

GOVERNMENT OF MADRAS.

MILITARY DEPARTMENT.

12th May 1886, No. 2919.

Sanitary.

Read the following paper:—

No. 201. *From F. C. DAUKES, Esq., C.S., Under Secretary to the Government of India, Home Department, to the Governments of Madras, Bombay, Bengal, North-Western Provinces and Oudh, and the Punjab; Chief Commissioners of the Central Provinces, British Burma, Assam, Coorg and Resident at Hyderabad; dated Calcutta, the 27th March 1886, No. 88-97—3.*

Sanitary.

I am directed to forward, for ^{the}_{your} information of H.E. the Governor in Council and for communication to the officers of the local Sanitary Department, a copy of a memorandum, which has been received from Her Majesty's Secretary of State, entitled "Ventilation with air from superior layers in place of inferior layers" by Mr. E. Chadwick, C.B., an eminent English sanitary authority.

VENTILATION WITH AIR FROM SUPERIOR LAYERS IN PLACE OF
INFERIOR LAYERS.

By Edwin Chadwick, C.B.

In sanitary inquiries my attention was early directed to instances of layers or *strata* of air of malarious influence, such as this: A medical officer, pointing to a mist spread like a sheet over a valley, said, "That sheet just covers the bulk of my patients; out of it or above it, I have nothing scarcely but midwifery cases and accidents." I have had instances of children whose heads were above a visible mist escaping attack, whilst the smaller children covered by the mist suffered from them; examples of the occupiers of the cellars, and the lower stages in towns suffering from cholera and other epidemic visitations, whilst those living in the upper flats or highest stories entirely escaped from them, except in the attics, for which there was special reason; cases of experiences in India, where men could not travel in safety at night across valleys, whilst men on elephants, being above the malarious layer, could do so; of people raising their habitations on stilts, as is universally done in Burma, to escape the mephitic influences of which they have had experience.

Mr. Glaisher, the aeronaut, writes to me:—"When in the car of a balloon I have been struck with the definite boundary of mists at times when there has been but little generally, and I found afterwards that the mists were located over marshes, or clay soil, when gravelly soil was free. The ventilation of the Underground Railway could be effectually carried out by your suggestion."

The general effect of land drainage has been to reduce mists, and in some instances to remove them entirely. In such instances it has reduced or removed the plague of midges in England. In one instance in Algeria, of which I was informed, the drainage of a district, and its close cultivation, entirely removed the plague of mosquitoes which had rendered it almost uninhabitable. In the Fen districts of Lincolnshire, the land drainage has reduced mists, and so reduced ague that ounces of bark are not now used where pounds were used formerly. It is for zoologists or microscopic observers to show on what these animalcules subsist where there are no human or animal subjects to prey upon, and what is the superficial extent of their feeding ground. On the occasion of choleraic visitations, extraordinary developments of insect life were in some instances observed, generally in low-lying layers, but they passed without any examination of which I am aware. I point out these incidents for the observation of naturalists, and the favor of information from them.

From Highgate Hill I have observed mists, spread over the Metropolis like a blanket, and the upper dome of St. Paul's Cathedral appearing clear and bright above it like a spike through the blanket. I have ascended that dome and found there a clear, freshening breeze, as good in sensation as any on the Surrey hills; whilst the air beneath in the adjacent streets was comparatively stagnant and unrefreshing.

Dr. Gordon Hardy writes:—"Riding on the 'Maidan' in Calcutta, I have often had sight only of riders' heads above a level of dense fog."

A friend, a great traveller, found out that mosquitoes lived and fed exclusively in the animalised gases diffused amongst the lower layers of air. He suffered intensely from the bite of these insects, and to escape them when he came near the coast, he made his bed aloft on the cross-trees of the mainmast; and when he went on shore, he astonished the natives by seeking for some steeple, where he could make his bed.

Colonel Graham, of Chiswick, states to me:—"In 1865 I was in charge of the police in the Deyra Doon district of the North-West Provinces, India. The district is covered with dense forest, and is unhealthy during the rainy season from June to September, *i.e.*, the forest portion of it. My men, if they slept on or near the ground, died off in numbers from malarious fever; so sleeping places were constructed for them in the trees about twenty feet from the ground, and the result was that the death-rate decreased enormously. Once, when out tiger shooting in 1868, in the forest at the foot of the Himalayas, we were overtaken in May by a very unusual event, a heavy fall of rain, which brought out the malaria from the mass of rank vegetation. We tried to get out in one march, but could not manage it, and had to sleep in the jungle in our tents. Three out of the four of us got severe jungle fever, from the effects of which I had to come home, and several of our camp followers died of it. Could we all have slept on trees, I believe not one of us would have got it. Another of my experiences in India may interest you. In 1867, when commanding the Mairwara Battalion in Rajputana, a severe epidemic of cholera broke out, and I lost a number of men. The air, as it often is during such epidemics, was very hot and close, and I had the whole regiment out morning and evening and fired volleys. Whether it was that the firing brought down a fresh and healthy current of air in the same way that firing cannon brings down rain, or that the smoke, composed as it was of sulphur, among other ingredients, had a sanitary effect on the men, situated as they were close by, I cannot say, but the result was certainly curious, as the cholera at once decreased and soon died out."

Dr. F. J. Mouat, of the Local Government Board, states to me:—"My observation of the probable height of the mists in Lower Bengal is confined to the Sunderbunds, where on two occasions, at periods separated by many months, I went up the mast of a river steamer, and ascertained that the limit of the mist was absolutely uniform as far as the eye could reach."

"I had no means of determining the exact height, but it could not have been less than 20 feet. Until the fogs were dispersed by the sun, sometimes as late as 11 A.M. in the cold weather, the steamer remained at anchor."

"As respects the care taken of the cattle in the Terai or low land at the foot of the hills in Eastern Bengal, the men, after shutting up the cattle in the large sheds provided, mounted to small sheltered platforms high up in the trees to sleep. This was to avoid the tigers which then abounded in those localities; and I was informed by natives acquainted with the localities that they enjoyed a remarkable immunity from the deadly fevers of those places."

The late Mr. Joseph Hume, M.P., who began his career as an Army Surgeon in India, told me that he ascertained in some districts that the low malarious gases, presumably heavy, were close to the ground, and that he found safety to the men while bivouacking in having their heads carefully raised eighteen inches above the surface.

In Italy it has been observed that sickness is most prevalent on the ground floors of the tall houses, constructed in flats, while those above are distinctly superior in health. In the late visitation of cholera at Naples, it was observed that the most severe attacks were very distinctly within the accustomed low-lying mists prevalent in the depressed districts.

I have been informed that in the epidemic visitations upon Calcutta the attacks have been upon the occupants of the ground floors, whilst those of the upper floors have had almost entire exemption.

Here in London, even in the model dwellings, instances have been observed of attacks of sickness upon the occupiers of the ground floors, from which the occupiers of the upper flats were exempt.

In hot and dry climates malaria appears to have but little influence under the direct rays of the sun. A plant collector for a horticultural firm found that he could traverse the most pestilential spots in Sierra Leone, provided he did not keep out after sunset, when he immediately took refuge in a hut prepared for him, with a large fire, which he kept alight during the night. He found that the natives did the same, and kept the fires in, as they said, to keep the devils out.

I believe that provision for the ventilation of public edifices, hospitals and schools may be obtained by mechanical means, such as I will now submit for consideration. On the repeated sight of the great blanket of fog spread over the Metropolis, I discussed the subject with Dr. Neil Arnott, who was a man of distinguished mechanical ability, and our conclusion then was that we might form a pure air company, which would engage to draw the air from a suitable height above the common layers, and distribute it into houses by engine power, or as gas is distributed, and do it with a profit, at a very low rate, or for some few shillings a year give even a better air than people generally obtain in suburban residences.

I have visited hospitals in Paris where the mechanical methods of *internal* ventilation are, in my view, excellent and superior, but where all draw in the air from the lower layers of the

outside street air. It is only recently, in one instance, of which I have not got the particulars, that the expedient of drawing in a superior air from a height has been adopted or thought of. In England I have known of hospitals very well ventilated—internally, mechanically—which have drawn their external air from lower couches that were positively very bad, and the more the wards were ventilated, the worse they often were. Indeed, it is sometimes proposed as a principle, as against that of extraction, that ventilation is best effected by "currents of fresh air brought in by open windows placed in opposite sides of the wards." But this so-called "fresh air" is the common street air, really foul air polluted by street emanations from sewers and cesspools requiring washings before operations can be safely performed. It is well known that surgical operations cannot be performed with safety in town air (unless it is washed) that may be performed with increased chances of favorable results in a good suburban air.

In Paris, when I visited the hospitals, the two systems of ventilation were in competition—one of "propulsion," or driving in the air; the other of "aspiration," or of drawing it out by suction. It appeared that the practice of propulsion drove the air in heaps, leaving corners stagnant; whilst the method of aspiration, or suction, operated perfectly in removing the air nearest to them from the points of vitiation in the time required, and in introducing really fresh air from the points farthest from vitiation and at the temperature required, and also in maintaining passages and cabinets at a temperature equal to that of the interior rooms. Notwithstanding the fault of ventilating with the generally cesspool-tainted and impure street air, the effect of the system of "aspiration" appeared to be in advance of at least one-fourth of the common methods of hospital ventilation.

This principle of "aspiration" appears to me to be peculiarly adapted to drawing in the air from the superior layer, obtained from two, three, four or five hundred feet, or whatever height it may be desired.

It is peculiarly applicable to India and to Southern cities generally for securing refreshing sleep free from the plague of mosquitoes. This principle would bring in air free from the insects, and carry those in the building away from it. The engine power required for the service would cost less than that for ventilation by the punkahs.

The system of extraction, as managed by Leon Duvoir le Blanc, allowed the most complete adaptation to requirements. At its outset he asked the medical authorities of the hospital to be ventilated, that of La Riboisiere:—"At what temperature do you require the air to be kept?—At 60 deg. How often do you require it to be changed?—Once every hour, night as well as day. In what direction do you require it to be removed?—Downwards, between each bed. All this was done completely by passing the vitiated air tubes through a hot-water tank on the roof, by which the air in them was heated and a steady draught created. But it appears to be questionable whether force-pumps are not equally eligible. Having been pressed by other questions, I have not been in a position to obtain by observation and experiments the precise results as I would now seek. I obtained a promise from my late lamented friend, Dr. Angus Smith, who had been the foremost in analysing air, that he would make the experiments I suggested, of sending up a balloon with a self-registering thermometer to ascertain the temperature at different heights, and also a bottle filled with water, with a self-closing tap capable of being opened from below, so as to bring down specimens of the air to be tested. Hence for the east or anywhere, it may be stated that we are not dependent on the superior layers of air for the temperature. It may be given to it below in various ways. I was assured that at La Riboisiere, the contract to keep the temperature night and day at sixty was duly performed. When it was below that temperature, it was warmed by being led over warmed surfaces on admission, and when it was above that temperature, it was cooled by being passed over surfaces cooled down by evaporation. I was assured that the practicability of doing this may be considered as settled. All this was done at a less expense than that of warming edifices by the ordinary method; and all this, it is suggested, can be done for sleeping-rooms in India, and for offices; but the most convenient power for working the system of "aspiration" would, I expect, be by hot-air engines, which may be had of one, two or three horse power, and go on working for a long time, with little care. The expense was ten centimes, or a penny per diem, for the warming and removal of sixty metres per head per diem, coal being then 40s. per ton. Small steam-engines would be available for larger buildings. If the principle be approved, plans for its application according to conditions may be got out.

In the construction of towers for the obtaining of pure air, it appeared to me undesirable that the common absorbent brick should be used. Constructions of non-absorbent concrete appeared to me to be the most eligible, and that constructions with large hexagonal pots would have considerable advantages. The requisite heights would have to be ascertained experimentally. The impure layers of air might often be avoided by inconsiderable elevations. Experimentation and observations on the points suggested would be of the greatest importance in the tropical districts, where rest and refreshing sleep are difficult to be got, and where even existence is a torment.

In some experiments made on the continent for ascertaining the presence of ozone, the ozone was obtained at the top of a cathedral, whilst none was to be got at the base.

The state of sanitary administration in our Metropolis has been displayed in the new Law Courts, where on the occurrence of crowded attendance, the proceedings have been interrupted,

and the judge, the jury and the attendants have been obliged to go out to obtain relief from oppression. At the Palais de Justice at Paris, relief is immediately given on any occasion of increased attendance by the increased action of the pump.

Large rooms, large enclosed spaces, not duly ventilated, are, as experienced at the new Government offices, only reservoirs of aerial impurity. Had the science of ventilation, as expounded by my correspondent, the late General Morin, in his work on ventilation, been adopted, double the number of officers might have been accommodated well, and with increased working ability, in those edifices on which three millions of money have been expended.

I am aware that it was a view of Dr. Reid to draw purer air than the street air from the Clock tower. But it was observed that there were adjacent tall chimneys, which discharged currents from the products of their manufactures, which might, if it came in the direction of the Houses of Parliament, have been drawn in. Possibly an elevation a hundred feet higher might have surmounted this risk, but it would have offended architectural proprieties. As it is, the Parliament houses are ventilated with street air sieved and washed, under the direction of Dr. Percy, in a manner which members have informed me they consider to be satisfactory. But the sievings of that street air, as detained in the cotton sieves, display what the outside population, including the population of the Government offices, have to breathe. Nevertheless, the Houses of Parliament are at times assailed by foul smells which will be found to arise from the man-sized sewers of putrid deposits which are not under the jurisdiction of Dr. Percy. The remedy will be found to be in the small self-cleansing pipe sewers which we had provided for the Houses of Parliament, but which by default were superseded by the larger man-sized sewers. These not only convey foul smells into the public offices, but give access to dynamiters and traitors, against whom Sir Henry de la Beche, with myself, were charged by the Lord Chamberlain to take precautions when Her Majesty went to Parliament. This we did by sentinels in the sewers underneath for the occasion.

The legislative remedy will, I apprehend, be in the compliance with the increasing demand for the consolidation of scattered functions of sanitation, and the creation of a Department of Health, under a Minister of Public Health, of which department a sub-department on ventilation with specialists would be charged with the collection of all the best and the most recent experiences for information and guidance of the specialists and the officers of local authorities.

Meantime, we must get on how we can provisionally, and by isolated effort, to which the experiences cited and those in progress may be subservient. Sanitary officers of the Indian Service approve of the principles I have stated, and consider that their application there is most pressing, especially for the hospitals.

Some new ventilators were displayed at the Inventions Exhibition, which appeared to be of great promise. I am informed that some of them have been introduced, and are in action for the ventilation of public edifices and schools in London. I propose to ascertain and state the results obtained.

I expect a contribution of information from Dr. Percy Frankland on examinations of the state and movement of the air, its temperature, and the presence of ozone at the top of St. Paul's Cathedral, as compared with the condition of the air in the adjacent streets. I expect similar investigations will be made at the Cathedral of York.

And now to advert further to the remedies, the preventives of these more specially common conditions.

These conditions are, at home as well as abroad, super-saturation of the land and stagnation of the super-saturated water, and the preventives are thorough land drainage, as I have elsewhere shown in a special treatise or minutes of information on the subject. The removal of the super-saturation elevates temperature and removes fogs and the insect life that germinates in conditions of stagnation, and yet regulates the hygroscopticity of the soil or the due moisture requisite for the advancement of agricultural production. The measures prepared for the thorough drainage of the land surrounding London, as well as the interior site of the houses, would have removed the main sources of its fogs, and would have had the effect of raising all the houses one storey higher, and have made them, as it were, second-storey flats. From a medical officer of France I received information of a case of a very efficient application of sanitary science for the removal of the lethal conditions of a site which it was held to be necessary to occupy for strategical purposes. The military death-rate was higher than the worst of ours under the old merely curative service of India, during which upwards of ninety per thousand and three sets of forces had been decimated, as also three sets of colonists, amongst whom the death-rates of the children exceeded the birth-rates. The place fell into the hands of a Sanitary Engineer, who drained the site extensively and thoroughly. The sanitary effect was the reduction of the military death-rate to twelve in a thousand, whilst the death-rate of the French army that occupied Rome was fifteen in a thousand, and the birth-rate of the children of the civil population raised high above the death-rate; thus a crop of children was raised as healthy as any of the children of the rural districts of France. But one marked result of the removal by the land drainage of the conditions of stagnation was the removal of the plague of the mosquitoes, which have rendered life there a constant suffering. I considered the example so important for India that I obtained the leave of Lord Ripon, then Minister of War, to have a special examination made of it, and a commission was sent there comprising Mr. Robert Ellis, who

had been chief of the Sanitary Commission of Madras, and had accomplished some important sanitary achievements in the suppression of cholera, and was afterwards member of the Indian Council at home, and General Ewart, of the Engineers, and Dr. John Sutherland, since acting member of the Army Sanitary Commission, which also advises on Indian sanitary work. They reported decisively that the example was applicable to the greater part of India.* I may add that it is applicable to the greater part of our most prosperous colonies, where, from ignorance and neglect of the sanitation of sites occupied, of the children born, and whom it is most important to preserve, more than one-half are in their graves by their fifth year. But action has yet to be taken on the conclusion in India. In the colonies, it is to be submitted that for them, as well as for home service, no provision of a commensurate special sanitary service, to be hereafter specified, will be required.

It is in evidence that of the land that would be benefited in England by drainage, there is now, after some forty years of exposition and legislative provisions for it, only a small proportion yet drained, although, when executed under the supervision of competent official specialists, as a rule, it repays the expense in seven years or by a return of 14 per cent. Legislative provisions are required for the removal of obstructions to outfalls, and for protection against the wastefulness of ignorance. But at the last the relief by general land drainage must be expected to occupy a considerable period. Meanwhile, protection is needed from the lower couches of air, especially from such air as the street air, polluted and extended cesspools, of a thousand miles of ill-constructed sewers of deposit; from such stagnant sewer and drain-polluted air as that which pervades the very Government offices about Downing street, and restricts the working ability there—such a quality of air that no surgeon who knew his duty, if he could not remove the case to a pure suburban air, would conduct a serious operation without washing the air by Lister's process.

As to the different degrees of purity of air at different altitudes, important experiments are being carried on at Paris by Messieurs Miguel and Davey. So far as they have been carried, they are entirely corroborative of the general results I have stated. Thus, at the lantern of the Pantheon, which is about 310 feet high, the air is found to be twenty times more pure than the street air in the vicinity of the Rue Rivoli. In high altitudes of 2,000 metres, no microbes have been found, whilst in the open part of Mont Louis at Paris, 7,000 were found in the cubic metre, but in the street of the great Rue Rivoli there were 35,000 in the cubic metre.

The qualities of these microbes are, doubtless, important subjects for examination, but these examinations ought not to delay the application of measures of sanitation. The question of the germination of insects found in the human body may be subjects of important scientific research, but those researches I have felt ought not to delay direct applications of soap and water.

In the minutes of information as to the drainage of land and on the distribution of sewage, published in 1850, I stated the sanitary objections even to the distribution of plain water by the old method of submersion of water meadows as productive of marsh surfaces which gave rheumatism and ague to men and the rot in sheep, and as being generally very expensive to construct, and as being wasteful of water. Since then I have received from India accounts of intense evils attendant on this method of distribution; and that on a very extensive line where it was adopted. The course of the irrigations of one extensive district was denoted by the size of the spleen of the people working on them or living near them. Dr. Robert Pringle, the Sanitary Commissioner for the North-Western Provinces and Oudh, in his report for 1880, displays at great length the excessive mortality attendant on this method of irrigation, creating super-saturated, water-logged, marshy and malarious surfaces, which are made lines of fever

* The Emperor Louis Napoleon went to Algeria to examine in person whether anything could be done to stay the waste then going on at the rate of some three millions a year, without any apparent return for it. But he failed to discover the chief remedy. In his view colonisation by the French was a failure. He did not dare look to the English; but he at that time recommended that the Germans should be invited to it. But the land was not fit for intelligent Frenchmen, or other fitting colonists as the example set proved that it might be made. Mr. Robert Ellis assured me that, under our Indian administration, Algeria would be held by less than one-third of the force with which it was held by the military authorities of France. The Emperor had at my suggestion directed some important trial works to be made, to ascertain the productive power of the sewage of Paris, and when he was at Brighton I took the opportunity of having some conversation with him about the example set in Algeria, for I was convinced that if the money spent by the military authorities in fortifying the towns of that province had been expended in their sanitation, and in the sanitation of the adjacent fields for agriculture, as displayed sufficiently in that example, a force of colonists, French as well as others, might have been got that would have been stronger, by volunteer force, than all the fortifications on which money had been wasted, and that might have restored the province to its ancient productiveness as the chief granary of Europe. But I found that his Majesty had never heard of this case. My conviction was that the jealousy of militarism, and possibly of the curative service—a jealousy such as has hitherto prevailed here in official quarters—had prevailed in keeping out of sight the example of a new service, requiring position and having claims to positions and distinctions, eclipsing the old ones invidiously. In India the sanitary service has reduced the Army death-rate from 69 to 10·84 per 1,000. More lives are now saved in one year than were lost by the sword during the ten years of the last decade. In the West Indies greater reductions have been effected. I proposed recently that medals of distinction should be given there for dangers successfully encountered, with as great dangers as in battle, for greater savings of life than are encountered in sacrificing life. But the proposal was refused, evidently in the common feeling of jealousy towards the new service, on which the decision of Parliament is to be sought. At a meeting of the Society of Arts, at which I was called upon to preside, General McMurdo read a paper on the expediency of colonisation by retired soldiers in India. The application of the sewage principles would form part of the practical means of effecting it for them and for others. A recent Commission on the condition of agriculture in Italy recommends as of the foremost remedies for its relief, "*les mesures nécessaires pour assurer la salubrité dans les campagnes et de l'assainissement des sol marécageux*," as I have done on such authority as that of the late Mr. Ponce Jones for Ireland.

attacks and excessive mortality. "As to the military stations," he says, "I can speak with the clearest evidence regarding the military cantonments of Meerut and the North-Western Provinces of India, my personal knowledge of which stations has extended continuously over twenty years. In this military station, the terrible outbreaks of fever are now considerably explained. There are barracks in this cantonment on the level of the ground, and many others but little raised above it; and, as if this was not enough, there is an appliance called the thermantidote, which forces in air from the outside into the barracks from about from one to three feet above the ground, over the faces of the men resting on their beds in the heat of the day, when the sun's rays are beating on a water-logged soil nothing like so free from surface impurities as it might be. Little wonder, therefore, that fever is prevalent among these men, and in some instances cholera also. And this has gone on for twenty years to my certain knowledge. Again, the pattern of double-storied barracks in this same cantonment. A considerable source of dysentery and diarrhoea, the result of biliary derangement, due to chills at night. General Sir W. Montagu McMurdo objected to the barracks of the 'sanatorium' as being wrong in principle and too costly. "Perched, as a rule, on the comb of some ridge, they are exposed at elevations of 7,000 feet to the cold winds from the snows, while the solid walls establish the means for thorough draughts between windows and doors, up staircases, and along passages, resulting, as I have observed, in accession of colds and chest complaints among the invalids fresh from the plains. If the thermantidote drew air from the upper couches of the atmosphere" (and it might be added warmed it), "which could be easily arranged, as you describe in your paper, I am confident that benefit would result at once; and the Government have at Meerut, as I know, a considerable number of barracks, to begin the experiment at once, and that before the fever season begins, and you are at liberty to quote my name in support of this." He adds that "in his district of four millions, the fever carried off 400,000 in one year. Only suppose this had been the mortality in India with its four hundred millions!"

In 1881 I received a plan by my friend Walter M. Ducat, Major of the Royal Engineers, for the sewerage of the city and cantonment of Poona. The plan was sound in its main principles, and was supported by Mr. John Lumsden, the Sanitary Commissioner to the Government of Bombay. The plan appeared to me to be of the highest importance to get forward as a first example of the full application of sanitary science, which has been effectual with the military science to the relief of depressed civil populations in India. But on inquiry for it, I learn that nothing has been done with it, or is likely to be yet. Delayed for financial reasons.

On this, it is to be observed, in respect to effectual sanitary works, that to delay them on the ground of expense is to economise the means of public economy on the largest scale. The saving by the reduced death-rate in the army during the last decade, at only £100 for each soldier saved, has been upwards of six millions sterling. When my son was in India thirteen years since, as a Lieutenant of the Royal Engineers, he was impressed by the financial difficulty of obtaining public money for sanitary works. He observed that the Hindoos hoard their savings in plate and jewels as well as in coin. He conceived a plan of circulating annuities for small amounts, bearing compound interest, which would be highly convenient to them, as bearing a continued interest which they lost upon their hoards. Bentham had an idea of a "circulating annuity," but my son's plan was worked out independently, and has practical improvements over that of Bentham. But he was then only a Lieutenant, and did not succeed in getting it forward. He has, however, recently proposed it for Malta, for raising the expense of sanitary works which he is carrying out there, where the plan meets with the support of Sir Lintorn Simmons, the Governor. At home we had got on fairly in my time without it, by means of distributed charges levied at private improvement works.

No. 98.

Copy, with copy of the memorandum referred to, forwarded to the Military Department for information.

(Signed) F. C. DAUKES,
Under Secy. to the Govt. of India.

No. 28-C.

Sanitary.

Copy of the foregoing, and of its enclosure, forwarded to the Secretary to the Government of Madras, Military Department.

(By Order.)

SIMLA,
8th April 1886.

(Signed) W. J. B. BIRD,
Asst. Secy. to the Govt. of India.

No. 202.

ORDER THEREON, 12th May 1886, No. 2919.

Communicated to His Excellency the Commander-in-Chief, the Public Works Department, and the Surgeon-General, Her Majesty's Forces, Madras.

(True Extract.)

(Signed) A. KENNEY-HERBERT, Lt.-Col.,
Secretary to Government.

To the Quarter Master General.

„ Adjutant-General.

„ Public Works Department.

„ Surgeon-General, Her Majesty's Forces, Madras.

Exd. E. C. Shunker.

Gobt. of {1886} Madras.

MILITARY.

No. 1283Wd/21 May 1886

Communicated to
Superintending Engineers
for information

12/5/86

To
THE QUARTER MASTER GENERAL,
&c., &c., &c.

Dated May 12th.

Issued

Recd.

Encl.

G.O., 12th May 1886, No. 2919.

B. No. 1283Wd/21 May 1886

MAY.

Nos. 201-202.

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Supy: Engineer
Consy. Architect to Govt
C. Engineer for Iron

With order

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MILITARY DEPARTMENT.

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INFERIOR LAYERS.

By Edwin Chadwick, C.B.

In sanitary inquiries my attention was early directed to instances of layers or strata of air of malarious influence, such as this: A medical officer, pointing to a mist spread like a sheet over a valley, said, "That sheet just covers the bulk of my patients; out of it or above it, I have nothing scarcely but midwifery cases and accidents." I have had instances of children whose heads were above a visible mist escaping attack, whilst the smaller children covered by the mist suffered from them; examples of the occupiers of the cellars, and the lower stages in towns suffering from cholera and other epidemic visitations, whilst those living in the upper flats or highest stories entirely escaped from them, except in the attics, for which there was special reason; cases of experiences in India, where men could not travel in safety at night across valleys, whilst men on elephants, being above the malarious layer, could do so; of people raising their habitations on stilts, as is universally done in Burma, to escape the mephitic influences of which they have had experience.

Mr. Glaisher, the aeronaut, writes to me:—"When in the car of a balloon I have been struck with the definite boundary of mists at times when there has been but little generally, and I found afterwards that the mists were located over marshes, or clay soil, when gravelly soil was free. The ventilation of the Underground Railway could be effectually carried out by your suggestion."

The general effect of land drainage has been to reduce mists, and in some instances to remove them entirely. In such instances it has reduced or removed the plague of midges in England. In one instance in Algeria, of which I was informed, the drainage of a district, and its close cultivation, entirely removed the plague of mosquitoes which had rendered it almost uninhabitable. In the Fen districts of Lincolnshire, the land drainage has reduced mists, and so reduced ague that ounces of bark are not now used where pounds were used formerly. It is for zoologists or microscopic observers to show on what these animalcules subsist where there are no human or animal subjects to prey upon, and what is the superficial extent of their feeding ground. On the occasion of choleraic visitations, extraordinary developments of insect life were in some instances observed, generally in low-lying layers, but they passed without any examination of which I am aware. I point out these incidents for the observation of naturalists, and the favor of information from them.

From Highgate Hill I have observed mists, spread over the Metropolis like a blanket, and the upper dome of St. Paul's Cathedral appearing clear and bright above it like a spike through the blanket. I have ascended that dome and found there a clear, freshening breeze, as good in sensation as any on the Surrey hills; whilst the air beneath in the adjacent streets was comparatively stagnant and unrefreshing.

Dr. Gordon Hardy writes:—"Riding on the 'Maidan' in Calcutta, I have often had sight only of riders' heads above a level of dense fog."

A friend, a great traveller, found out that mosquitoes lived and fed exclusively in the animalised gases diffused amongst the lower layers of air. He suffered intensely from the bite of these insects, and to escape them when he came near the coast, he made his bed aloft on the cross-trees of the mainmast; and when he went on shore, he astonished the natives by seeking for some steeple, where he could make his bed.

Colonel Graham, of Chiswick, states to me:—"In 1865 I was in charge of the police in the Deyra Doon district of the North-West Provinces, India. The district is covered with dense forest, and is unhealthy during the rainy season from June to September, *i.e.*, the forest portion of it. My men, if they slept on or near the ground, died off in numbers from malarious fever; so sleeping places were constructed for them in the trees about twenty feet from the ground, and the result was that the death-rate decreased enormously. Once, when out tiger shooting in 1868, in the forest at the foot of the Himalayas, we were overtaken in May by a very unusual event, a heavy fall of rain, which brought out the malaria from the mass of rank vegetation. We tried to get out in one march, but could not manage it, and had to sleep in the jungle in our tents. Three out of the four of us got severe jungle fever, from the effects of which I had to come home, and several of our camp followers died of it. Could we all have slept on trees, I believe not one of us would have got it. Another of my experiences in India may interest you. In 1867, when commanding the Mairwara Battalion in Rajputana, a severe epidemic of cholera broke out, and I lost a number of men. The air, as it often is during such epidemics, was very hot and close, and I had the whole regiment out morning and evening and fired volleys. Whether it was that the firing brought down a fresh and healthy current of air in the same way that firing cannon brings down rain, or that the smoke, composed as it was of sulphur, among other ingredients, had a sanitary effect on the men, situated as they were close by, I cannot say, but the result was certainly curious, as the cholera at once decreased and soon died out."

Dr. F. J. Mouat, of the Local Government Board, states to me:—"My observation of the probable height of the mists in Lower Bengal is confined to the Sunderbunds, where on two occasions, at periods separated by many months, I went up the mast of a river steamer, and ascertained that the limit of the mist was absolutely uniform as far as the eye could reach."

"I had no means of determining the exact height, but it could not have been less than 20 feet. Until the fogs were dispersed by the sun, sometimes as late as 11 A.M. in the cold weather, the steamer remained at anchor."

"As respects the care taken of the cattle in the Terai or low land at the foot of the hills in Eastern Bengal, the men, after shutting up the cattle in the large sheds provided, mounted to small sheltered platforms high up in the trees to sleep. This was to avoid the tigers which then abounded in those localities; and I was informed by natives acquainted with the localities that they enjoyed a remarkable immunity from the deadly fevers of those places."

The late Mr. Joseph Hume, M.P., who began his career as an Army Surgeon in India, told me that he ascertained in some districts that the low malarious gases, presumably heavy, were close to the ground, and that he found safety to the men while bivouacking in having their heads carefully raised eighteen inches above the surface.

In Italy it has been observed that sickness is most prevalent on the ground floors of the tall houses, constructed in flats, while those above are distinctly superior in health. In the late visitation of cholera at Naples, it was observed that the most severe attacks were very distinctly within the accustomed low-lying mists prevalent in the depressed districts.

I have been informed that in the epidemic visitations upon Calcutta the attacks have been upon the occupants of the ground floors, whilst those of the upper floors have had almost entire exemption.

Here in London, even in the model dwellings, instances have been observed of attacks of sickness upon the occupants of the ground floors, from which the occupants of the upper flats were exempt.

In hot and dry climates malaria appears to have but little influence under the direct rays of the sun. A plant collector for a horticultural firm found that he could traverse the most pestilential spots in Sierra Leone, provided he did not keep out after sunset, when he immediately took refuge in a hut prepared for him, with a large fire, which he kept alight during the night. He found that the natives did the same, and kept the fires in, as they said, to keep the devils out.

I believe that provision for the ventilation of public edifices, hospitals and schools may be obtained by mechanical means, such as I will now submit for consideration. On the repeated sight of the great blanket of fog spread over the Metropolis, I discussed the subject with Dr. Neil Arnott, who was a man of distinguished mechanical ability, and our conclusion then was that we might form a pure air company, which would engage to draw the air from a suitable height above the common layers, and distribute it into houses by engine power, or as gas is distributed, and do it with a profit, at a very low rate, or for some few shillings a year give even a better air than people generally obtain in suburban residences.

I have visited hospitals in Paris where the mechanical methods of *internal* ventilation are, in my view, excellent and superior, but where all draw in the air from the lower layers of the

outside street air. It is only recently, in one instance, of which I have not got the particulars, that the expedient of drawing in a superior air from a height has been adopted or thought of. In England I have known of hospitals very well ventilated—internally, mechanically—which have drawn their external air from lower couches that were positively very bad, and the more the wards were ventilated, the worse they often were. Indeed, it is sometimes proposed as a principle, as against that of extraction, that ventilation is best effected by "currents of fresh air brought in by open windows placed in opposite sides of the wards." But this so-called "fresh air" is the common street air, really foul air polluted by street emanations from sewers and cesspools requiring washings before operations can be safely performed. It is well known that surgical operations cannot be performed with safety in town air (unless it is washed) that may be performed with increased chances of favorable results in a good suburban air.

In Paris, when I visited the hospitals, the two systems of ventilation were in competition—one of "propulsion," or driving in the air; the other of "aspiration," or of drawing it out by suction. It appeared that the practice of propulsion drove the air in heaps, leaving corners stagnant; whilst the method of aspiration, or suction, operated perfectly in removing the air nearest to them from the points of vitiation in the time required, and in introducing really fresh air from the points farthest from vitiation and at the temperature required, and also in maintaining passages and cabinets at a temperature equal to that of the interior rooms. Notwithstanding the fault of ventilating with the generally cesspool-tainted and impure street air, the effect of the system of "aspiration" appeared to be in advance of at least one-fourth of the common methods of hospital ventilation.

This principle of "aspiration" appears to me to be peculiarly adapted to drawing in the air from the superior layer, obtained from two, three, four or five hundred feet, or whatever height it may be desired.

It is peculiarly applicable to India and to Southern cities generally for securing refreshing sleep free from the plague of mosquitoes. This principle would bring in air free from the insects, and carry those in the building away from it. The engine power required for the service would cost less than that for ventilation by the punkahs.

The system of extraction, as managed by Leon Duvoir le Blanc, allowed the most complete adaptation to requirements. At its outset he asked the medical authorities of the hospital to be ventilated, that of La Riboisière:—"At what temperature do you require the air to be kept?—At 60 deg. How often do you require it to be changed?—Once every hour, night as well as day. In what direction do you require it to be removed?—Downwards, between each bed. All this was done completely by passing the vitiated air tubes through a hot-water tank on the roof, by which the air in them was heated and a steady draught created. But it appears to be questionable whether force-pumps are not equally eligible. Having been pressed by other questions, I have not been in a position to obtain by observation and experiments the precise results as I would now seek. I obtained a promise from my late lamented friend, Dr. Angus Smith, who had been the foremost in analysing air, that he would make the experiments I suggested, of sending up a balloon with a self-registering thermometer to ascertain the temperature at different heights, and also a bottle filled with water, with a self-closing tap capable of being opened from below, so as to bring down specimens of the air to be tested. Hence for the east or anywhere, it may be stated that we are not dependent on the superior layers of air for the temperature. It may be given to it below in various ways. I was assured that at La Riboisière, the contract to keep the temperature night and day at sixty was duly performed. When it was below that temperature, it was warmed by being led over warmed surfaces on admission, and when it was above that temperature, it was cooled by being passed over surfaces cooled down by evaporation. I was assured that the practicability of doing this may be considered as settled. All this was done at a less expense than that of warming edifices by the ordinary method; and all this, it is suggested, can be done for sleeping-rooms in India, and for offices; but the most convenient power for working the system of "aspiration" would, I expect, be by hot-air engines, which may be had of one, two or three horse power, and go on working for a long time, with little care. The expense was ten centimes, or a penny per diem, for the warming and removal of sixty metres per head per diem, coal being then 40s. per ton. Small steam-engines would be available for larger buildings. If the principle be approved, plans for its application according to conditions may be got out.

In the construction of towers for the obtaining of pure air, it appeared to me undesirable that the common absorbent brick should be used. Constructions of non-absorbent concrete appeared to me to be the most eligible, and that constructions with large hexagonal pots would have considerable advantages. The requisite heights would have to be ascertained experimentally. The impure layers of air might often be avoided by inconsiderable elevations. Experimentation and observations on the points suggested would be of the greatest importance in the tropical districts, where rest and refreshing sleep are difficult to be got, and where even existence is a torment.

In some experiments made on the continent for ascertaining the presence of ozone, the ozone was obtained at the top of a cathedral, whilst none was to be got at the base.

The state of sanitary administration in our Metropolis has been displayed in the new Law Courts, where on the occurrence of crowded attendance, the proceedings have been interrupted,

and the judge, the jury and the attendants have been obliged to go out to obtain relief from oppression. At the Palais de Justice at Paris, relief is immediately given on any occasion of increased attendance by the increased action of the pump.

Large rooms, large enclosed spaces, not duly ventilated, are, as experienced at the new Government offices, only reservoirs of aerial impurity. Had the science of ventilation, as expounded by my correspondent, the late General Morin, in his work on ventilation, been adopted, double the number of officers might have been accommodated well, and with increased working ability, in those edifices on which three millions of money have been expended.

I am aware that it was a view of Dr. Reid to draw purer air than the street air from the Clock tower. But it was observed that there were adjacent tall chimneys, which discharged currents from the products of their manufactures, which might, if it came in the direction of the Houses of Parliament, have been drawn in. Possibly an elevation a hundred feet higher might have surmounted this risk, but it would have offended architectural proprieties. As it is, the Parliament houses are ventilated with street air sieved and washed, under the direction of Dr. Percy, in a manner which members have informed me they consider to be satisfactory. But the sievings of that street air, as detained in the cotton sieves, display what the outside population, including the population of the Government offices, have to breathe. Nevertheless, the Houses of Parliament are at times assailed by foul smells which will be found to arise from the man-sized sewers of putrid deposits which are not under the jurisdiction of Dr. Percy. The remedy will be found to be in the small self-cleansing pipe sewers which we had provided for the Houses of Parliament, but which by default were superseded by the larger man-sized sewers. These not only convey foul smells into the public offices, but give access to dynamiters and traitors, against whom Sir Henry de la Beche, with myself, were charged by the Lord Chamberlain to take precautions when Her Majesty went to Parliament. This we did by sentinels in the sewers underneath for the occasion.

The legislative remedy will, I apprehend, be in the compliance with the increasing demand for the consolidation of scattered functions of sanitation, and the creation of a Department of Health, under a Minister of Public Health, of which department a sub-department on ventilation with specialists would be charged with the collection of all the best and the most recent experiences for information and guidance of the specialists and the officers of local authorities.

Meantime, we must get on how we can provisionally, and by isolated effort, to which the experiences cited and those in progress may be subservient. Sanitary officers of the Indian Service approve of the principles I have stated, and consider that their application there is most pressing, especially for the hospitals.

Some new ventilators were displayed at the Inventions Exhibition, which appeared to be of great promise. I am informed that some of them have been introduced, and are in action for the ventilation of public edifices and schools in London. I propose to ascertain and state the results obtained.

I expect a contribution of information from Dr. Percy Frankland on examinations of the state and movement of the air, its temperature, and the presence of ozone at the top of St. Paul's Cathedral, as compared with the condition of the air in the adjacent streets. I expect similar investigations will be made at the Cathedral of York.

And now to advert further to the remedies, the preventives of these more specially common conditions.

These conditions are, at home as well as abroad, super-saturation of the land and stagnation of the super-saturated water, and the preventives are thorough land drainage, as I have elsewhere shown in a special treatise or minutes of information on the subject. The removal of the super-saturation elevates temperature and removes fogs and the insect life that germinates in conditions of stagnation, and yet regulates the hygroscopticity of the soil or the due moisture requisite for the advancement of agricultural production. The measures prepared for the thorough drainage of the land surrounding London, as well as the interior site of the houses, would have removed the main sources of its fogs, and would have had the effect of raising all the houses one storey higher, and have made them, as it were, second-storey flats. From a medical officer of France I received information of a case of a very efficient application of sanitary science for the removal of the lethal conditions of a site which it was held to be necessary to occupy for strategical purposes. The military death-rate was higher than the worst of ours under the old merely curative service of India, during which upwards of ninety per thousand and three sets of forces had been decimated, as also three sets of colonists, amongst whom the death-rates of the children exceeded the birth-rates. The place fell into the hands of a Sanitary Engineer, who drained the site extensively and thoroughly. The sanitary effect was the reduction of the military death-rate to twelve in a thousand, whilst the death-rate of the French army that occupied Rome was fifteen in a thousand, and the birth-rate of the children of the civil population raised high above the death-rate; thus a crop of children was raised as healthy as any of the children of the rural districts of France. But one marked result of the removal by the land drainage of the conditions of stagnation was the removal of the plague of the mosquitoes, which have rendered life there a constant suffering. I considered the example so important for India that I obtained the leave of Lord Ripon, then Minister of War, to have a special examination made of it, and a commission was sent there comprising Mr. Robert Ellis, who

had been chief of the Sanitary Commission of Madras, and had accomplished some important sanitary achievements in the suppression of cholera, and was afterwards member of the Indian Council at home, and General Ewart, of the Engineers, and Dr. John Sutherland, since acting member of the Army Sanitary Commission, which also advises on Indian sanitary work. They reported decisively that the example was applicable to the greater part of India.* I may add that it is applicable to the greater part of our most prosperous colonies, where, from ignorance and neglect of the sanitation of sites occupied, of the children born, and whom it is most important to preserve, more than one-half are in their graves by their fifth year. But action has yet to be taken on the conclusion in India. In the colonies, it is to be submitted that for them, as well as for home service, no provision of a commensurate special sanitary service, to be hereafter specified, will be required.

It is in evidence that of the land that would be benefited in England by drainage, there is now, after some forty years of exposition and legislative provisions for it, only a small proportion yet drained, although, when executed under the supervision of competent official specialists, as a rule, it repays the expense in seven years or by a return of 14 per cent. Legislative provisions are required for the removal of obstructions to outfalls, and for protection against the wastefulness of ignorance. But at the last the relief by general land drainage must be expected to occupy a considerable period. Meanwhile, protection is needed from the lower couches of air, especially from such air as the street air, polluted and extended cesspools, of a thousand miles of ill-constructed sewers of deposit; from such stagnant sewer and drain-polluted air as that which pervades the very Government offices about Downing street, and restricts the working ability there—such a quality of air that no surgeon who knew his duty, if he could not remove the case to a pure suburban air, would conduct a serious operation without washing the air by Lister's process.

As to the different degrees of purity of air at different altitudes, important experiments are being carried on at Paris by Messieurs Miguel and Davey. So far as they have been carried, they are entirely corroborative of the general results I have stated. Thus, at the lantern of the Pantheon, which is about 310 feet high, the air is found to be twenty times more pure than the street air in the vicinity of the Rue Rivoli. In high altitudes of 2,000 metres, no microbes have been found, whilst in the open part of Mont Louis at Paris, 7,000 were found in the cubic metre, but in the street of the great Rue Rivoli there were 35,000 in the cubic metre.

The qualities of these microbes are, doubtless, important subjects for examination, but these examinations ought not to delay the application of measures of sanitation. The question of the germination of insects found in the human body may be subjects of important scientific research, but those researches I have felt ought not to delay direct applications of soap and water.

In the minutes of information as to the drainage of land and on the distribution of sewage, published in 1850, I stated the sanitary objections even to the distribution of plain water by the old method of submersion of water meadows as productive of marsh surfaces which gave rheumatism and ague to men and the rot in sheep, and as being generally very expensive to construct, and as being wasteful of water. Since then I have received from India accounts of intense evils attendant on this method of distribution; and that on a very extensive line where it was adopted. The course of the irrigations of one extensive district was denoted by the size of the spleen of the people working on them or living near them. Dr. Robert Pringle, the Sanitary Commissioner for the North-Western Provinces and Oudh, in his report for 1880, displays at great length the excessive mortality attendant on this method of irrigation, creating super-saturated, water-logged, marshy and malarious surfaces, which are made lines of fever

* The Emperor Louis Napoleon went to Algeria to examine in person whether anything could be done to stay the waste then going on at the rate of some three millions a year, without any apparent return for it. But he failed to discover the chief remedy. In his view colonisation by the French was a failure. He did not dare look to the English; but he at that time recommended that the Germans should be invited to it. But the land was not fit for intelligent Frenchmen, or other fitting colonists as the example set proved that it might be made. Mr. Robert Ellis assured me that, under our Indian administration, Algeria would be held by less than one-third of the force with which it was held by the military authorities of France. The Emperor had at my suggestion directed some important trial works to be made, to ascertain the productive power of the sewage of Paris, and when he was at Brighton I took the opportunity of having some conversation with him about the example set in Algeria, for I was convinced that if the money spent by the military authorities in fortifying the towns of that province had been expended in their sanitation, and in the sanitation of the adjacent fields for agriculture, as displayed sufficiently in that example, a force of colonists, French as well as others, might have been got that would have been stronger, by volunteer force, than all the fortifications on which money had been wasted, and that might have restored the province to its ancient productiveness as the chief granary of Europe. But I found that his Majesty had never before heard of the case. My conviction was that the jealousy of militarism, and possibly of the curative service—a jealousy such as has hitherto prevailed here in official quarters—had prevailed in keeping out of sight the example of a new service, requiring position and having claims to positions and distinctions, eclipsing the old ones invidiously. In India the sanitary service has reduced the Army death-rate from 69 to 10·84 per 1,000. More lives are now saved in one year than were lost by the sword during the ten years of the last decade. In the West Indies greater reductions have been effected. I proposed recently that medals of distinction should be given there for dangers successfully encountered, with as great dangers as in battle, for greater savings of life than are encountered in sacrificing life. But the proposal was refused, evidently in the common feeling of jealousy towards the new service, on which the decision of Parliament is to be sought. At a meeting of the Society of Arts, at which I was called upon to preside, General McMurdo read a paper on the expediency of colonisation by retired soldiers in India. The application of the sewage principles would form part of the practical means of effecting it for them and for others. A recent Commission on the condition of agriculture in Italy recommends as of the foremost remedies for its relief, "*les mesures nécessaires pour assurer la salubrité dans les campagnes et de l'assainissement des sol marécageux*," as I have done on such authority as that of the late Mr. Bence Jones for Ireland.

attacks and excessive mortality. "As to the military stations," he says, "I can speak with the clearest evidence regarding the military cantonments of Meerut and the North-Western Provinces of India, my personal knowledge of which stations has extended continuously over twenty years. In this military station, the terrible outbreaks of fever are now considerably explained. There are barracks in this cantonment on the level of the ground, and many others but little raised above it; and, as if this was not enough, there is an appliance called the thermantidote, which forces in air from the outside into the barracks from about from one to three feet above the ground, over the faces of the men resting on their beds in the heat of the day, when the sun's rays are beating on a water-logged soil nothing like so free from surface impurities as it might be. Little wonder, therefore, that fever is prevalent among these men, and in some instances cholera also. And this has gone on for twenty years to my certain knowledge. Again, the pattern of double-storied barracks in this same cantonment. A considerable source of dysentery and diarrhoea, the result of biliary derangement, due to chills at night. General Sir W. Montagu McMurdo objected to the barracks of the 'sanatorium' as being wrong in principle and too costly. "Perched, as a rule, on the comb of some ridge, they are exposed at elevations of 7,000 feet to the cold winds from the snows, while the solid walls establish the means for thorough draughts between windows and doors, up staircases, and along passages, resulting, as I have observed, in accession of colds and chest complaints among the invalids fresh from the plains. If the thermantidote drew air from the upper couches of the atmosphere" (and it might be added warmed it), "which could be easily arranged, as you describe in your paper, I am confident that benefit would result at once; and the Government have at Meerut, as I know, a considerable number of barracks, to begin the experiment at once, and that before the fever season begins, and you are at liberty to quote my name in support of this." He adds that "in his district of four millions, the fever carried off 400,000 in one year. Only suppose this had been the mortality in India with its four hundred millions!"

In 1881 I received a plan by my friend Walter M. Ducat, Major of the Royal Engineers, for the sewerage of the city and cantonment of Poona. The plan was sound in its main principles, and was supported by Mr. John Lumsden, the Sanitary Commissioner to the Government of Bombay. The plan appeared to me to be of the highest importance to get forward as a first example of the full application of sanitary science, which has been effectual with the military science to the relief of depressed civil populations in India. But on inquiry for it, I learn that nothing has been done with it, or is likely to be yet. Delayed for financial reasons.

On this, it is to be observed, in respect to effectual sanitary works, that to delay them on the ground of expense is to economise the means of public economy on the largest scale. The saving by the reduced death-rate in the army during the last decade, at only £100 for each soldier saved, has been upwards of six millions sterling. When my son was in India thirteen years since, as a Lieutenant of the Royal Engineers, he was impressed by the financial difficulty of obtaining public money for sanitary works. He observed that the Hindoos hoard their savings in plate and jewels as well as in coin. He conceived a plan of circulating annuities for small amounts, bearing compound interest, which would be highly convenient to them, as bearing a continued interest which they lost upon their hoards. Bentham had an idea of a "circulating annuity," but my son's plan was worked out independently, and has practical improvements over that of Bentham. But he was then only a Lieutenant, and did not succeed in getting it forward. He has, however, recently proposed it for Malta, for raising the expense of sanitary works which he is carrying out there, where the plan meets with the support of Sir Lintorn Simmons, the Governor. At home we had got on fairly in my time without it, by means of distributed charges levied at private improvement works.

No. 98.

Copy, with copy of the memorandum referred to, forwarded to the Military Department for information.

(Signed) F. C. DAUKES,
Under Secy. to the Govt. of India.

No. 28-C.

Sanitary.

Copy of the foregoing, and of its enclosure, forwarded to the Secretary to the Government of Madras, Military Department.

(By Order.)

SIMLA,
8th April 1886.

(Signed) W. J. B. BIRD,
Asst. Secy. to the Govt. of India.

No. 202.

ORDER THEREON, 12th May 1886, No. 2919.

Communicated to His Excellency the Commander-in-Chief, the Public Works Department, and the Surgeon-General, Her Majesty's Forces, Madras.

(True Extract.)

(Signed) A. KENNEY-HERBERT, Lt.-Col.,
Secretary to Government.

To the Quarter Master General.
" Adjutant-General.
" Public Works Department.
" Surgeon-General, Her Majesty's Forces, Madras.

Exd. E. C. Shunker.

Govt. of (1886) Madras.

MILITARY.

No. 1283 Wd/21 May 1886

Communicated to
Superintending Engineers
for information

12/5/86

To
THE QUARTER MASTER GENERAL,
&c., &c., &c.

Dated May 12th.

Issued

Recd.

Encl.

G.O., 12th May 1886, No. 2919.

B. No. 1283 Wd/21 May 1886

MAY.
Nos. 201-202.

Sanitary.

Memorandum received from Her Majesty's Government entitled "Ventilation with air from superior layers in place of inferior layers" by Mr. E. Chadwick, c.b., communicated to the Departments concerned.

With orders

GOVERNMENT OF MADRAS.

MILITARY DEPARTMENT.

12 May 1886, No. 2919

Sanitary.

Read the following paper:—

No. From F. C. DAUKES, Esq., C.S., Under Secretary to the Government of India, Home Department, to the Governments of Madras, Bombay, Bengal, North-Western Provinces and Oudh, and the Punjab; Chief Commissioners of the Central Provinces, British Burma, Assam, Coorg and Resident at Hyderabad; dated Calcutta, the 27th March 1886, No. 88-97—3.

Sanitary.

I am directed to forward, for the your information of H.E. the Governor in Council and for communication to the officers of the local Sanitary Department, a copy of a memorandum, which has been received from Her Majesty's Secretary of State, entitled "Ventilation with air from superior layers in place of inferior layers" by Mr. E. Chadwick, c.b., an eminent English sanitary authority.

VENTILATION WITH AIR FROM SUPERIOR LAYERS IN PLACE OF
INFERIOR LAYERS.

By Edwin Chadwick, c.b.

In sanitary inquiries my attention was early directed to instances of layers or strata of air of malarious influence, such as this: A medical officer, pointing to a mist spread like a sheet over a valley, said, "That sheet just covers the bulk of my patients; out of it or above it, I have nothing scarcely but midwifery cases and accidents." I have had instances of children whose heads were above a visible mist escaping attack, whilst the smaller children covered by the mist suffered from them: examples of the occupiers of the cellars, and the lower stages in towns suffering from cholera and other epidemic visitations, whilst those living in the upper flats or highest stories entirely escaped from them, except in the attics, for which there was special reason; cases of experiences in India, where men could not travel in safety at night across valleys, whilst men on elephants, being above the malarious layer, could do so; of people raising their habitations on stilts, as is universally done in Burma, to escape the mephitic influences of which they have had experience.

Mr. Glaisher, the aeronaut, writes to me:—"When in the ear of a balloon I have been struck with the definite boundary of mists at times when there has been but little generally, and I found afterwards that the mists were located over marshes, or clay soil, when gravelly soil was free. The ventilation of the Underground Railway could be effectually carried out by your suggestion."

The general effect of land drainage has been to reduce mists, and in some instances to remove them entirely. In such instances it has reduced or removed the plague of midges in England. In one instance in Algeria, of which I was informed, the drainage of a district, and its close cultivation, entirely removed the plague of mosquitoes which had rendered it almost uninhabitable. In the Fen districts of Lincolnshire, the land drainage has reduced mists, and so reduced ague that ounces of bark are not now used where pounds were used formerly. It is for zoologists or microscopic observers to show on what these animalcules subsist where there are no human or animal subjects to prey upon, and what is the superficial extent of their feeding ground. On the occasion of choleraic visitations, extraordinary developments of insect life were in some instances observed, generally in low-lying layers, but they passed without any examination of which I am aware. I point out these incidents for the observation of naturalists, and the favor of information from them.

From Highgate Hill I have observed mists, spread over the Metropolis like a blanket, and the upper dome of St. Paul's Cathedral appearing clear and bright above it like a spike through the blanket. I have ascended that dome and found there a clear, freshening breeze, as good in sensation as any on the Surrey hills; whilst the air beneath in the adjacent streets was comparatively stagnant and unrefreshing.

Dr. Gordon Hardy writes:—"Riding on the 'Maidan' in Calcutta, I have often had sight only of riders' heads above a level of dense fog."

A friend, a great traveller, found out that mosquitoes lived and fed exclusively in the animalised gases diffused amongst the lower layers of air. He suffered intensely from the bite of these insects, and to escape them when he came near the coast, he made his bed aloft on the cross-trees of the mainmast; and when he went on shore, he astonished the natives by seeking for some steeple, where he could make his bed.

Colonel Graham, of Chiswick, states to me:—"In 1865 I was in charge of the police in the Deyra Doon district of the North-West Provinces, India. The district is covered with dense forest, and is unhealthy during the rainy season from June to September, *i.e.*, the forest portion of it. My men, if they slept on or near the ground, died off in numbers from malarious fever; so sleeping places were constructed for them in the trees about twenty feet from the ground, and the result was that the death-rate decreased enormously. Once, when out tiger shooting in 1868, in the forest at the foot of the Himalayas, we were overtaken in May by a very unusual event, a heavy fall of rain, which brought out the malaria from the mass of rank vegetation. We tried to get out in one march, but could not manage it, and had to sleep in the jungle in our tents. Three out of the four of us got severe jungle fever, from the effects of which I had to come home, and several of our camp followers died of it. Could we all have slept on trees, I believe not one of us would have got it. Another of my experiences in India may interest you. In 1867, when commanding the Mairwara Battalion in Rajputana, a severe epidemic of cholera broke out, and I lost a number of men. The air, as it often is during such epidemics, was very hot and close, and I had the whole regiment out morning and evening and fired volleys. Whether it was that the firing brought down a fresh and healthy current of air in the same way that firing cannon brings down rain, or that the smoke, composed as it was of sulphur, among other ingredients, had a sanitary effect on the men, situated as they were close by, I cannot say, but the result was certainly curious, as the cholera at once decreased and soon died out."

Dr. F. J. Mouat, of the Local Government Board, states to me:—"My observation of the probable height of the mists in Lower Bengal is confined to the Sunderbunds, where on two occasions, at periods separated by many months, I went up the mast of a river steamer, and ascertained that the limit of the mist was absolutely uniform as far as the eye could reach."

"I had no means of determining the exact height, but it could not have been less than 20 feet. Until the fogs were dispersed by the sun, sometimes as late as 11 A.M. in the cold weather, the steamer remained at anchor."

"As respects the care taken of the cattle in the Terai or low land at the foot of the hills in Eastern Bengal, the men, after shutting up the cattle in the large sheds provided, mounted to small sheltered platforms high up in the trees to sleep. This was to avoid the tigers which then abounded in those localities; and I was informed by natives acquainted with the localities that they enjoyed a remarkable immunity from the deadly fevers of those places."

The late Mr. Joseph Hume, M.P., who began his career as an Army Surgeon in India, told me that he ascertained in some districts that the low malarious gases, presumably heavy, were close to the ground, and that he found safety to the men while bivouacking in having their heads carefully raised eighteen inches above the surface.

In Italy it has been observed that sickness is most prevalent on the ground floors of the tall houses, constructed in flats, while those above are distinctly superior in health. In the late visitation of cholera at Naples, it was observed that the most severe attacks were very distinctly within the accustomed low-lying mists prevalent in the depressed districts.

I have been informed that in the epidemic visitations upon Calcutta the attacks have been upon the occupants of the ground floors, whilst those of the upper floors have had almost entire exemption.

Here in London, even in the model dwellings, instances have been observed of attacks of sickness upon the occupiers of the ground floors, from which the occupiers of the upper flats were exempt.

In hot and dry climates malaria appears to have but little influence under the direct rays of the sun. A plant collector for a horticultural firm found that he could traverse the most pestilential spots in Sierra Leone, provided he did not keep out after sunset, when he immediately took refuge in a hut prepared for him, with a large fire, which he kept alight during the night. He found that the natives did the same, and kept the fires in, as they said, to keep the devils out.

I believe that provision for the ventilation of public edifices, hospitals and schools may be obtained by mechanical means, such as I will now submit for consideration. On the repeated sight of the great blanket of fog spread over the Metropolis, I discussed the subject with Dr. Neil Arnott, who was a man of distinguished mechanical ability, and our conclusion then was that we might form a pure air company, which would engage to draw the air from a suitable height above the common layers, and distribute it into houses by engine power, or as gas is distributed, and do it with a profit, at a very low rate, or for some few shillings a year give even a better air than people generally obtain in suburban residences.

I have visited hospitals in Paris where the mechanical methods of *internal* ventilation are, in my view, excellent and superior, but where all draw in the air from the lower layers of the

outside street air. It is only recently, in one instance, of which I have not got the particulars, that the expedient of drawing in a superior air from a height has been adopted or thought of. In England I have known of hospitals very well ventilated—internally, mechanically—which have drawn their external air from lower couches that were positively very bad, and the more the wards were ventilated, the worse they often were. Indeed, it is sometimes proposed as a principle, as against that of extraction, that ventilation is best effected by "currents of fresh air brought in by open windows placed in opposite sides of the wards." But this so-called "fresh air" is the common street air, really foul air polluted by street emanations from sewers and cesspools requiring washings before operations can be safely performed. It is well known that surgical operations cannot be performed with safety in town air (unless it is washed) that may be performed with increased chances of favorable results in a good suburban air.

In Paris, when I visited the hospitals, the two systems of ventilation were in competition—one of "propulsion," or driving in the air; the other of "aspiration," or of drawing it out by suction. It appeared that the practice of propulsion drove the air in heaps, leaving corners stagnant; whilst the method of aspiration, or suction, operated perfectly in removing the air nearest to them from the points of vitiation in the time required, and in introducing really fresh air from the points farthest from vitiation and at the temperature required, and also in maintaining passages and cabinets at a temperature equal to that of the interior rooms. Notwithstanding the fault of ventilating with the generally cesspool-tainted and impure street air, the effect of the system of "aspiration" appeared to be in advance of at least one-fourth of the common methods of hospital ventilation.

This principle of "aspiration" appears to me to be peculiarly adapted to drawing in the air from the superior layer, obtained from two, three, four or five hundred feet, or whatever height it may be desired.

It is peculiarly applicable to India and to Southern cities generally for securing refreshing sleep free from the plague of mosquitoes. This principle would bring in air free from the insects, and carry those in the building away from it. The engine power required for the service would cost less than that for ventilation by the punkahs.

The system of extraction, as managed by Leon Duvoir le Blance, allowed the most complete adaptation to requirements. At its outset he asked the medical authorities of the hospital to be ventilated, that of La Riboisiere:—"At what temperature do you require the air to be kept?—At 60 deg. How often do you require it to be changed?—Once every hour, night as well as day. In what direction do you require it to be removed?—Downwards, between each bed. All this was done completely by passing the vitiated air tubes through a hot-water tank on the roof, by which the air in them was heated and a steady draught created. But it appears to be questionable whether force-pumps are not equally eligible. Having been pressed by other questions, I have not been in a position to obtain by observation and experiments the precise results as I would now seek. I obtained a promise from my late lamented friend, Dr. Angus Smith, who had been the foremost in analysing air, that he would make the experiments I suggested, of sending up a balloon with a self-registering thermometer to ascertain the temperature at different heights, and also a bottle filled with water, with a self-closing tap capable of being opened from below, so as to bring down specimens of the air to be tested. Hence for the east or anywhere, it may be stated that we are not dependent on the superior layers of air for the temperature. It may be given to it below in various ways. I was assured that at La Riboisiere, the contract to keep the temperature night and day at sixty was duly performed. When it was below that temperature, it was warmed by being led over warmed surfaces on admission, and when it was above that temperature, it was cooled by being passed over surfaces cooled down by evaporation. I was assured that the practicability of doing this may be considered as settled. All this was done at a less expense than that of warming edifices by the ordinary method; and all this, it is suggested, can be done for sleeping-rooms in India, and for offices; but the most convenient power for working the system of "aspiration" would, I expect, be by hot-air engines, which may be had of one, two or three horse power, and go on working for a long time, with little care. The expense was ten centimes, or a penny per diem, for the warming and removal of sixty metres per head per diem, coal being then 40s. per ton. Small steam-engines would be available for larger buildings. If the principle be approved, plans for its application according to conditions may be got out.

In the construction of towers for the obtaining of pure air, it appeared to me undesirable that the common absorbent brick should be used. Constructions of non-absorbent concrete appeared to me to be the most eligible, and that constructions with large hexagonal pots would have considerable advantages. The requisite heights would have to be ascertained experimentally. The impure layers of air might often be avoided by inconsiderable elevations. Experimentation and observations on the points suggested would be of the greatest importance in the tropical districts, where rest and refreshing sleep are difficult to be got, and where even existence is a torment.

In some experiments made on the continent for ascertaining the presence of ozone, the ozone was obtained at the top of a cathedral, whilst none was to be got at the base.

The state of sanitary administration in our Metropolis has been displayed in the new Law Courts, where on the occurrence of crowded attendance, the proceedings have been interrupted,

and the judge, the jury and the attendants have been obliged to go out to obtain relief from oppression. At the Palais de Justice at Paris, relief is immediately given on any occasion of increased attendance by the increased action of the pump.

Large rooms, large enclosed spaces, not duly ventilated, are, as experienced at the new Government offices, only reservoirs of aerial impurity. Had the science of ventilation, as expounded by my correspondent, the late General Morin, in his work on ventilation, been adopted, double the number of officers might have been accommodated well, and with increased working ability, in those edifices on which three millions of money have been expended.

I am aware that it was a view of Dr. Reid to draw purer air than the street air from the Clock tower. But it was observed that there were adjacent tall chimneys, which discharged currents from the products of their manufactures, which might, if it came in the direction of the Houses of Parliament, have been drawn in. Possibly an elevation a hundred feet higher might have surmounted this risk, but it would have offended architectural proprieties. As it is, the Parliament houses are ventilated with street air sieved and washed, under the direction of Dr. Percy, in a manner which members have informed me they consider to be satisfactory. But the sievings of that street air, as detained in the cotton sieves, display what the outside population, including the population of the Government offices, have to breathe. Nevertheless, the Houses of Parliament are at times assailed by foul smells which will be found to arise from the man-sized sewers of putrid deposits which are not under the jurisdiction of Dr. Percy. The remedy will be found to be in the small self-cleansing pipe sewers which we had provided for the Houses of Parliament, but which by default were superseded by the larger man-sized sewers. These not only convey foul smells into the public offices, but give access to dynamiters and traitors, against whom Sir Henry de la Beche, with myself, were charged by the Lord Chamberlain to take precautions when Her Majesty went to Parliament. This we did by sentinels in the sewers underneath for the occasion.

The legislative remedy will, I apprehend, be in the compliance with the increasing demand for the consolidation of scattered functions of sanitation, and the creation of a Department of Health, under a Minister of Public Health, of which department a sub-department on ventilation with specialists would be charged with the collection of all the best and the most recent experiences for information and guidance of the specialists and the officers of local authorities.

Meantime, we must get on how we can provisionally, and by isolated effort, to which the experiences cited and those in progress may be subservient. Sanitary officers of the Indian Service approve of the principles I have stated, and consider that their application there is most pressing, especially for the hospitals.

Some new ventilators were displayed at the Inventions Exhibition, which appeared to be of great promise. I am informed that some of them have been introduced, and are in action for the ventilation of public edifices and schools in London. I propose to ascertain and state the results obtained.

I expect a contribution of information from Dr. Percy Frankland on examinations of the state and movement of the air, its temperature, and the presence of ozone at the top of St. Paul's Cathedral, as compared with the condition of the air in the adjacent streets. I expect similar investigations will be made at the Cathedral of York.

And now to advert further to the remedies, the preventives of these more specially common conditions.

These conditions are, at home as well as abroad, super-saturation of the land and stagnation of the super-saturated water, and the preventives are thorough land drainage, as I have elsewhere shown in a special treatise or minutes of information on the subject. The removal of the super-saturation elevates temperature and removes fogs and the insect life that germinates in conditions of stagnation, and yet regulates the hygroscopicity of the soil or the due moisture requisite for the advancement of agricultural production. The measures prepared for the thorough drainage of the land surrounding London, as well as the interior site of the houses, would have removed the main sources of its fogs, and would have had the effect of raising all the houses one storey higher, and have made them, as it were, second-storey flats. From a medical officer of France I received information of a case of a very efficient application of sanitary science for the removal of the lethal conditions of a site which it was held to be necessary to occupy for strategical purposes. The military death-rate was higher than the worst of ours under the old merely curative service of India, during which upwards of ninety per thousand and three sets of forces had been decimated, as also three sets of colonists, amongst whom the death-rates of the children exceeded the birth-rates. The place fell into the hands of a Sanitary Engineer, who drained the site extensively and thoroughly. The sanitary effect was the reduction of the military death-rate to twelve in a thousand, whilst the death-rate of the French army that occupied Rome was fifteen in a thousand, and the birth-rate of the children of the civil population raised high above the death-rate; thus a crop of children was raised as healthy as any of the children of the rural districts of France. But one marked result of the removal by the land drainage of the conditions of stagnation was the removal of the plague of the mosquitoes, which have rendered life there a constant suffering. I considered the example so important for India that I obtained the leave of Lord Ripon, then Minister of War, to have a special examination made of it, and a commission was sent there comprising Mr. Robert Ellis, who

had been chief of the Sanitary Commission of Madras, and had accomplished some important sanitary achievements in the suppression of cholera, and was afterwards member of the Indian Council at home, and General Ewart, of the Engineers, and Dr. John Sutherland, since acting member of the Army Sanitary Commission, which also advises on Indian sanitary work. They reported decisively that the example was applicable to the greater part of India.* I may add that it is applicable to the greater part of our most prosperous colonies, where, from ignorance and neglect of the sanitation of sites occupied, of the children born, and whom it is most important to preserve, more than one-half are in their graves by their fifth year. But action has yet to be taken on the conclusion in India. In the colonies, it is to be submitted that for them, as well as for home service, no provision of a commensurate special sanitary service, to be hereafter specified, will be required.

It is in evidence that of the land that would be benefited in England by drainage, there is now, after some forty years of exposition and legislative provisions for it, only a small proportion yet drained, although, when executed under the supervision of competent official specialists, as a rule, it repays the expense in seven years or by a return of 14 per cent. Legislative provisions are required for the removal of obstructions to outfalls, and for protection against the wastefulness of ignorance. But at the last the relief by general land drainage must be expected to occupy a considerable period. Meanwhile, protection is needed from the lower couches of air, especially from such air as the street air, polluted and extended cesspools, of a thousand miles of ill-constructed sewers of deposit; from such stagnant sewer and drain-polluted air as that which pervades the very Government offices about Downing street, and restricts the working ability there—such a quality of air that no surgeon who knew his duty, if he could not remove the case to a pure suburban air, would conduct a serious operation without washing the air by Lister's process.

As to the different degrees of purity of air at different altitudes, important experiments are being carried on at Paris by Messieurs Miguel and Davey. So far as they have been carried, they are entirely corroborative of the general results I have stated. Thus, at the lantern of the Pantheon, which is about 310 feet high, the air is found to be twenty times more pure than the street air in the vicinity of the Rue Rivoli. In high altitudes of 2,000 metres, no microbes have been found, whilst in the open part of Mont Louis at Paris, 7,000 were found in the cubic metre, but in the street of the great Rue Rivoli there were 35,000 in the cubic metre.

The qualities of these microbes are, doubtless, important subjects for examination, but these examinations ought not to delay the application of measures of sanitation. The question of the germination of insects found in the human body may be subjects of important scientific research, but those researches I have felt ought not to delay direct applications of soap and water.

In the minutes of information as to the drainage of land and on the distribution of sewage, published in 1850, I stated the sanitary objections even to the distribution of plain water by the old method of submersion of water meadows as productive of marsh surfaces which gave rheumatism and ague to men and the rot in sheep, and as being generally very expensive to construct, and as being wasteful of water. Since then I have received from India accounts of intense evils attendant on this method of distribution; and that on a very extensive line where it was adopted. The course of the irrigations of one extensive district was denoted by the size of the spleen of the people working on them or living near them. Dr. Robert Pringle, the Sanitary Commissioner for the North-Western Provinces and Oudh, in his report for 1880, displays at great length the excessive mortality attendant on this method of irrigation, creating super-saturated, water-logged, marshy and malarious surfaces, which are made lines of fever

* The Emperor Louis Napoleon went to Algeria to examine in person whether anything could be done to stay the waste then going on at the rate of some three millions a year, without any apparent return for it. But he failed to discover the chief remedy. In his view colonisation by the French was a failure. He did not dare look to the English; but he at that time recommended that the Germans should be invited to it. But the land was not fit for intelligent Frenchmen, or other fitting colonists as the example set proved that it might be made. Mr. Robert Ellis assured me that, under our Indian administration, Algeria would be held by less than one-third of the force with which it was held by the military authorities of France. The Emperor had at my suggestion directed some important trial works to be made, to ascertain the productive power of the sewage of Paris, and when he was at Brighton I took the opportunity of having some conversation with him about the example set in Algeria, for I was convinced that if the money spent by the military authorities in fortifying the towns of that province had been expended in their sanitation, and in the sanitation of the adjacent fields for agriculture, as displayed sufficiently in that example, a force of colonists, French as well as others, might have been got that would have been stronger, by volunteer force, than all the fortifications on which money had been wasted, and that might have restored the province to its ancient productiveness as the chief granary of Europe. But I found that his Majesty had never before heard of the case. My conviction was that the jealousy of militarism, and possibly of the curative service—a jealousy such as has hitherto prevailed here in official quarters—had prevailed in and kept out of sight the example of a new service, requiring position and having claims to positions and distinctions, eclipsing the old ones invidiously. In India the sanitary service has reduced the Army death-rate from 60 to 10.84 per 1,000. More lives are now saved in one year than were lost by the sword during the ten years of the last decade. In the West Indies greater reductions have been effected. I proposed recently that medals of distinction should be given there for dangers successfully encountered, with as great dangers as in battle, for greater savings of life than are encountered in sacrificing life. But the proposal was refused, evidently in the common feeling of jealousy towards the new service, on the decision of Parliament is to be sought. At a meeting of the Society of Arts, at which I was called upon to preside, General McMurdo read a paper on the expediency of colonisation by retired soldiers in India. The application of the sewage principles would form part of the practical means of effecting it for them and for others. A recent Commission on the condition of agriculture in Italy recommends as of the foremost remedies for its relief, "*Les mesures nécessaires pour assurer la salubrité dans les campagnes et de l'assainissement des sol marécageux*," as I have done on such authority as that of the late Mr. Bence Jones for Ireland.

attacks and excessive mortality. "As to the military stations," he says, "I can speak with the clearest evidence regarding the military cantonments of Meerut and the North-Western Provinces of India, my personal knowledge of which stations has extended continuously over twenty years. In this military station, the terrible outbreaks of fever are now considerably explained. There are barracks in this cantonment on the level of the ground, and many others but little raised above it; and, as if this was not enough, there is an appliance called the thermantidote, which forces in air from the outside into the barracks from about from one to three feet above the ground, over the faces of the men resting on their beds in the heat of the day, when the sun's rays are beating on a water-logged soil nothing like so free from surface impurities as it might be. Little wonder, therefore, that fever is prevalent among these men, and in some instances cholera also. And this has gone on for twenty years to my certain knowledge. Again, the pattern of double-storied barracks in this same cantonment. A considerable source of dysentery and diarrhoea, the result of biliary derangement, due to chills at night. General Sir W. Montagu McMurdo objected to the barracks of the 'sanatorium' as being wrong in principle and too costly. "Perched, as a rule, on the comb of some ridge, they are exposed at elevations of 7,000 feet to the cold winds from the snows, while the solid walls establish the means for thorough draughts between windows and doors, up staircases, and along passages, resulting, as I have observed, in accession of colds and chest complaints among the invalids fresh from the plains. If the thermantidote drew air from the upper couches of the atmosphere" (and it might be added warmed it), "which could be easily arranged, as you describe in your paper, I am confident that benefit would result at once; and the Government have at Meerut, as I know, a considerable number of barracks, to begin the experiment at once, and that before the fever season begins, and you are at liberty to quote my name in support of this." He adds that "in his district of four millions, the fever carried off 400,000 in one year. Only suppose this had been the mortality in India with its four hundred millions!"

In 1881 I received a plan by my friend Walter M. Ducat, Major of the Royal Engineers, for the sewerage of the city and cantonment of Poona. The plan was sound in its main principles, and was supported by Mr. John Lumsden, the Sanitary Commissioner to the Government of Bombay. The plan appeared to me to be of the highest importance to get forward as a first example of the full application of sanitary science, which has been effectual with the military science to the relief of depressed civil populations in India. But on inquiry for it, I learn that nothing has been done with it, or is likely to be yet. Delayed for financial reasons.

On this, it is to be observed, in respect to effectual sanitary works, that to delay them on the ground of expense is to economise the means of public economy on the largest scale. The saving by the reduced death-rate in the army during the last decade, at only £100 for each soldier saved, has been upwards of six millions sterling. When my son was in India thirteen years since, as a Lieutenant of the Royal Engineers, he was impressed by the financial difficulty of obtaining public money for sanitary works. He observed that the Hindoos hoard their savings in plate and jewels as well as in coin. He conceived a plan of circulating annuities for small amounts, bearing compound interest, which would be highly convenient to them, as bearing a continued interest which they lost upon their hoards. Bentham had an idea of a "circulating annuity," but my son's plan was worked out independently, and has practical improvements over that of Bentham. But he was then only a Lieutenant, and did not succeed in getting it forward. He has, however, recently proposed it for Malta, for raising the expense of sanitary works which he is carrying out there, where the plan meets with the support of Sir Lintorn Simmons, the Governor. At home we had got on fairly in my time without it, by means of distributed charges levied at private improvement works.

No. 98.

Copy, with copy of the memorandum referred to, forwarded to the Military Department for information.

(Signed) F. C. DAUKES,
Under Secy. to the Govt. of India.

No. 28-C.

Sanitary.

Copy of the foregoing, and of its enclosure, forwarded to the Secretary to the Government of Madras, Military Department.

(By Order.)

SIMLA,
8th April 1886.

(Signed) W. J. B. BIRD,
Asst. Secy. to the Govt. of India.

No. ORDER THEREON, 12 May 1886, No. 2919

Communicated to His Excellency the Commander-in-Chief, the Public Works Department, and the Surgeon-General, Her Majesty's Forces, Madras.

(True Extract.)

Alfred Herbert Lt.-Col.,
Secretary to Government.

To the Quarter Master General.

" Adjutant-General.

" Public Works Department.

" Surgeon-General, Her Majesty's Forces, Madras.

Exd. E. C. Shunker.

Prd 3716 ✓

Gobt. of 1886 Madras.

MILITARY.

No. 12 83W d/21st May 1886

Communicated
to Supg. Engineers for
information.

Ul
15.5.86

17/5/86

To
THE QUARTER MASTER GENERAL,
&c., &c., &c.



Dated May

Issued

Recd. 17/5/86

Encl.

G.O., 12th May 1886, No. 2919.

B. No. 1283W d/21 May 1886

MAY.

Nos.

Done
27/5/86

Supg. Engineer ✓
Ch. E. Ford ✓
C.A. ✓

Sanitary.

Memorandum received from Her Majesty's Government entitled "Ventilation with air from superior layers in place of inferior layers" by Mr. E. Chadwick, c.b., communicated to the Departments concerned.

2 copies to 1886
G.O. with 11/11/86