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ARTICLE

Malaria during the construction of Sarda Canal in United Provinces (1918–28)

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Abstract
The Sarda Canal, constructed during the second decade of the twentieth century in the United Provinces, has been one of the longest irrigation systems in the world, covering more than 6,000,000 acres. The canal comprised about 4000 miles of main line and distributaries that took off from the Sarda River at Katarniyaghat in Kheri district of the Nainital region and passed through the various districts of the region. During the course of the construction of the canal, malarial fever and other related diseases also erupted and affected the public health in the nearby regions. Subsequently, the Director of Public Health, United Provinces, set up a committee under the chairmanship of Dr. A. N. Mukerji in 1920 to undertake a preliminary survey and suggest anti-malarial measures. Subsequently, D. Clyde published a report titled 'Report on the Control of Malaria during the Sarda Canal Construction, 1920–1929'. However, the historiography on canals in India has mainly dealt with the construction and public works aspect, but how it affected public health has not been highlighted. Viewed in this context, the present paper explores how the construction of Sarda Canal led to the transmission of malaria disease and affected public health. Subsequently, it also studies the response of the colonial state and its policies to deal with the situation.

Keywords Sarda Canal · Malaria · United Provinces · Labour

1 Introduction

The construction of the Sarda Canal provides an important case study from the standpoint of scientific history for examining the relationship between massive colonial infrastructure projects and the public health problems that emerged in India in the early twentieth century. This research places the malaria outbreak during the canal's construction within the context of colonial medical science, environmental change, and disease ecology. The study examines how administrative measures and health regulations were used to apply scientific knowledge of vector-borne diseases, thus attempting to illustrate the changing links between engineering, epidemiology, and the colonial state's bio-political control.

The Sarda Canal, constructed during the second decade of the twentieth century in the United Provinces, has been one of the longest irrigation systems in the world, covering more than 6,000,000 acres (Turner, 1933, p. 31). The canal comprised about 4000 miles of main line and distributaries that took off from the Sarda river at Katarniyaghat in Kheri district of Nainital region and passed through the district of Shahjahanpur, Barabanki, Pilibhit, Hardoi, Lucknow, Unnao, Raebareli, Pratapgarh, Sultanpur and Allahabad region.[1] Various stakeholders welcomed the news of the construction of Sarda Canal, and it was hoped in the public sphere that the opening of the canal in the region would lead to check hunger, famine and increase the agricultural production.[2] Amidst these encouraging hopes, the malarial fever and other related diseases also erupted and affected the public health in the nearby regions during the course of the construction of canal. United Provinces reported 1,361,920 deaths during the year 1921 from malarial fever (Turner, 1933, p. 260). Subsequently, the Director of Public Health, United Provinces set up a committee under the chairmanship

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[1] File No. 263W, *Public works department*, Uttar Pradesh State Archives, Lucknow, 1938, Figs. 1 and 2.

[2] The Evening Independent, 10 September 1923; The Blair Press, 11 October 1923.

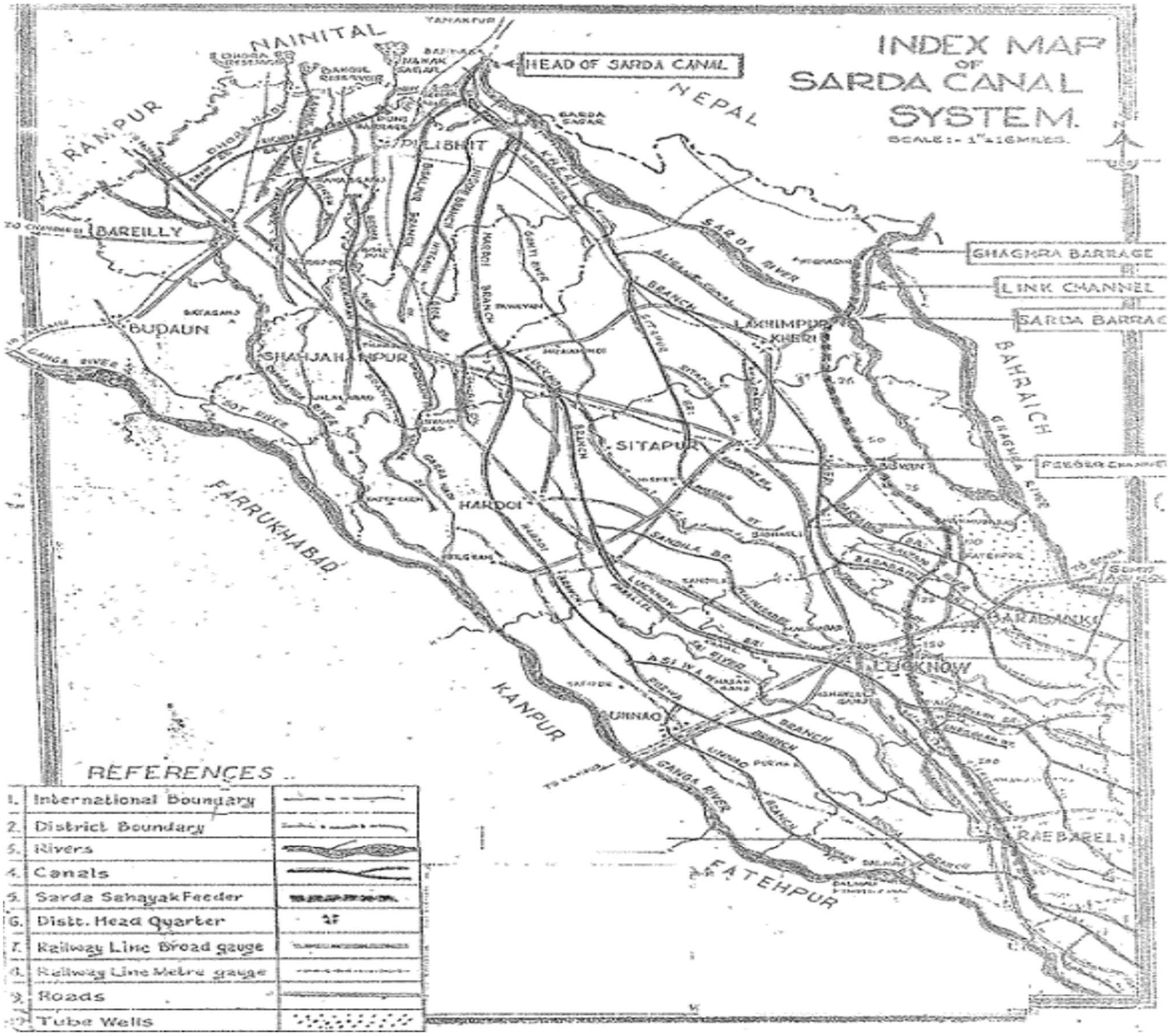

Fig. 1 A map of Sarda Canal system, United Provinces. Source: Index map of Sarda Canal System (2024)

of Dr. A.N. Mukerji, Assistant Malaria Officer, to undertake a preliminary survey in 1920–21 and D. Clyde, Assistant Director of Public Health, published a 'Report on the Control of Malaria during the Sarda Canal Construction, 1920–1929' (Clyde, 1931, pp. 49–110).

Historiography on the subject of malaria in colonial India has linked the increase and spread of malaria to the agencies of modernization and development policies like construction of railways, embankments and expansion of the irrigation system (Klein, 1972, 1973; Samanta, 2002; Sinha, 1998; Stone, 2002; Watts, 1999; Whitcombe, 1996). The relationship between environmentalism, changing crop patterns, labour migration, mortality and malaria in colonial India has been a subject of discussion (Roy, 2017; Samanta, 2001; Shlomowitz & Brennan, 1990; Thorner & Alice, 1962). Subsequently, the historiography on canals in India has mainly dealt with the construction and public works aspect, but how it affected public health has not been highlighted, especially in case of Sarda Canal (Stone, 2002; Whitcombe, 1972). As Whitcombe (1996, p. 258) rightly pointed that, 'Sarda's malaria history has yet to be written'. The trajectory of anti-malarial measures and their impact on health and agriculture has been less explored.

Viewed in the context, the present paper explores how the construction of Sarda Canal led to the proliferation of malaria and affected public health in nearby regions. Subsequently, it also studies the response of the colonial state, changing cropping patterns, and collects statistics on deaths from other diseases like smallpox, cholera, pneumonia, and dysentery. To address these issues, the article has elicited

Fig. 2 A map of United Provinces. Source: Blunt (1912), preface

data from sources including Reports of the Director of Public Health of the United Provinces (1924), Census of India (1931), Records of the Malaria Survey of India (1931), Indian Medical Gazette Report (1934) and others.

2 Malaria epidemic in India

Infection with malaria in humans causes a wide range of symptoms, including fever and chills, and affects the kidneys, spleen, muscles, liver, lungs, brain, and other organs. In the Western European intellectual tradition, the connection between symptoms of malaria and wet, swampy land has been recognized for thousands of years. Marshy areas with foul air as the cause of malaria have been mentioned in the *Hippocratic Corpus,* written around the fifth century BCE. References to malaria fever are also found in Indian texts like *Atharvaveda*, *Caraka Saṁhitā*, and *Suśruta Saṁhitā* from ancient times. These texts mention seasonal prevalence and periodicity of the fever. The *Atharvaveda* classifies the fever according to the periodicity of its attack, *i.e. sadaindin* or quotidian, *tṛtīyaka* or tertian, and *cāturthaka* or quartan. The *Caraka* and *Suśruta Saṁhitā* used the word *jvara* for fever, found in lowlands or the foothills, and compared its advent to the flood and ebb tides of the ocean (Bhishgratna, 1911, V. 39.69, 70.7; Choudhury, 1985, pp. 243–248; Griffith, 1968, Book 1, Hymn 25, No. 4; Sharma, 1998, C.I. 3.34, 3.67; also see Samanta, 2018, pp. 24–25). In the Middle Ages, malaria referred to intermittent fever caused by foul air (Hall & Grant, 1891, p. 353). The transmission of malaria through the Anopheles mosquitoes' vector was discovered only in the late nineteenth century by Ronald Ross. Thereafter, malaria was redefined as the name of a mosquito-borne fever disease. It was found that five species of malaria protozoa, *Plasmodium falciparum, Plasmodium vivax, Plasmodium malaria, Plasmodium knowlesi* and *Plasmodium ovale* can infect humans (Lessard, 2022, p. 5).

Development projects during the British colonial rule had unintended negative economic and health effects (Lessard, 2022, p. 10). The increasing construction of canal, railways, ports, industries and tea gardens for economic and trade motives led to the spread of malaria. The British-engineered scheme gave rise to swamps, seepage and bogs which provided a plethora of new breeding places for malaria (Watts, 1999, p. 173).[3] There were significant outbreaks of malaria during the construction of the Colaba causeway between 1821 and 1841, as well as the construction of Alexander Dock and Hughes Dry Dock in Bombay. Subsequently, Burdwan Fever and the cases of malaria at Calcutta, Darjeeling and Duar region in the late nineteenth and early twentieth century had an adverse impact on local demography (Choudhury, 1985, pp. 243–248). The spread of terrible malaria epidemics in Punjab and United Provinces in the year 1908 was widely discussed in the parliamentary debates. The region between Pinjaur and the Ghaggar tract of Patiala state was intensely malarious (Covell, 1932a, p. 91). Subsequently, the Government of India convened an Imperial Malaria Conference in Shimla in 1909 and set up a Malaria Bureau in 1910. During the third decade of twentieth century, the consistent cases of malaria at in various parts of United Provinces, Bengal and in mines and tea companies like Bengal Iron Company, Desoi and Parbutti Tea Company, Scottish Assam Tea Company, Tyroon Tea Company, and Titabar Tea Company forced the colonial government to carry a malaria survey at all India level (Choudhury, 1985, pp. 243–248; Clyde, 1931). Finally, the malaria survey of India was conducted during 1930–31, and an institutionalized study of the nature and causes of malaria took place.

Apart from contaminated water, food, poor sanitation and other environmental factors, the movement of labour was considered the main reason behind the spread of malaria. This movement took place through the 'aggregation of labour' process, referring to places, such as plantations or railway construction sites, where large numbers of labourers lived and congregated. Continuous' non-immune immigration' and 'physiological poverty and hardship' in these places increased infection rates (Wakimura, 2002). This was clearly evident in Duars, where the aggregation of labour happened because of work in tea plantations.

The Duars were a portion of the terai[4] land that stretched along the eastern Himalayas. This was a 'hyper-endemic' area, meaning that people living there had often suffered from malaria from infancy and had acquired certain degrees of immunity. The problem in this area was not malaria among the indigenous people who had lived there for generations, but rather severe infection among the immigrants to the tea plantations. Intense malaria epidemics sometimes attacked this area, a problem, according to Christophers and Bentley, that resulted from the continuous entry of non-immune immigrants into the tea estates and their poor living conditions (Christophers & Bentley, 1911). They argued that the rising demand for labour was the main factor in the high rate of malaria on tea plantations. Plantation sites with immigrant workers acquired new significance as locations of malarial fever (Bhattacharya, 2011, pp. 183–202). The immigrants came from Chota Nagpur and the Santal Pargannas in Bihar, Nepal, and the Darjeeling Hills. The labour population in the tea plantations of the Duars was estimated to be 150,000 in the early twentieth century, annually receiving approximately 30,000 newcomers (Wakimura, 2002). In the Duars, malaria carriers from malarious districts and susceptible people from healthy areas were mingled, and the presence of anopheles made it a centre of spreading epidemic malaria. Anti-malarial measures, such as screening European bungalows, segregation, and using quinine as prophylaxis, did not stop the menace of epidemic malaria (Covell, 1932a, 1932b, pp. 15–18). Subsequently, the poor living conditions of labourers in tea plantations aggravated the disease. As Christophers and Bentley in their report on Duars highlighted that 'an inadequate dietary in the case of new coolies leading to the vicious cycle of—inadequate diet—physiological poverty—increased liability to sickness especially to malaria—less wages earned—increased hardship and privation with still less adequate diet, and so on' (Christophers & Bentley, 1911, p. 89).

Amidst these processes, workers also acquired immunity to malaria through repeated infections suffered by the newly immigrant labourers and by newborn children and infants. Therefore, the adult population was not unduly affected, as they had acquired immunity through repeated malarial infections. The communities of the Sub-Himalayan terai and Duars who became immune to malaria were Rajbanshis and aboriginal Meches, and later the immigrant labourers like Chotanagpuris, Kols, Santhals also became immune (Christophers & Bentley, 1911, pp. 21, 36). The colonial government didn't deploy such people on the construction site of Sarda Canal as labourers. As a result, the non-immune labourers faced debility and death (Lessard, 2022, p. 10). The United Provinces reported the highest death rate from malaria during the construction of Sarda Canal between 1918 and 1928 (Graham, 1930). In these ways, malaria became a disease of the greatest concern to the British administration as it had a significant impact on the health of the labour force working for the empire.

[3] The Indian Express, 12 August 1933, 21 September, 1940.

[4] *Terai* consists of belt of marshy land at the foot of mountains.

Table 1 Death rate in various zones of Sarda Canal, 1924–1928

Districts	Crude death rate	Crude fever death rate
Plains of Oudh		
Barabanki	22.44	16.24
Lucknow	21.75	15.88
Unao	20.77	12.66
Hardoi	22.51	18.06
Sitapur	2.74	18.09
Plains of Rohilkhand		
Shahjahanpur Plains	30.97	23.95
Bareilly	30.80	23.60
Terai and Headwork Region		
Nainital Terai	48.00	42.00
Kheri	52.00	40.00
Shahjahanpur Terai	39.00	31.00
Bareilly Terai	36.00	29.00

Source: Clyde (1931). Report on the control of malaria during the Sarda Canal construction, 1920–1929, p. 51

Table 2 Malarial death rate in various zones of Sarda Canal

Season (daily average)	Population	Malaria death rate
1923–24	1440	27.90
1924–25	2185	27.49
1925–26	2821	27.36
1926–27	2567	30.62
1927–28	4106	26.29

Source: Clyde (1931). Report on the control of malaria during the Sarda Canal construction, 1920–1929, p. 85

Table 3 Death of inhabitants with several diseases, United Provinces, 1921–30

Year	Fever (malaria)	Plague	Cholera	Smallpox
1921	1,361,920	24,009	149,667	1,439
1922	909,293	23,291	2,330	242
1923	780,049	74,187	2,591	747
1924	947,807	56,210	67,000	2,724
1925	875,594	49,091	7,653	9,373
1926	867,939	57,297	6,166	12,020
1927	786,552	15,570	28,285	7,894
1928	765,954	80,943	44,941	3,012
1929	810,583	37,678	50,924	11,725
1930	942,469	10,860	61,334	11,071
1921–1930	9,048,160	429,136	420,891	60,247

Source: Turner (1933). *Census of India 1931, United Provinces of Agra and Oudh*. p. 260

3 Migration and malaria during construction days

The Sarda Canal was divided into three distinct zones: the plain of Oudh, the plain of Rohilkhand and the *terai* region. From the perspective of health, the condition of the spleen, an organ that generates an immune response to the malaria parasite and becomes enlarged, was considered for deciding the state of health in the region.[5] The plains of Oudh were considered the 'healthy zone' with a spleen rate of less than 10 percent. However, the plains of Rohilkhand came under the less healthy zone where the spleen rate was between 10 to 50 percent, whereas the terai region, headworks and the upper reaches of the main branches were the unhealthiest zone as the spleen rate averaged 75 per cent (Clyde, 1931, p. 51). In this context, the terai region, consisting of headwork areas of Banbassa, Nainital, Kheri, Shahjahanpur, Pilibhit and Bareilly terai, was considered notoriously malarious and reported the highest death rate due to malarial fever (Tables 1, 2, 3). Subsequently, the province was also affected by other diseases like plague, smallpox and cholera. However, malaria reported the highest mortality between 1921 and 1930, with a total death rate of 90,48,160 people, whereas plague, smallpox, and cholera collectively accounted for 9,10,274 inhabitants (Table 3). It meant that almost ten times more deaths happened due to fever compared to the other three diseases together, and the severity of malaria affected the province.

The heavy incidence of malaria in the terai region was attributed to the combined effects of climate, jungle, heavy rain, high water table and excessive moisture with heat. The area, intersected by ravines, was densely covered with Sal, Khair and Shisham trees, and the average monsoon rainfall was over 100 inches yearly (Darley, 1941, p. 42). D. Clyde in his Report on the Control of Malaria during the Sarda Canal Construction, 1920–1929, noted that the temperature and humidity after rain were such that the mosquito breeding occurred throughout the year and became very active, especially between March and June and September to October (p. 56). With the beginning of canal construction in 1918, increasing cases of malarial fever were reported due to the presence of Anopheles mosquitoes. Labourers themselves formed an annual 'reservoir' of malarial infection.

The aboriginal tribes of the headwork region belonging to Tharus and Bhuksas communities were considered immune to the high fever and malaria due to their 'cultural practices' and the presence of Sickle Cell Trait, a gene which provides resistance against malaria (Gupta, 2021, pp. L88–L93). In fact, Sickle Cell Trait protects against malaria by modifying the shape and functionality of red blood cells. The malaria parasite finds it challenging to thrive in those who possess this trait, such as Tharus and Bhuksas communities. The

[5] Abstracts from Reports. *The Indian Medical Gazette*, 69.1 (1934): 53–58.

immune system becomes more prone to eliminate infected cells before the parasite can finish its life cycle, which diminishes the severity and transmission of the disease. Apart from the presence of Sickle Cell Trait, the aboriginal tribes of Tharus and Bhuksas built their houses better suited for a rainy climate, and organised the villages in such a way as to avoid waterlogging and creating mosquito breeding grounds (Strahorn, 2009, p. 29). J.C. Robertson, an Imperial Medical Service Officer, during his visit to Tharu villages appreciated the 'cleanness' of the residents and low morbidity rate, and recorded that if they survived exposure to malaria in childhood, then they became immune to it as adults (Robertson, 1930, pp. 98, 112). In this regard, H.J. Boas, the Assistant Commissioner in charge of the Terai region, reported that that:

> Tharus have adapted their customs and mode of life to the Tarai. They are good and careful cultivators... Their houses are models of cleanliness, are well apart from one another, and are built in such a manner as to prevent the damp accumulating in the walls...The Tharu from long experience of these malarious jungle tracts, has found out what manner of habitation is likely to enable him to withstand the climate, and it is to this that he owes his immunity from fever (Strahorn, 2009, p. 29).

In spite of being immune to malaria and high fever, the aboriginal tribes were not interested in labour work as they claimed to be the descendants of a mighty kingdom in Rajputana (Darley, 1941, p. 42). Labours from nearby plains were not interested in the construction as they thought visiting and settling in the headwork region 'means certain death'. It was reported that owing to 'the sinister reputation of the Terai', it was also impossible to import labourers from neighbouring districts (Clyde, 1931, p. 65). C.A. Mumford, the Deputy Commissioner of Nainital District, stated that the plainsmen cannot live in the headwork region and terai's reputation as 'unhealthiness' deterred labourers from nearby regions from working at the construction site (Mumford, 1921, p. 1). In this situation, Pathans, a nomadic and pastoral ethnic group from Eastern Iran primarily residing in the North-Western part of India, were recruited as labourers. As a result, the Census of India, 1931, reported that the population of Pathans increased by 20 per cent in the United Provinces during the period between 1921 and 1931 (Turner, 1933, pp. 537–38). But they were found unsuitable amidst the outbreak of malaria in 1919. Lieutenant Colonel W. A. Mearns, categorically stated that the malaria among Pathans was due to difficulty in inculcating cleanliness as they refused to take daily bath (Clyde, 1931, p. 65). Amidst the prevailing circumstances, the colonial government decided to recruit labourers in groups from Bundelkhand and Rajputana regions.

Interestingly, the workers from Bundelkhand and Rajputana agreed to work as they were not much aware of the reputation of terai and were not recruited as permanent workers at the construction site. They agreed to work during the period when they did not have any agricultural or other work in their native place. Labourers came in November after the Diwali festival and left for their homes at the Holi festival in March to reap the Rabi crop and prepare the fields for their Kharif crop[6] (Clyde, 1931, 65). As a result of the movement of labour, the migration rate from Rajputana increased by 20.5 per cent during 1921 and 1931, with the total number of emigrants recorded at 68,000 in the Census of 1931 (Turner, 1933, p. 198). Pilibhit district, a part of the terai region of headwork, returned 20,005 male and 27,673 female immigrants from the province (Turner, 1933, p. 191).

Apart from recruiting new labourers, the contractors brought a large percentage of the work force each year who had been to the headworks in the previous years. Thus, regular streams of non-immunes from non-malarious zones were brought in and were kept with the old labourers who had developed immunity. After these measures, it was reported that 90 per cent of the labour force was infected with malaria in 1919–20. Subsequently, contractors refused to do the work and the construction site was closed. Amidst these circumstances, it was realised by Sir B. Darley, the Chief Engineer of the Sarda Canal, that unless active measures were taken the headworks would never be completed. Lieutenant Colonel Dunn, the Director of Public Health, United Provinces, put up certain proposals towards the end of 1919 'for the provision of medical and sanitary arrangements during the canal operations' (Clyde, 1931, pp. 56–57). It was decided that all breeding grounds adjacent to the area of the headworks and the main branches of the canal passing through the terai areas should be eradicated, and no work would be carried out in these areas between May 15 and November 15. A Deputy Sanitary Commissioner was deputed to be in charge of medical and sanitary arrangements and a committee was appointed under the chairmanship of Dr. A. N. Mukerji, an Assistant Malaria Officer, to undertake a preliminary survey in the month of March 1920 and to suggest the measures necessary for safeguarding the health of the staff and labourers to be employed on the construction site (Clyde, 1931, p. 58).

By April 1920, the preliminary survey led by Dr. Mukerji was completed. The survey identified various species of adult Anopheline mosquitoes, such as *A. willmori, A. listoni, A. barbriostris, A. fuliginosus, A. stephensi, A. turkhudi, A. maculatus* and others (Report of the Malaria Commission, 1930, p. 58). These mosquitoes mainly breed in the months

[6] The *Rabi* crop is sown in winter and reaped in spring whereas the *Kharif* crop is sown in summer before the monsoon and reaped in autumn after the monsoon.

of October, November, May, and June, and their breeding ground is at pools, swamps, jungles, seepage holes, rice, sugarcane, and overgrown grass fields. Some larvae were also found repeatedly in the sides of concrete anti-malaria drains, which were badly designed. Besides identifying the large number of species, the Committee dissected the mosquitoes and studied the blood examination of patients to understand the nature of the infection. Overall, the malaria epidemic exposed the public health to diseases like malaria and forced the colonial government to take anti-malarial measures amidst the growing question on the inefficiency of colonial administration due to nationalist protests.

4 Anti-malarial measures and its impact on health and agriculture

Dr. Mukerji Committee recommended various anti-malarial measures: cutting down jungle grass, exposing actual and potential breeding places, carrying out a weekly rapid malaria survey, and distributing mosquito curtains and traps to all staff and labourers. The anti-malarial measures also included persuading labourers to take prophylactic quinine of ten grains for two consecutive days per week. Subsequently, the Committee recommended introducing small larvae-eating fish like *Barbusteria, Barbusphutunio, Trichogasterfasciatus*, *Nuriadanrica* and others in streams, ponds and borrow-pits and to also apply Paris green as larvicide (Graham, 1930). The Committee considered larvicidal fish of great value in destroying mosquito larvae. It was also suggested that showing 'malaria film' and performing 'malaria drama' might be helpful in persuading people to treat their malarial fever properly.[7]

The recommendations of the Committee were not followed up properly due to a lack of sufficient funds and the passiveness of contractors and government officials (Clyde, 1931, pp. 58–61). Malariologists were not in favour to issue the mosquito curtains and prepare mosquito-proof houses especially for subordinate government staffs and coolies in view of the significant expenditure. The stone houses of officers and overseers were not provided with mosquito-proofed verandahs**.** Subsequently, no attempt was made by the contractors to keep children, old people or pregnant women safe and secure. As the Records of the Malaria Survey, 1931 highlighted that it was a common sight to see infants wrapped in rags, places in the shade among stones in the river bed, while their mothers working as coolies (p. 66). Subsequently, the government officials had no authority to force contractors' labour to take quinine. The constant refusal of contractors to take effective steps to have their workers at Quinine Paradise made the situation worse. Coolies often refused to take quinine and stayed out in the works till late evening and entered the camp when the medical officers had gone away, fearing the risk of wild animals less than the supposed ill effects of quinine (Clyde, 1931, pp. 60–61). Subsequently, it was difficult to clear the dense jungles of the headwork region (Darley, 1932, pp. 140–60). Amidst these developments, the incidence of malaria again rose in mid-April 1921 to such an extent that the complete labour corps got ill and the contractors refused to continue to work (Issaris et al., 1953, pp. 311–333).

Amidst the growing nationalist fervour and Non-Cooperation Movement, the government was forced to take concrete steps towards disease control. Subsequently, a canal hospital under a sub-assistant surgeon was opened to treat all cases of minor ailments amongst the labour force. A Malaria Officer started to reside in the headworks camp in Banbassa from 1922 to April 1927. Six Health Officers were appointed to carry out the quinine treatment. Approximately a hundred men were employed to clear the jungle and prepare the area for the arrival of the main body of labour.[8] Elephant grass was removed, and the use of Paris green was popularised to facilitate free drainage, efficient oiling, and destroy adult mosquitoes in stream and ravine areas.[9] By the end of 1926, Paris green was planted, and the oiling was carried out in all the relevant areas. In the terai and Bhabar estates, 50 villages were Paris-greened and 285 persons were trained to carry out the anti-larval work, including clearing drains and filling depressions. Fumigation by cresol, carbolic acid, sulphur, pyrethrum and tobacco leaves were carried out near labourers huts and shops made of grass and bamboos (Clyde, 1931, p. 81). Using sand as diluents over the areas covered with reeds and jungle grass gave better results than using dried dust. The presence of sand killed *Culex* larvae in greater numbers. Subsequently, 10,874 boys were given a simple training in the causation and the principles of prevention of malaria at 33 urban and 127 rural centres. Their services

[7] Report of the malaria commission, on its study tour in India, August 23rd to December 28th, 1929, League of Nations Health Organisations, 1930, p. 64.

[8] Fifty seventh annual report of the director of public health of the United Provinces of Agra and Oudh, 1924. Government Press, 1925, p. 23.

[9] In the early times, only kerosene oil was used by coolies but this was found inefficient, non-lasting and expensive. Crude oil was also found to be too expensive as its spreading power was low. While certain breeding grounds required oiling at the regular intervals only. The mode of oiling was chiefly by means of tow tied to the end of a bamboo stick but other methods such as, using a broom dipped in oil for sweeping over a sodden area, using the ordinary oil sprays, burning tow soaked in oil under the head of seepage areas and using drip cans, were also employed. Paris green, introduced in the year 1921, was reported upon by Hackett at the International Malaria Congress in Rome in October 1925. It suited to the conditions prevailing in the headworks area and was more effective.

Table 4 Incidence and recorded death rates of Pneumonia in headworks camps

Year	Total cases treated	Deaths in cases treated	Case mortality	Deaths in camps. Cause verified as pneumonia	Death rate in all camps	Death rate for District-Crude reported	Death rate for Districts-Verified by medical agencies
1925	205	18	8.78	30	19.4	0.37	7.90
1926	283	19	6.73	40	25.5	0.39	7.20
1927	178	24	13.48	10	8.1	0.49	9.8
1928	192	33	17.19	20	2.4	Not available	Not available
1929 (upto June)	61	1	1.641	11	5.9	Not available	Not available

Source: Records of the Malaria Survey of India, 1931, pp. 88–89

Table 5 Incidence of diarrhoea and dysentery

Year	Outdoor	Indoor or clinical dysentery	Deaths	Death rate	Death rate for Districts-Reported crude rate	Death rate for Districts-Verified by medical agencies
1925	470	21	4	1.6	0.21	2.46
1926	8091	16	10	4.4	0.24	6.44
1927	948	46	4	0.9	0.27	2.7
1928	1129	55	32	0.4	Not available	Not available
1929 (upto June)	234	6	4	1.9	Not available	Not available

Source: Records of the Malaria Survey of India, 1931, p. 90

were utilised for carrying out minor anti-mosquito measures, which cost about Rs. 10,634.[10]

The government also started to work on the drainage system. No permanent drains existed till the year 1927. The local authorities decided to re-dig the *kaccha* drain in October 1927, as the heavy rains had invariably filled them with silt and boulders and their edges had become broken down (Clyde, 1931, p. 64). Subsequently, in one of the worst waterlogged breeding grounds of the Salani channel, an attempt was made to reduce the volume of water. In other areas, government officials visited the areas periodically to examine the incidence of sickness and inspect the local dispensaries to look at anti-malarial activities. Through these measures, the death rate did not drop considerably, which can be seen from the data compiled by Lieutenant Colonel Dunn, the Director of Public Health, United Provinces (Table 2). Table 2 shows that the death rate remained above 26 during the period between 1923 and 1928. Pilibhit district was reputed as the 'most unhealthy district' which had the highest recorded death-rate of 36.8 on account of the spread of malaria in tarai region of Sarda Canal (Turner, 1933, p. 74).

Besides malaria in the headwork region, there were several cases of pneumonia, diarrhoea and dysentery (Tables 4 and 5). The cases of pneumonia admitted to the hospital were almost invariably detected in the camps by medical officers during their hut-to-hut visits. Eighty per cent of the cases were not reported or detected. The outdoor attendance for diarrhoea was high from January to March and again in May. This was due to consuming raw fruit, sugar cane, and melons. Cases passing blood or mucus were admitted, and of these, approximately 70 per cent were clinically bacillary dysentery and 30 per cent clinically amoebic dysentery (Table 4).

The construction of the Sarda Canal also adversely affected public health by bringing major changes in the cropping pattern. The region covered by the canal was known for the production of millets, which was the main staple diet, but after the construction of canal, the cultivation of food crops was shifted to sugarcane and other commercial and non-food crops (Ansari, 1963).[11] The net area under sugarcane cultivation nearly doubled between 3 and 6 per cent during the beginning and completion of canal (Singh & Misra, 1965, p. 57). Amidst the rise of sugarcane, the cultivation of two industrial crops, indigo and poppy, became negligible. The percentage area of cultivation of non-food crops in Sarda canal region increased from 7.5 to 10.6, whereas the food crops declined from 92.5 to 89.4 between 1921 and 1941 (Table 4). Between 1930–31 and 1936–37, the number of sugar factories in India rose from 29 to 137, with those in UP registering a fivefold jump from 15 to 75. In the

[10] Annual Report of the Public Health Commissioner, 1927, p. 45.

[11] Millets needed only one or two waterings, whereas sugarcane require eleven waterings. In the post-canal times, the water was in so much of abundance that the peasants can grow commercial crops needing much water like sugarcane.

Table 6 Percentage area of food and non-food crops

Year	Percentage area of food crops	Percentage area of non-food crops
1921–26	92.5	7.5
1926–31	92.3	7.7
1931–36	90.7	9.3
1936–41	89.4	10.6

Source: Shah (1963). Cropping pattern in relation to irrigation. p. 158

post-canal times, the water was so abundant that the peasants could grow crops that needed excess water. Subsequently, the water level also came down. The farmers reported the declining underground water level (Khan & Ahmad, 2019).

Overall, the anti-malarial measures did not significantly reduce the malaria's death rate, as seen in Tables 1, 2, 3. Its severity continued, leading to other related diseases like pneumonia and dysentery, especially in the headwork region (Tables 4 and 5). Subsequently, the changing cropping pattern focusing on growing the commercial crops/non-food items (Table 6) also affected the health condition.

5 Conclusion

The malaria epidemic that occurred during the construction of the Sarda Canal from 1918 to 1928 provides an important perspective for analysing the intersection of scientific progress and colonial infrastructure. This period highlights the relationship between scientific knowledge, technological development, and social and environmental impacts in colonial settings. The inability to effectively combine medical science with engineering skills during British times illustrated the disjointed and stratified nature of the colonial administration, which placed greater emphasis on economic and infrastructural objectives rather than on public health issues.

The Sarda Canal case highlighted the limitations of colonial scientific methods in addressing ecological and epidemiological issues. Despite their insufficient understanding, the use of basic anti-malarial strategies and Paris green insecticides failed to address complex disease dynamics in a rapidly changing environment. The climate and geography of the region played an important role in promoting the breeding ground for the Anopheles mosquitoes. Subsequently, the aggregation of labour and coolies at construction and plantation sites and their further migration from malarious zone to non-malarious zone spread the disease in different regions. The construction sites provided a number of breeding locations for the malaria vectors, while the labourers introduced different strains of the parasite to the areas in which they worked.

The anti-malarial measures, consisting of cutting of jungle grass, oiling and use of Paris green, fumigation, quinine treatment, introduction of larvicidal fish and many others, as suggested by Dr. Mukerji Committee, were not properly implemented. The death rate remained same before and after the anti-malarial measures.

The Sarda Canal case highlights the translocal consequences of vector-borne diseases, exacerbated by human mobility, which colonial health authorities failed to address. The lack of systems to monitor laborer' health during transit and their integration into new ecological environments indicates a failure to manage the unintended proliferation of malaria. The crisis underscores the need for a comprehensive strategy integrating scientific research, technological innovation, and ecological awareness. It warns that a disconnect between scientific understanding and practical implementation can lead to public health emergencies. This historical event underscores the importance of considering historical contexts and ecological frameworks in development planning and execution.

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