came to fruition. NCL was launched ahead of any other National Laboratory. It succeeded the early research facilities at the Bureau in Calcutta and Delhi University. The laboratory owes its particular debt to Tata's for their generous donations. Thus, public munificence, government patronage, and above all the unsparing efforts of Indian men of science, especially the long cherished dream of Sir Shanti Swarup Bhatnagar, culminated in ultimately establishing a *"temple of science* (Figs. 6 & 7)*."*

[21] Opening of the National Chemical Laboratory of India, *Nature,* vol. 165, p. 174 (1950).

[22] National Chemical Laboratory, *Chemical and Engineering News,* ACS, vol. 28, no. 7, p. 476 (1950).

[23] The NCL of India, CSIR, Poona (1950).

Fig. 6 Opening of the NCL by the Honorable Prime Minister Pandit Jawaharlal Nehru on January 03, 1950. Courtesy: CSIR-NCL Archives

Fig. 7 Madam Irene Joliot-Curie, Sir Arthur H. Compton, and Sir Robert Robinson on the dais (from left to right) during the inauguration of NCL on January 3, 1950. Courtesy: CSIR-NCL Archives

5 Coordinating for research

NCL began its journey in alignment with the country's industrial development plan, which aimed to address the urgent problems of various industries and ensure the efficient utilization of key raw materials. The lab focused on research related to the manufacturing of basic chemicals and dyestuffs to establish connections with the emerging industries in independent India. It also catalysed the development of small-scale industries, which absorbed local talent and provided new jobs to workers. An advisory board, comprising eminent scientists and technologists from industry, sister laboratories, universities, as well as executives from central and state ministries and government departments, was constituted in 1953 to assist the Director in matters of policy and strategy. Shri P. A. Narielwala of Tata Industries Ltd. served as the chairman of the board. Other members included Shri D. D. Karve of Ferguson College, Poona; Shri A. Nagaraja Rao, Industrial Adviser (Chemicals), Ministry of Commerce & Industry; Shri Kasturbhai Lalbhai of Central Public Works Department Industry Committee; Shri B. B. Chowdhury, Chief Inspector of Explosives; Sir S. S. Bhatnagar, CSIR; and Prof. G. I. Finch FRS, Director, NCL. The Director was also assisted by the heads of different divisions for the overall research program. Much of the research was initiated and conducted in close collaboration with, and under the guidance of, various organizations and institutions. Notable among these were the Indian Institute of Science, Bangalore; the Armed Forces Medical College, Pune; and the Central Laboratories of Hyderabad (Deccan), among others. Additionally, key collaborations were established with the Indian Council of Agricultural Research, the Indian Council of Medical Research, and the Atomic Energy Commission. The library, which began in a spacious 8,500 square feet hall, housed over 25,000 volumes of books and periodicals on pure and applied chemistry, with subscriptions to around 300 journals. It was the largest collection of its kind in the country in the fields of chemistry and chemical technology. Additionally, it served as the Inspection Centre for Indian Patents.[24]

Based on the experiences of NCL's predecessor, the chemical laboratories at the CSIR headquarters in Delhi, it became evident that the application of science was seriously hindered by a lack of foundational knowledge, an issue that significantly affected scientific work more than many other factors. Chemists require accurate data to guide them in understanding what reactions can be expected to occur, to what extent, and at what speed. A knowledge of physical properties is also essential for the scientific design of chemical plants by chemical engineers. This is as much a national concern as the application of science to solve problems of immediate and obvious economic importance, as the resolution of industrial challenges almost always depends on the utilization of fundamental knowledge. When this knowledge is insufficient or absent, progress is either slowed or completely halted. Therefore, the laboratory began focusing on fundamental chemical science from its early days. The work of the lab was categorized into two main areas: a general program of research and numerous special investigations conducted on request for government departments, industrial firms, and others. Thus, NCL had a dual role, designed to address both immediate problems and long-range needs. The research plans were not kept rigid, allowing them to adapt to new ideas or unexpected discoveries.

[24] Poona District, Gazette of Bombay Government (1954).

While planning its research programs, the laboratory took special care to avoid overlapping with the work of newly established national laboratories and other government research councils. Like its counterpart in physics, the National Physical Laboratory, there were no formal limitations on the scope of NCL, allowing it to undertake multidisciplinary initiatives to address large-scale, complex challenges. The lab recognized that its national impact depended significantly on the efficiency of disseminating the results of its investigations. NCL's experimental work was conducted in close cooperation with the industries concerned, allowing the results to be widely adopted almost automatically. In certain cases, advisory work was an integral part of the lab's normal program. In other areas, the results were swiftly transferred into practical applications. The laboratory adopted the model of the Mellon Institute of Industrial Research in the USA, which served as a parallel example of an organization of research workers, where a system of industrial fellowships was created by individual industrial concerns or groups of manufacturers. As a testament to the early research endeavours, renowned Swiss biochemist, Sir Arthur Stoll FRS, during his visit to the lab on February 28, 1952, shared his admiration:

> One of my most treasured memories is of my visit to the National Chemical Laboratory, which ranks among the most perfectly equipped chemical institutes I have ever seen. I was glad to see that this institute has become one of the leading research centres in India, and I am confident that it will continue to make valuable contributions to the advancement of chemical knowledge in India and across the world.[25]

One of the most important programs proposed and initiated was the maintenance of basic standards essential for high-precision work. Facilities were established for testing manufactured and other products, as well as for conducting research related to various industries. Later, the custodianship of fundamental standards was assigned to the National Physical Laboratory, New Delhi, while the responsibility for standardization was given to the Indian Standards Institution (now the Bureau of Indian Standards) by the Government. The National Collection of Type Cultures was transferred to the laboratory from the Indian Institute of Science, Bangalore. The primary aim of this collection was to collect, preserve, and distribute pure cultures of bacteria, fungi, yeasts, and other microorganisms that were of industrial importance or were required for research.[26] An isolated radio tracer laboratory began functioning in 1954 for the study of radioactive isotopes. The various divisions and sections of NCL evolved gradually from small nuclei, which in the early years were often housed in inadequate or makeshift premises. By the end of the 1950s, the Central Electrochemical Research Institute[27] in Karaikudi (Tamil Nadu) and the Central Salt Research Institute (now, Central Salt and Marine Chemicals Research Institute[28] in Bhavnagar (Gujarat) emerged from NCL's R&D divisions, owing to their growing capabilities and potential for independent existence and development.

6 NCL's journey of seven decades

Over the course of seventy-five years, NCL's evolution has both reflected and contributed to India's broader scientific and industrial transformation. From its early years in the 1950s, when the focus lay on developing fundamental chemical research capabilities, to its later engagement with innovation-driven industrial partnerships and national missions, NCL's trajectory has been shaped by changing national priorities and global technological trends. Each phase reveals not only the lab's capacity to adapt but also the challenges of sustaining a balance between basic research and industrial relevance. While NCL has often been celebrated as a symbol of India's faith in science as an instrument of progress and self-reliance, its journey also underscores the complexities of translating that vision into long-term technological impact.

6.1 1950s: Basic chemicals and dyestuff

In its first decade, the lab undertook a wide gamut of activities to support the nascent Indian industry. These included surveying raw materials and evaluating their industrial potential, utilizing by-products from existing industries, conducting analysis and testing, and providing expert advice to industries.[29] Some important works undertaken were the fermentative production of citric acid using *Aspergillus niger* for the pharmaceutical, food, and printing industries; *bacterial diastase* for desizing in cotton textile industry; transfusion gelatine for use as a plasma substitute in blood transfusion (Goldsmith, 1951); gelatine for the manufacture of photographic and movie films; the extraction of nicotine sulphate from tobacco waste for insecticides[30]; the creation

[25] The National Chemical Laboratory of India, CSIR, New Delhi (1952).

[26] Reorganization of the Work of Maintenance and Supply of Type Culture of Microorganisms in India, National Archives of India (1952).

[27] Central Electrochemical Research Institute, CSIR, New Delhi (1954).

[28] CSIR: A Review, CSIR, New Delhi (1954).

[29] Press Information Bureau Broadcast (1958).

[30] Science in the Service of Industry Exhibition, CSIR, New Delhi (1956).

of paints and varnishes from the oil of *Kamala* seeds (*Mallotus philippinensis*); ion exchange resins for water softening from cashew shell liquid; manufacturing techniques for polystyrene and polyvinyl chloride (PVC) etc.[31] The lab undertook research into the chemistry of natural products isolated from *Nardostachys jatamansi, Luffa aegyptiaca, Stephania glabra, Alangium lamarkii,* and other plants. One notable achievement was the development of a cost-effective and efficient method for inducing artificial rain in the Poona region when normal rains failed, at the request of the Bombay Government. NCL was equipped with a wide range of instruments for precision research, including an electron microscope, electron diffraction camera, Langmuir surface pressure balance, Tiselius electrophoresis apparatus, light scattering photometer, X-ray diffraction spectroscope, infrared absorption spectrometer, and instruments for emission spectrography, spectrophotometry, polarography, and chromatography, some of which were not available elsewhere in the country at the time.[32]

Although NCL's published work during its founding decade was impressive and it was widely recognized as the leading center for chemical research in India, its impact on industry remained marginal. CSIR, in its third reviewing committee headed by Sir Ramaswamy Mudaliar, was critical of NCL *"leaning towards fundamental research."*[33] While many useful products and processes were developed at NCL, turning these innovations into commercial production proved difficult. Industry often saw NCL as too academic and not supportive enough of their practical needs. Although there is some truth to these criticisms, it is also recognized that industries themselves were partly responsible for the lack of cooperation.

6.2 1960s: Agro-chemicals and organic chemicals

When India launched the Green Revolution in the early 1960s with the goal of achieving self-sufficiency in food production, NCL aligned its efforts by developing process technologies for agrochemicals and organic chemicals. As the demand for fertilizers increased, numerous factories were established, creating the need for economically viable production methods for key building-block chemicals used in the fertilizer and pesticide industries. State-led public sector companies such as Hindustan Organic Chemicals Ltd. (HOCL) and Hindustan Insecticides Ltd. (HIL) were founded based on processes and plant designs developed at NCL. The lab also served as a professional consultant for several public sector enterprises, including Indian Petrochemicals Corporation Ltd., Baroda; Hindustan Organic Chemicals Ltd., Rasayani; and Hindustan Antibiotics Ltd., Pimpri, playing a vital role in their growth and development. At the request of the Ministry of Finance, NCL undertook the modernization of the Government Opium and Alkaloid Works in Ghazipur, Uttar Pradesh, the world's largest and oldest opium factory. The lab developed a simplified method for isolating four major alkaloids: morphine, codeine, thebaine, and narcotine.[34] Among NCL's notable innovations was the development of unique fluidized bed reactors for the production of key chloromethanes, including carbon tetrachloride, chloroform, and methyl chloride, which are used in a variety of industrial applications. Processes were developed for the pharmaceutical industry (calcium hypophosphite, 4-hydroxycoumarin, hexylresorcinol, berberine hydrochloride, acriflavine, benzoic acid, menthol, and beta-ionone, an intermediate for vitamin A), the dyestuff industry (chlorobenzene, ethyl acetoacetate, and diethyl-meta-aminophenol), and the chemical and materials industry (ethylene oxide condensates for surface-active agents, titanium tetrachloride for industrial chemicals).[35] Other developments included thermistors and ferrites for electronics, anti-priming compositions for railways, anion exchange resins for demineralization of liquids, single crystal cadmium sulphide photoconductor cells, adhesives for decorative laminates etc.[36] By the end of 1960s, NCL emerged as a major center for research in organic chemistry, with a focus on synthetic dyes, drugs and pharmaceuticals, perfumery chemicals, flavonoids, terpenoids, and wood phenolics.

6.3 1970s: Fine chemicals and pharmaceuticals

NCL played a pioneering role in establishing India's low-cost generic API (Active Pharmaceutical Ingredient) industry by leveraging the Indian Patent Act of 1970, which removed product patent protection and enabled local companies to innovate in process chemistry for drug molecules. With the lab's established expertise in the pharmaceutical sector, it developed processes for acetanilide, an important intermediate for sulpha drugs; sorbitol for vitamin C (ascorbic acid); bemegride, a respiratory stimulant; and carbimazole for hyperthyroidism. NCL continued to support the Department of Revenue, Ministry of Finance, Government of India, in the production of opium-derived alkaloids, mainly morphine and codeine. The lab's efforts were centred on developing efficient processes for alkaloid extraction, which ultimately led to the establishment of an alkaloid plant at the Government Opium and Alkaloid Factory in Neemuch, Madhya Pradesh, in 1976.[37] NCL's contributions

31 High Polymers Symposium and Exhibition, NCL, Pune (1957).

32 Decade Report (Internal), NCL, Pune (1960).

33 Report of the Third Reviewing Committee, CSIR (1964).

34 National Chemical Laboratory, NCL, Pune (1961).

35 Research Programme, NCL, Pune (1966).

36 National Chemical Laboratory, NCL, Pune (1968).

37 Research Programme, NCL, Pune (1973).

to the Indian pharmaceutical industry and the development of generic drugs were fondly recalled by Dr. Y. K. Hamied, Chairman of Cipla Ltd., who said,

> This was the start of a very useful and productive partnership between NCL and the pharmaceutical industry. Our collective effort in the post–Indian Patents Act 1970 era laid the foundation on which the API manufacturing industry, as it exists today, was built.[38]

Beyond pharmaceuticals, the lab made significant contributions to the chemical and materials industries, including processes for phthalates (used in molded plastics and rexine cloth), phenylethyl alcohol (for perfumes), nonylphenol (for the textile industry), and nitrile rubber, the first indigenously developed process for a polymer in India. Other developments include monochloroacetic acid and dimethylaniline for industrial organic chemicals, as well as a process for phenthoate (an insecticide) and indothrin (for pesticides). For defence applications, NCL developed monoethyl aniline, which is used as an intermediate for carbamate compounds, and hexachloroethane, utilized in creating smoke screens.[39]

In celebration of completing twenty-five years of its existence, the lab marked its Silver Jubilee on February 1, 1975. The Honourable Prime Minister of India, Shrimati Indira Gandhi, graciously inaugurated the event, while the Honourable Chief Minister of Maharashtra, Shri V. P. Naik, presided over the function. NCL's contributions over the past 25 years were highlighted by a documentary film titled *'NCL in the Service of the Nation',* which was released by the Films Division, Ministry of Information and Broadcasting, in the first week of February and subsequently shown in several cities. Prof. Y. Nayudamma, Director General of CSIR, remarked during the celebration:

> As the first laboratory established under CSIR, NCL has been a trailblazer and a pioneer in industrial research, earning the trust of both the nation and the chemical industry. Your achievements over the past 25 years stand as a testament to this legacy. NCL has continuously adapted to the evolving needs of industry and society, tackling complex technological challenges with in-depth expertise, confidence, and a wealth of experience in both basic and applied research.[40]

6.4 1980s: Catalysis

NCL set a unique example by establishing a triple helix collaboration among catalysis research, catalyst manufacturing, and end users in the 1980s, earning it the nickname *"The Catalyst's Catalyst"* from HOCL, a name to reckon with in both national and international arenas. The lab became an expert in synthesis, characterization, performance testing, and pilot-scale production of commercial catalysts. NCL made advances in developing a range of eco-friendly, high-performance zeolite-aluminium silicate catalysts, known as *Encilites* (NCL's Zeolites), used in Xylofining technology for producing ortho- and para-xylenes, which are basic raw materials for phthalic anhydride and polyesters, and in Albene technology for producing ethylbenzene from ethanol. These technologies were commercialized by public sector companies, such as Indian Petrochemicals Corporation Ltd. and Hindustan Polymers, for use in the petroleum refining and petrochemical industries.[41] Furthermore, NCL's capability in reverse technology transfer culminated in the successful export of catalysts and processes to advanced countries. This achievement effectively broke the monopoly of multinational cartels in the production and supply of catalysts.

NCL's first major foray into the front-line area of life sciences was the development of processes for producing superior plants and crops through tissue culture, a modern approach that yields uniform, disease-resistant, and high-yielding plants.[42] This helped farmers and horticulturists increase both the quantity and quality of their produce. NCL was a leading laboratory in this field, both in India and globally, with expertise in crops such as sugarcane, cardamom, teak, eucalyptus, pine, cashew, pomegranate, ginger, and turmeric.[43] The lab's early emphasis on organic chemicals of plant origin later gave way to synthetic strategies for producing many vital and bulk chemicals. NCL has contributed to the development of processes for several important drugs, including vinblastine and vincristine (anticancer agents from *Catharanthus roseus*), Taxol (anticancer agents from *Taxus baccata*), and Nevirapine, a drug effective in preventing the transmission of HIV from an infected mother to her child, along with other antiretroviral drugs used to control HIV-AIDS symptoms, was made available to the Indian population for the first time. NCL also developed ibuprofen (an analgesic), Flematic oil (a veterinary drug), vitamin B6, butanediol, and a detection kit for narcotics.

NCL's *Jalshakti,* a superabsorbent polymer capable of absorbing 100 to 1000 g of water per gram of material, giving it an extraordinary ability to absorb, retain, and release large quantities of water. This innovation was particularly suited to India's unique agro-climatic conditions. With

[38] Dr. Y. K. Hamied, Chairman, Cipla Ltd., speech at IICT, Hyderabad (2005).

[39] Achievements in Technology Transfer, NCL, Pune (1975).

[40] National Chemical Laboratory Silver Jubilee, NCL, Pune (1975).

[41] NCL's Zeolites *Encilites,* Internal Report, NCL, Pune.

[42] Plant Tissue Culture, A Pioneering Effort, Internal Report, NCL, Pune.

[43] Tissue Culture Pilot Plant, Internal Report, Department of Biotechnology, Government of India.

approximately 70% of India's cultivable area dependent on rain-fed agriculture (1980s), *Jalshakti* helped enhance agricultural production by alleviating soil moisture stress during periods of uncertain rainfall and revolutionized the reclamation of waste-lands. The versatility had the potential to extend its use to applications in diapers and sanitary napkins.[44] Another achievement was NCL's *Encilium* process, a unique self-immobilizing yeast strain that significantly improved the efficiency of continuous molasses fermentation to ethanol, compared to conventional processes.[45] Other achievements in the decade included turnkey technologies for the production of ethylene diamine and polyethyl amines, acryl esters, chlorosilanes, phenylglycyl chloride, polyurethane printing rollers, sodium–potassium ferrocyanides, fibre reinforced plastics for making two-wheeler components etc.

The Bhopal gas disaster in 1984, which led to the loss of over 3,800 lives and affected thousands more, remains one of the most tragic industrial accidents in the history of the Indian chemical industry. In the aftermath of the catastrophe, a team of researchers from NCL visited the site to investigate the causes of the failure and provide safety recommendations to prevent such tragedies in the future. Leveraging its expertise in process simulation modelling, NCL studied the methyl isocyanate (MIC) leakage from the accident tank for the Government of India's Varadarajan Commission. Their investigation conclusively ruled out sabotage, as claimed by Union Carbide. Instead, the team demonstrated that the disaster resulted from poor design of the MIC tank and unsafe operational practices. These factors led to the corrosion of the steel tank, which released iron chloride, a substance that catalysed the explosive reaction responsible for the tragedy. Subsequently, the lab developed a safer, non-MIC method for synthesizing carbamates for pesticides.[46]

6.5 1990s: Patenting and global technology transfer

In the 1990s, NCL began offering research and consultancy services to international clients, a move that aligned well with India's economic liberalization and its increasing integration into the global marketplace following the landmark New Industrial Policy of 1991. The policy dictates the motto that *"only technically and commercially competitive technology with global markets would be relevant."* Recognizing that the chain from concept to commercialization extends beyond national boundaries, NCL has become an integral part of the global research network, facilitating the transfer of technology, know-how, and intellectual property between countries. This transition was reflected in the sentiments of David S. Weir, Vice President of Global Technology at DuPont, who noted,

> We have had a hot and cold relation with India for the past 10 years mainly because of stringent government regulations. But now we are attracted by the economic liberalization policies and the new IP regime in line with the GATT policies.

The lab's focus on branding, innovation, and value led to landmark research agreements with global leaders like General Electric, DuPont, Unilever, Neste, Akzo, Ciba-Geigy, Solvay, Genencor, and FMC, establishing its reputation as a trusted R&D partner and pioneering global R&D services at a time when India was not yet recognized for knowledge services. These developments raised a serious question: *Why should infrastructure built with Indian taxpayer's money be used to conduct research for multinational corporations?* Prof. R. A. Mashelkar FRS, Former Director, NCL and Director General, CSIR, convincingly argued the benefits. At a time of national economic hardship, such partnerships provided vital funding, enabling Indian researchers, capable of world-class work, to access cutting-edge technologies and collaborate with the best minds globally, thereby raising the overall standard of research in the country. Furthermore, multinational companies showed interest in transferring jointly developed technologies to Indian firms for domestic manufacturing, often through buy-back arrangements. This enabled Indian industries to expand internationally and compete in global markets.[47] To remain globally competitive, NCL enhanced its infrastructure, analytical facilities, business planning, and marketing with support from a World Bank loan, committing to repay the principal and interest over ten years (1995–2005) using its commercial earnings. A notable milestone during the nineties was when NCL was selected by the Chinese government for a pioneering consultancy project, assisting the China National Chemical Construction Corporation and the Jiangsu Petroleum and Chemical Industry Department in strengthening their R&D capabilities in engineering plastics and fine and specialty chemicals. This project was supported by a grant from the International Bank for Reconstruction and Development, marking the first time an Indian organization was chosen by China to enhance its research facilities, underscoring NCL's rising international reputation.[48]

The laboratory developed strong expertise in the design, modelling, simulation, and optimization of industrial reactor systems and entire chemical plants, including those for

[44] NCL's *Jalshakti,* Internal Report, NCL, Pune.

[45] *Encilium* Process for Ethanol, Internal Report, NCL, Pune.

[46] Report on Scientific Studies on the Factors Related to Bhopal Toxic Gas Leakage, Government of India (1985).

[47] S. Kanavi, Global Chemistry, *Business India,* p. 185–188 (1995).

[48] Contract for Consultants' services between CNCCC/JPCID, China & NCL (CSIR), Pune, India, (1990).

acrylonitrile, naphtha processing, and penicillin production in the public sector. It provided end-to-end support for scaling up laboratory processes, basic engineering design, and the installation and commissioning of pilot or semi-commercial plants. The lab specialized in the development of various reactor types, including fixed-bed, fluidized-bed, and multiphase catalytic reactors, for manufacturing chemicals such as toluidine, N-ethyl aniline, chloromethane, dimethylaniline, chlorosilanes, and butenediol.[49] NCL won laurels in polymer science, particularly in polymer melt rheology and non-Newtonian fluid mechanics. The lab developed the technology for producing hydroxyl-terminated polybutadiene (HTPB), a liquid prepolymer used as a binder in rocket propellants, drag-reducing agents for oil pipelines, polyurethane waterproofing systems, polytetrafluoroethylene (PTFE) pistons and wear rings, polyethylene cable compounds, and polymer supports for enzyme immobilization.[50] Advances in catalysis include zeolite catalysts for linear alkyl benzene production[51]; novel homogeneous catalysts, *Encicarb,* for multiple applications[52]; and *Enciox* for oxidizing C4 hydrocarbons to methyl ethyl ketone.

NCL's research on unravelling the mysteries of molecular evolution, which led to the first-ever report on the flowering of three species of bamboo using tissue culture technique, garnered an enormous response from all over the world in March 1990 (Nadgauda et al., 1990). Bamboo was once considered unsuitable for breeding because it flowers only once every 50–150 years and dies afterward. However, NCL uncovered the molecular mechanisms behind bamboo flowering, leading to the development of varieties that propagate rapidly. Not only did it revolutionise the bamboo industries in the world, but it became a significant boon to the people of Northeast India, where bamboo is an integral part of social, cultural, and economic life. NCL's dedicated team of researchers also studied the *Alphonso* mango's distinctive taste, texture, and aroma, exploring its flavour variations by identifying key compounds that significantly contribute to its unique profile. (Kulkarni et al., 2012). The study further revealed that the mango's distinctive qualities are influenced by the laterite rock plantations of the *Devgad* (Maharashtra) region, winds from the Arabian Sea, and specific climatic conditions, including wind speed, humidity, and temperature. These findings were instrumental in securing the Geographical Indication (GI) tag for the *Devgad Alphonso* mango in 2017. Additionally, the lab produced homobrassinolide, a potent plant growth hormone that accelerates cell elongation and division, thereby promoting the growth of high-quality grapes. NCL also identified a versatile bacterial strain that produces cellulase-free xylanase in high levels. The team developed an optimized fermentation process for its production. This unique enzyme effectively degrades xylan without affecting cellulose, making it ideal for the paper industry.[53]

6.6 2000s: Innovation, entrepreneurship and public–private-partnership models

On January 3, 1999, NCL commenced a year-long celebration to mark its 50 years of leadership, with Shri Mukesh Ambani, Vice Chairman and Managing Director of Reliance Industries Ltd., inaugurating the occasion. The Golden Jubilee celebrations concluded on January 3, 2000, graced by the auspicious presence of Shri Atal Bihari Vajpayee, the Honourable Prime Minister of India. These 50 years of inspiration enabled NCL, in the new millennium, to create one of the country's first and finest science-based technology business incubators, the Venture Center, with a focus on innovation, entrepreneurship, and partnerships. Since its founding in 2006, this initiative has supported over 850 deep tech start-ups and nurtured more than 175 resident incubatees, contributing significantly to India's entrepreneurial landscape. NCL's contributions to the intellectual property landscape in the last decade led to the establishment of CSIR's Unit for Research and Development of Information Products (URDIP) on its campus. URDIP specializes in patent analytics and informatics, supporting the pre-research and pre-development phases of CSIR projects and aiding research institutions, startups, SMEs, corporates, and multinationals. NCL began participating in public–private partnership projects under the CSIR's New Millennium Indian Technology Leadership Initiative (NMITLI) programme.

In the first decade of the new millennium, NCL developed proprietary processes for the manufacturing of Tris(4-hydroxyphenyl)ethane (THPE), Acrylamide Tertiary Butyl Sulfonic Acid (ATBS), polyallylamine, and more. Membrane technology enabled the separation of oxygen and nitrogen from air without liquefaction, facilitating the development of ultrafiltration membranes. This technology provided affordable potable water, particularly to cyclone-affected areas in Odisha during the devastating 1999 disaster and earthquake-hit regions in Gujarat in 2001. NCL's *Encecaps* technology enabled the microencapsulation of agrochemicals, such as carbofuran for soil broadcast and seed

49 Industry Oriented R&D at NCL, NCL, Pune (1990).

50 Polymer Science and Engineering in NCL, Internal Report, NCL, Pune.

51 Zeolites are zapping the Catalyst Market, *Business World* (1994).

52 Homogeneous Catalysis *Encicarb* Series, Internal Report, NCL, Pune.

53 *Xylanase,* A Small Enzyme-Big Potential, Internal Report, NCL, Pune.

coating, and quinalphos for foliar spray applications. It was also applied in detergents for controlled fragrance release.[54] The lab developed a process for preparing the internationally renowned crystalline microporous Titanium Silicate-1 (TS-1) catalyst, which demonstrates excellent catalytic properties in the partial oxidation of various organic compounds.

NCL developed porous polyethylene biomedical implants, including ocular types, and highly porous materials for feminine hygiene products. Additionally, it advanced biomedical compounds, including prostanoids, epichlorohydrin, cyclopentenone derivatives for cancer therapy, and pharmaceuticals such as L-salbutamol, L-atenolol, L-amlodipine, famciclovir, hydroquinone/catechol, para-chlorotoluene, biotin intermediates, and antifungal furanones. The lab developed methods and apparatus for the online identification of safe operating conditions and early detection of unsafe system behaviour, as well as for separating complex composite signals into deterministic and noisy components. In collaboration with the Nimbkar Agricultural Research Institute (NARI), NCL developed a high-yielding sheep breed called *'NARI Suwarna'* by crossbreeding *Deccani* sheep from Maharashtra with *Garole* sheep from West Bengal. This breed produces multiple offspring per lambing, significantly enhancing productivity and making a notable impact on the Indian sheep breeding industry.[55] NCL developed a process for preparing primary alkyl glycerol ethers from glycerol, which serve as effective biofuel additives. DNA marker technology enabled the first PCR-based Seedling Sex Diagnostic Assay (SSDA) for early sex determination in papaya seedlings. The lab also developed a method for fractionating sugarcane bagasse into high-alpha cellulose pulp, xylan, and lignin, enabling the value-added utilization of agricultural waste.

6.7 2010s: Mission mode projects for future technologies

On April 1, 2010, CSIR-NCL celebrated its Diamond Jubilee,[56] a milestone marked by the visit of the Honorable Prime Minister Manmohan Singh. During the event, Singh unveiled the foundation stone for the main campus of the Indian Institute of Science Education and Research (IISER), Pune, an institution of national importance under the Ministry of Education dedicated to advancing research and teaching in the basic sciences. CSIR-NCL had earlier donated 98 acres of its green-field campus for the establishment of IISER, which began its academic operations on August 16, 2006. The lab also unveiled a new 72,000 square-foot Polymer and Advanced Materials Laboratory (PAML), located on the southwestern outskirts of its main campus. Together, CSIR-NCL, IISER, CSIR-URDIP, and the Venture Center formed the foundation of the Pune Innovation Cluster, a vibrant ecosystem where a knowledge pool is seamlessly created, shared, and applied to drive scientific and technological advancements.[57]

In the 2010s, NCL's research closely aligned with the Government of India's vision for the decade, celebrated as the *"Decade of Innovation"* (2010–2020), and marked by initiatives such as *"Make in India"* and *"Innovate India."* CSIR-NCL, in collaboration with KPIT and CSIR-CECRI, successfully conducted the trial run of India's first indigenously developed hydrogen fuel cell prototype car at the campus. The vehicle is powered by a Low-Temperature Polymer Electrolyte Membrane Fuel Cell (LT-PEMFC) stack that was developed under the NMITLI programme. This breakthrough technology represents a major step toward reducing pollution and dependence on fossil fuel imports. In addition, the lab developed the country's first indigenous High-Temperature Fuel Cell System, marking further progress toward clean, sustainable energy solutions. The lab succeeded in producing Dimethyl Ether (DME) from methanol dehydration, with its indigenous pilot plant producing 20–24 kg of DME per day. To test this green fuel as a domestic cooking solution, CSIR-NCL developed a burner *'Aditi Urja Sanch'* unit and DME-LPG blended fuel cylinders.

For the Fine and Specialty Chemicals industry, the lab developed modular, agile, intensified, and continuous processes for a wide range of chemical reactions. These include the nitration of acetophenone, pendimethalin, and o-xylene, as well as the continuous flow synthesis of Direct Yellow 11 dye, alpha-nitronaphthalene, and para-aminophenol from nitrobenzene. The lab also developed a process for the large-scale production of silver nanowires and successfully synthesized folic acid at the pilot scale. CSIR-NCL engineered intensified metallic reactors, tubular glass-lined reactors, and a reaction calorimeter to support process optimization and scale-up. The lab also advanced ultrafiltration-based water purification technologies to provide affordable potable water, with its mobile purification unit, *Jaldoot,* delivering clean water to rural households and flood-affected regions in Uttarakhand (2014), and Chennai (2015).

CSIR-NCL developed a low-pressure process for manufacturing para-aminophenol, a key intermediate in paracetamol production, along with a continuous, intensified synthesis technology. The lab contributed to drug development, including Miltefosine for leishmaniasis, and Amlodipine

[54] Controlled Release Technology, *Encecaps,* Internal Report, NCL, Pune.

[55] NCL among Winners of CSIR Award for Innovation aimed at Rural Development, *Chemical Weekly* (2009).

[56] NCL Diamond Jubilee-Journey of Six Decades, Internal Report (2010).

[57] NCL Diamond Jubilee-Sixty Years and Beyond, Internal Report (2010).

Besylate and Asomex for hypertension. Biomedical research included resorbable silk-based bone graft implants, bone fixation screws, and expandable biliary stents. In polymer science, CSIR-NCL worked on long-chain branched polypropylene, emulsion polymers, polypeptides from fish protein, and perfluoropolyether (PFPE)-based copolymers. Other achievements included a modeling framework for underground coal gasification, microfiltration for biomass slurries, vortex diode-based effluent treatment, porous carbon supercapacitors, hydrothermal conversion of lipid oils, microencapsulation of insect pheromones, integrated pest/pathogen management using fungal metabolites, total synthesis of biologically active alkaloids, materials for hydrogen storage, carbon sequestration using metal–organic frameworks, and ENSEL, a greener biodiesel production process utilizing a solid, reusable acid catalyst and a continuous fixed-bed process.

When the COVID-19 pandemic struck, CSIR-NCL responded swiftly and with unwavering resolve, channeling its scientific expertise to address urgent needs. The lab developed critical healthcare technologies, including nasopharyngeal swabs and the Poly-Ti medical-grade mask, coated with a biopolymer-nano layer for enhanced protection. It introduced an ozone decomposition catalyst for personal protective equipment (PPE) decontamination and designed a membrane-based system to generate oxygen-enriched air. In addition, CSIR-NCL conducted sewage surveillance to aid early detection of viral load in communities and developed environmentally responsible methods for recycling PPE waste. This rapid and impactful response underscored CSIR-NCL's commitment to public welfare through science and innovation.

7 Sustained excellence and contribution to nation-building

CSIR-NCL was born from the aspirations of visionary leaders and, over the years, advanced by leaps and bounds, pushing the frontiers of knowledge and extending its influence far beyond national boundaries. Over the past seven decades, it has continually reinvented itself to address the evolving challenges of each era, building on its strong traditions, leveraging opportunities from challenges, and maintaining a proud record of achievements. Its true significance lay not merely in its ability to adapt to the global technology regime but in its foresight to anticipate and shape it. The laboratory skilfully balanced the diverse expectations and shifting objectives of both Indian and global clients. It partnered with the Indian chemical and allied industry to bridge the gap between concept and commercialization, enabling the sector to remain globally competitive. Simultaneously, it had close and long-standing collaborations with leading enterprises worldwide, acted as a consultant for major chemical companies, and played a key role in restructuring R&D in both developing and developed countries. CSIR-NCL is a nationally and internationally recognised laboratory, renowned for its scientific temper, its contributions to the Science, Technology, and Innovation ecosystem, and its thought leadership to stay ahead of the curve.

NCL continues to serve as a vibrant and essential link between the government, universities, and industries. Its contribution to building scientific and technological capability through advisory support to the government and industry, as well as by mentoring professionals who have risen to leadership in research, education, and industry, is a legacy that, while not easily quantifiable, remains deeply impactful. Each year, around 400 students pursue their research degrees at the laboratory, with approximately 70 earning PhDs through the Academy of Scientific and Innovative Research (AcSIR), significantly contributing to the development of human resources in specialized fields of chemistry, chemical engineering, biochemical, and materials science. The results of its research, particularly of a more fundamental kind, are frequently published in the form of papers in various scientific journals. On average, about 400 research articles are published in prestigious scientific journals annually, and nearly 100 patents are granted each year, in India and abroad. The institution is visited by distinguished luminaries from across the country and around the world, and has been home to some of the outstanding scientists in the country. As of 2024, it has 11 Padma Awardees—the highest civilian honours in India—three Fellows of the Royal Society (Prof. J. W. McBain and Prof. G. I. Finch were FRS recipients before they joined NCL), eight Fellows of The World Academy of Sciences (TWAS), and 17 recipients of the Shanti Swarup Bhatnagar Prize. Faculty members associated with the laboratory serve on editorial boards of prestigious national and international journals, are part of major international academies and learned societies, and contribute to global organizations.

8 Conclusion

For over seventy-five years, the CSIR-National Chemical Laboratory has been instrumental in advancing India's scientific and technological landscape, significantly contributing to the nation's economic prosperity and development. Through its pioneering work in research, innovation, and commercialization, CSIR-NCL has earned the public's trust and recognition as a cornerstone of India's scientific heritage. In 2023, the Department of Posts, Ministry of Communications, honoured the laboratory with a commemorative postcard, underscoring its enduring impact. CSIR-NCL's contributions align with the Government of

India's *Vision 2047*, which aims to elevate the quality of life through transformative science, globally competitive R&D, and sustainable solutions. NCL, born from the dream of a newly independent nation, was poised to symbolize India's future greatness, serving both the country and the world, inspiring generations to come, and continually striving to adapt, innovate, and stay ahead in the ever-evolving scientific landscape.

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