Sulphuric Utopias

A History of Maritime Fumigation

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4 Clayton and the "Defense of Europe"

With his patent granted in September 26, 1899, Clayton moved his business to New York City, where he incorporated the "Clayton Fire Extinguishing & Disinfecting Company of New York." His machine was immediately praised in *Engineering Magazine* for the ingenious ways in which temperature and oxygen supply could be controlled while the machine was running, allowing for rapid reactions and careful adjustments to a variety of scenarios.[1] Clayton's company became swiftly the sole supplier of fumigation machines to the Federal Marine Hospital Service, and his machines were introduced into the ports of Philadelphia, New York, and San Francisco.[2] From here, the Clayton machine emerged as a standard method of fumigation against plague, yellow fever, and other infectious diseases carried across the sea. Over the following years, he registered a holding company in West Virginia as "Sulphur Dioxide Fumigation and Fire Extinguishing Company" to manage his global endeavors. The company was incorporated with a capital stock of $1,000,000, which was doubled to $2,000,000 in 1901. Indicative for the astounding success of his overseas endeavors, Clayton established a second company in West Virginia, which was incorporated with an impressive capital stock of $5,000,000 in April 1900. Among the registered directors ranked the former president of the Louisiana State Board of Health, Samuel R. Olliphant. Clayton himself remained acting President of his growing global business until 1909. After 1900, he began to open a series of international branches. He founded the "Compagnie du Gaz Clayton Company of France" in Paris and the "Clayton Gas Company" of Egypt. But his most successful overseas endeavor would eventually become the "Clayton Fire Extinguishing and Ventilating Company" of London.[3]

As Krista Maglen has noted in her history of quarantine and immigration in England, "by the late nineteenth century, Britain's ports were teeming with ships from around the world. The empire's prosperity and power were at their peak, and commercial and passenger shipping reached levels never before seen."[4] Maglen calculates that by 1892 over 10,000 ships were arriving in London alone on an annual basis from overseas harbors. Through the innovative introduction of the Port Sanitary Authorities in 1872, British ports relied increasingly on "a combination of port sanitation and sanitary surveillance."[5] This so-called English System was intended to meet the needs of the increasing traffic in maritime trade, by basing quarantine and isolation not on the existence of disease at the port of origin, but rather on its direct observation by port authorities at the moment of arrival. Eventually, in 1896, the Quarantine Act was repealed in Britain, including for diseases like plague and yellow fever, for which the United Kingdom's legislation had specifically been designed. However, Maglen notes, as quarantine continued to prevail in the control of the international traffic of both humans and merchandise across the globe, "the English System remained in the shadow of quarantine legally and internationally."[6]

Whereas, as Graham Mooney has shown, disinfection formed an important part of British sanitary intervention on *terra firma*, maritime fumigation appears to have been less well established as regards holds and their cargo, than on the deck of vessels. According to Maglev's calculations, of 362,823 vessels inspected in the Port of London between 1873 and 1893 only 451 were fumigated.[7]

Introducing the Clayton to Britain

The first notification of Downing Street on the disinfecting properties of the Clayton apparatus appears to have been made on April 29, 1901, when the British Colonial Office received the copy of a letter written by the illustrious "father" of tropical medicine: the Scottish physician and founder of the London School of Hygiene and Tropical Medicine, Patrick Manson. The letter enclosed a report by the Superintendent of the British India Steam Navigation Company, Captain George Hodgkinson, on experiments carried out with the apparatus in London. Urging further enquiry into this "practicable and promising method," Manson offered his unambiguous endorsement, stating that the experiments "seem to show that by this apparatus ships can be effectually cleared of rats and similar vermin without damage to cargo and at small cost."[8]

Hodgkinson's presentation of the Clayton machine had all the characteristics of an introduction of a machine that held the promise of revolutionizing maritime trade. It stressed that the fire-extinguishing and ship-disinfecting properties of the apparatus were based on a common principle: "The rapid generation and application of sulphur-dioxide gas (SO_2) which being heavier than the atmosphere will quickly replace the natural atmosphere of a hold being assisted by the action of the return pipe which sucks the air from the hold to the generator and converts it into SO_2."[9]

Hodgkinson explained that on March 26 and April 3, 1901, a demonstration of the two properties of the machine had been undertaken on the Orchard Wharf and on *S.S. Manora* respectively.[10] The report focused on the apparatus's disinfecting properties, stating that "Each hold and each section of the passenger accommodation was filled with the gas with the result that great quantities of cockroaches and 301 rats were destroyed. It is important to note that all animal life on finding itself choking with the gas deserts its lurking place and comes out into the open to die and the remains are therefore easily removed."[11]

Even more promising was the apparently harmless nature of the process as regards cargo. Samples of coffee, tea, sugar, flour, cocoa, salt, vegetables, a polished velvet upholster chair, broads painted with zinc, and other material were tested, with only cocoa and flour reported as "slightly affected."[12] Finally, on April 19, the saloon accommodation of the boat was treated with "samples left for 24 hours exposed to the air and then tested"; the only tarnish was on the saloon's gilding.[13]

The results, Hodgkinson concluded, proved to be "highly satisfactory," as "by the use of one of these machines ships could be kept almost, if not entirely free of vermin."[14] A few days later, a second experiment, this time at the London Docks, replicated the results. Hodgkinson reasoned that, for a time when the disinfection of vessels arriving from plague-infected ports was "of such vital importance to eastern shipping interests," the Clayton process promised a fast and efficient solution to the mutual benefit of traders, shipowners, passengers, and governments alike.[15]

Both the lay and scientific press were quick to cover the story, with *The British Medical Journal* concluding that the opinion formed in light of the spring experiments was so favorable that "the system is likely to be introduced into Indian ports."[16] At a time when not only trade but also plague, and their entanglement, were recognized as being irreducibly international and maritime-dependent, newspapers like Edinburgh's flagship daily, *The Scotsman*, and the shipping magazine *Fairplay* hailed a major breakthrough.[17]

Perceptions of the silver-bullet qualities of the Clayton machine were fueled by a robust if aggressive promotion campaign by the Clayton Company, which had established its offices as "The Clayton Fire Extinguishing and Ventilating Company," at 22 Craven Street, London, in the beginning of 1901. The Company provided British authorities with comprehensive booklets, containing information on the functioning of the machine, and extracts of scientific articles, endorsing its efficacy (including such as originally published in Louisiana with regard to the Olliphant machine) (figure 4.1). It also maintained a sustained correspondence with them on various aspects of the apparatus.

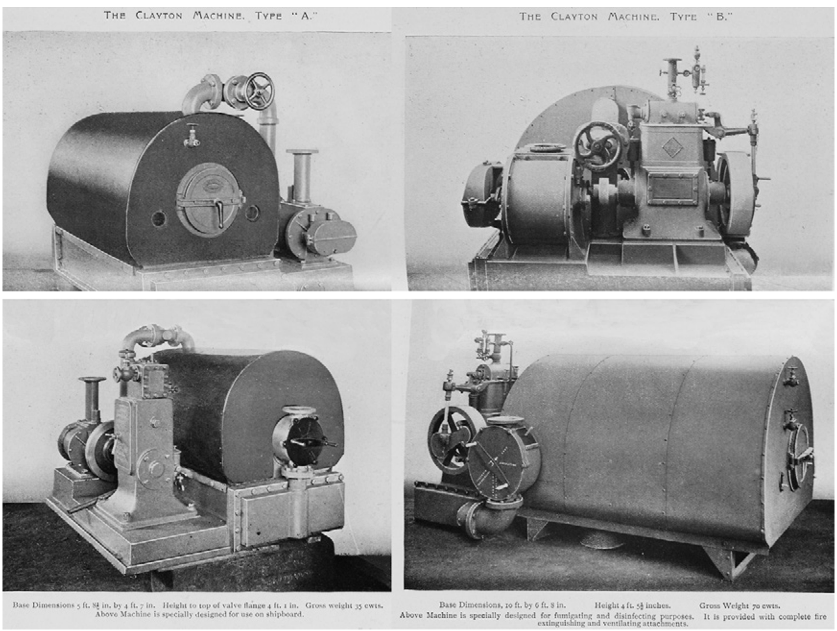

Figure 4.1
Two types of the Clayton machine from promotional pamphlet, "The Clayton Fire Extinguishing and Ventilating Company, Limited."
Credit: The National Archives (UK), ref. MH19/274.

In a lengthy letter dated October 29, 1901, the Company developed an iconic argument insofar as it exercised pressure on the British government from a range of perspectives.[18] Noting the urgency of the adoption of plague-protection measures and underlining the relation of the disease to rats, the Company argued that the measures proposed by the Port Sanitary Authority of London at the time, consisting in rat-trapping and poisoning, were grossly inadequate. Even less effective, it was argued, was the alternate method advised by the Authority: burning sulphur in the vessel's holds. Not only was this method unscientific, as its efficacy was limited to the combustion allowed by the existing oxygen in the hold, but it also risked causing a fire, which could consume the entire cargo. By contrast, the Clayton machine was presented as a revolutionary invention, as it operated on the basis of scientific engineering principles: first, in that it was pressure-driven, and second, in that rather than merely charging the hold's atmosphere with gas, the machine *converted* it, by means of a return pipe, into SO_2.

The *Sénégal* Incident

The reach of the Clayton machine was not, however, limited to Britain. French concerns about rats as propagators of plague had been growing in scientific investigations of plague ever since Alexander Yersin's initial work on the disease's pathogen in Hong Kong in 1894. The Pasteur Institute was at the forefront of research regarding rats in the context of outbreaks in British India, which in 1898 led to the articulation of Paul-Louis Simond's theory regarding the role of the rat flea in plague transmission.[19] What, however, functioned as a catalyst of French interest in rats, and their relation to maritime trade in particular, was an incident not in Asia or even in the North African territories of the French Empire, but instead in continental France itself.

The incident that "underlined anew the question of plague prophylaxis" involved the *S.S. Sénégal*.[20] The ship, which had been previously used to transport spectators to the first Olympic Games in Athens, had been in the course of a leisurely cruise organized by the leading French scientific journal *Revue générale des sciences pures et appliquées*, carrying 174 passengers, including seventeen doctors.[21] Then, on September 16, 1901, two days after leaving Marseilles, and with Lipari in view, a plague case was discovered in a member of the boat's crew named Marius Fabre.[22] Within two days the boat was back to Marseilles, where its illustrious passengers, including the future President of the Republic, Raymond Poincaré, were kept in quarantine in the Frioul lazaretto.[23] Having previously arrived in the noncontaminated port of Marseilles (August 28, 1901) from Beirut with a stop at the contaminated port of Alexandria in Egypt, the boat had been considered free of plague on the basis that no human cases of the disease had been observed on board.[24]

The scandalous event made headlines and galvanized medical opinion regarding the question of the role of the rat in the propagation of plague.[25] Did rats indeed pose a danger to the health and wellbeing of Europe? Was it true that they could not only maintain plague onboard ships (with the presence of the disease being overlooked in the temporary absence of human victims) but also mix with native rats and contaminate them after disembarking from vessels? Could they thus create long-term reservoirs of plague in French and other European harbors? Or were they, as sceptics declaimed, simply victims of blanket accusations—scapegoats held responsible for the "crimes" of the true, but less loathsome, plague-spreaders like grain, soil, or clothes?[26] Entwined with these scientific questions was an array of administrative ones. Given the growing consensus that rats did play a role in the transmission of plague, and as sulphurization of vessels had been part of government maritime regulations since July 1899, why had no deratization measures been followed in Marseilles?[27] If plague on the *Sénégal* was only one among several similar incidents in preceding months, was this to be attributed to the "apathy of navigation companies"?[28] Or, as Jules Bucquoy, the doctor sent to attend the plague-stricken boat, seemed to suggest, should it be blamed on the inadequacy of the existing regulations regarding deratization?[29]

Supporting Bucquoy's thesis, Henri Monod, director of public health at the Interior Ministry of the Republic, proposed that the rules applied to cholera did not offer sufficient protection against plague, and that the lesson of the *Sénégal* suggested that the sulphurization with the purpose of rat destruction should be made obligatory for all vessels arriving at French ports.[30] On September 26, 1901, Monod issued a ministerial circular, which drew sharp lessons from the recent crisis. The circular stressed that, while existing maritime regulations regarding deratization were an important precedent, a renewed focus on the *total destruction* of rats on board of all vessels derived from infected ports, even those on "non-infected boats," by means of sulphurization was urgently necessary.[31] Monod stressed the need for this procedure to be followed closely, and to avoid reloading the boat before disinfection was complete. As a result, the sulphurization of boats deriving from plague-infected ports, after the unloading of their cargo, was made obligatory.

What was meant by sulphurization in this context is not made explicit in Monod's circular, but becomes obvious in the inclusion of a report on a deratization process employed a few months earlier in the Egyptian port of Alexandria, which Monod directly praised as exemplary. The report, written by the director of the Alexandria Quarantine Office for the president of the Quarantine Council of Egypt, stated that, following the unloading of goods from the boat's hold, sulphur was prepared for burning: after creating a thick bed of earth carrying a 20–40 cm^3 piece of charcoal, the latter was set aflame with the help of petroleum or tar, upon which sulphur was added at a quantity of 8–10 kilos.[32] The burning sulphur hence produced asphyxiating gases within the hermetically closed hold and was thus maintained in locus for twenty-four hours. Then the hold was reopened, and after one hour had passed crewmembers descended to pick the dead rats. These were in turn incinerated with the help of cattle manure in the nearby lazaretto. Following this deratization process, the port authorities proceeded to disinfect the hold by means of quicklime applied to its floor, and "phenic acid" (carbolic acid also known as phenol) on the ceiling and walls of the hold.[33]

It was this combined method of disinfestation and disinfection that the Marseilles port authorities reported as having been applied, in compliance with the September 26 instructions, to seventy-one boats out of a total of 132 disembarking in the port between September 26 and December 21, 1901. The authorities stated that, as all other boats were carrying goods in transit, sulphurization was not applied to them and they were allowed to sail without being fumigated.[34] For besides damaging metallic surfaces, this method had the major disadvantage of being suspect for damaging goods. Hence, even in the cases where it was undertaken, goods were first unloaded on the dock, with the danger being that rats removed together with cargo would then seek refuge in buildings or sewers nearby.[35]

As a result, in order to both avert this danger, and to minimise the duration of the fumigation procedure, and thus placate shipowners, the application of liquid carbonic acid to loaded holds was tried in Marseilles by Dr. Catelan under the supervision of Dr. Jacques:

> On the deck is placed a barrel containing hot caution at 50 degrees in which five bottles of liquid carbonic acid are placed at once. The hot water serves to prevent freezing of the gas as it exits the bottle. Each bottle contains 10 kilograms of liquefied CO_2, or 5 cubic meters of gaseous carbonic acid. To these bottles, screw the coupling nut (not universal screw) of the rubber pipes 2 centimeters in diameter and about 6 meters long, intended to conduct the gas in the hold. The pipes plunge into the hold at a depth of 1 meter and pass through the flange of a panel. A bottle empties in less than three minutes.[36]

Employed in this manner (including some alternations), five fumigation experiments were undertaken between December 4, 1901, and March 25, 1902. The aims of these ranged from seeing whether CO_2 could, in spite of its density, penetrate the entire hold at a concentration of 25 percent, to ascertaining the time needed to kill rats, and whether the introduction of gas at different intervals affected the ability of CO_2 to spread homogeneously across the hold. In spite of this extensive experimentation, however, the trials remained inconclusive on account of conflicting opinions regarding the exact concentration of the gas needed to effectively deratize a boat on empty and full holds.[37]

Still haunted by the *Sénégal* incident, a session of the National Academy of Medicine was held on March 18, 1902, to discuss the sanitary services in the Frioul lazaretto. The discussion quickly developed into one regarding deratization, with Charles Louis Alphonse Laveran (the discoverer of the protozoan cause of malaria) endorsing sulphurization by means of sulphuric acid as superior to CO_2. However Laveran's position was countered by the influential founder of the *Revue d'hygiène et de police sanitaire* and author of the 1882 *Traité des désinfectants et de la désinfection*, Émile-Arthur Vallin, who stressed that the misapplication of such fumigation measures in even just one case would cost several hundred thousand francs.[38] Who would then take responsibility for such disaster, including not simply financial cost but also the fact that it would discredit the whole fumigation process? Moreover, issuing such orders was a mute verdict, Vallin reasoned, when it was not even clear if the correct amount employed in this fumigation process should be forty grams (as used in Marseilles) or ten grams (as employed in Hamburg).[39] Being an old but disappointed partisan of sulphuric acid, Vallin declared himself unable to share Laveran's optimism. Yet not all was bleak in Vallin's opinion, as from the United States a new method beaconed as a hope whereby such primitive fumigation methods could be overcome—a method that, he urged, needed to be tested by the French sanitary authorities as a matter of great urgency: the Clayton machine.

The Dunkirk Experiments

Resulting from the aforementioned meeting of the Academy, on April 12, 1902, a ministerial circular boldly decreed that the obligatory sulphurization of boats arriving from plague-infected ports should be performed on loaded holds. This led to further calls of making a specific method of fumigation under the control of public health authorities legally binding for navigation companies.[40] It was, however, another minor incident that in fact triggered the first application of the Clayton method in France.

Arriving in Dunkirk on June 10, 1902, from Calcutta (via Aden, the Suez, and Malta) the British vessel *City of Perth* reported two plague patients among its crew, both of whom died the following morning. As a result, French authorities ordered the boat out of the port, forbidding any communication with the shore until, on June 17, it was decided to sail to London, but it was ordered by British authorities to anchor in the lower part of the Gravesend Reach. As all indications pointed at infected rats being the source of the outbreak, there, the boat's holds and cargo were subjected to fumigation by means of the Clayton machine. Dr. Adrien Loir was allowed to follow the procedures as a member of the French health authorities.[41] More than two hundred rat carcasses were consequently removed with the help of tongs and burned in the boat's furnace after being immersed in corrosive sublimate. Following the combined method of disinfestation and disinfection, the holds were then also "washed down by a powerful hose with disinfecting fluid."[42]

This was a most embarrassing situation, for, in spite of all the aforementioned circulars and legislation, a vital French port like Dunkirk was internationally exposed as being unable to provide fumigation services for infected boats. Saint-Nazaire, the closest lazaretto, was a three-day journey away, but it too did not possess appropriate fumigation facilities.[43] This "painful incident," as it was plainly described by French medical authorities, led Dr. Duriau, the public health officer in charge of the incident in Dunkirk, to assert: "this [the Clayton] is the machine that we need to address ourselves to defend our maritime frontiers against exotic epidemics."[44] Petitioning the Inspector of Sanitary Services of the Ministry of Interior, Paul Faivre, permission was thus granted for Clayton apparatus trials to be undertaken in the port of Dunkirk.

This was not strictly speaking the first trial of the Clayton on French territory. A few months earlier, experiments on maritime rat destruction had been led by Drs. Langlois and Loir of the Pasteur Institute's branch in Tunis. Their endorsement of the Clayton, however lukewarm, caused Apéry's acute reaction in Istanbul, when he demanded that the International Board of Health "rejects [*sic*] all systems based on sulphuric acid, whether these be pot systems or the Clayton system, as rat destruction methods that are illusionary and expensive."[45] During the experiments in Tunis, use of CO_2 was compared to Clayton-generated SO_2. It was concluded that the general suspicion against the latter, on account of Robert Koch having demonstrated that SO_2 could not kill anthrax spores, was misguided when applied to other pathogens. Hence, Langlois and Loir maintained that, with the exception of spore-bearing microbes, sulphurous acid gas was indeed useful against diseases like cholera but particularly against plague, as it was so much better at killing rats and their fleas.[46] The report was revealing on many fronts. For example, it showed that Pictolin was too weak for effective deratization. More importantly perhaps, it also reproduced an account by the eminent Alsatian chemist Daniel-Auguste Rosenstiehl regarding the chemical properties of the gas generated by the Clayton machine, which, for its French audience, produced a certain epistemic stabilization of this fumigant.[47]

However, back in Dunkirk, not content with their colleague's dictum, "Let us stick to sulphurous acid gas until we find a better gas to replace it," Duriau and Albert Calmette (then director of the Institute's branch at Lille) decided to undertake a series of trials with the apparatus, seeking to test so-called Claytonization on a range of microbial agents.[48] This was indeed the first time that the germicidal properties of the machine would be put to the test in Europe. The vessel of choice was the 1,200-ton iron steamer *René*, moored in the port of Dunkirk and carrying barley from the Algerian port of Oran. The experiment took place on September 27, 1902, with the Clayton machine being placed on a barge alongside the steamer.

With the collaboration of the Chief Chemist of the Ministry of Finance, the Pasteur Institute in Lille prepared typhoid fever, cholera, and plague samples with which Calmette saturated strips of flannel.[49] This artificially infected material was then placed in both dry and moist condition in cylindrical tubes (30mm diameter) which had been previously sterilized and were kept open at both ends with cotton stops attached. At the same time, other similarly impregnated strips (both moist and dry) were "packaged" in sterilized blotted paper, in sterilized flannel, and in doubled oiled foolscap, which provided the researchers with unique packages per microbial agent. Parallel to these preparations, moist and dry controls were kept on the deck, unaffected by the experimental vapors.

Two experiments were performed with these preparations. The first took place in the after hold of the boat where the microbial samples were placed in both the lower hold and in the upper part of the 'tween deck hatch. After closing the upper deck hatches, with the help of two pipes (for suction and discharge) the Clayton machine was led to introduce its vapors for two hours and fifteen minutes at a concentration varying between 8 and 15 percent. Opening the hold after two further hours, scores of rats were seen scurrying in the 'tween decks. In his report to the Ministry, Duriau explained: "As soon as it is possible to go down into the slipway, 15 dead rats were collected: Twelve other corpses of rats, plus that of a cat which can not be traced back, were discovered the following day. The floor of the cabin was strewn with dead flies."[50]

No harm was observed on the structural elements of the boat or on the furniture, including leather armchairs, whereas various types of merchandise that had been placed in the boat's hold in order to test whether the Clayton gas had damaging properties were tested and found to be unharmed. This included, among other things, beef, cheese, carrots, potatoes, and tobacco. Only exposed water and wine were judged considerably altered.

The second experiment was conducted in the deck cabin, a 250 cubic feet space containing two fully fitted bunk beds where gas was similarly inserted for two hours and forty-eight minutes. In this case, the concentration of the gas was found to be unequally distributed with SO_2 easily escaping the room, as this had not been hermetically sealed. Samples from both experiments were processed in Lille the following day by developing cultures at 37°C. In seven days, from among the experimental sample, only the dry typhoid bacilli from the 'tween deck packages demonstrated a development of microbes; a fact attributed to a possible fault in the sealing of the upper hatch, near which the said samples were placed. By contrast, all control samples with the exception of cholera in a dry state developed cultures. Calmette enthusiastically concluded that the success of the gas with regards to all microbes tested pointed to the necessity to make the use of the Clayton obligatory on all vessels “in the shortest possible time.”[51]

The success of the Clayton, in Calmette’s eyes at least, did not, however, mean that other modes of fumigation should no longer be tried and experimented upon, contending for the primacy of French deratization methods and official endorsement. For example, Dr Sené, director of health at Pauillac, reported that on July 17, 1902, the deratization of the cargo ship *Matapan* was undertaken in Bordeaux. The boat carried a range of products including sacs of corn, cocoa, tobacco, and barrelled sardines. After removing tobacco and cochineal bags, at the request of the merchant company, 400 kilos of sulphur were placed in furnaces allocated on different compartments of the hold (figure 4.2) and were left to burn for twenty-four hours approximately. With no impact on the cargo goods, forty-four rats were found asphyxiated and forty living, out of which only one adult animal. All living rats were found under sacs, which were believed to function as barriers to the fumes. This led Sené to suggest that, in the case of infected boats, the process should be extended up to seventy-two hours to make sure all rats have been asphyxiated.

As a result of the different and indeed conflicting opinions voiced by scientific experts and port authorities across France, Adrien Proust and Paul Faivre were charged with composing a report on different deratization methods. Presented on November 15, 1902, the report compared and contrasted three methods: sulphurization by burning sulphur in free air, the Clayton process, and CO_2-based fumigation.

In relation to the Clayton, Proust and Faivre sought to secure more information by Dr. Souchon, the President of the Louisiana Board of Health at New Orleans. He replied on March 14, 1902, confirming that the Clayton machine had been in operation in Louisiana in the last ten years, its “chief objective [being] the destruction of germs; secondarily to obtain the destruction of rats, mosquitoes and vermin.”[52] Asked regarding the duration of the procedure, Souchon replied that the production of gas took between one and six hours, according to the vessel’s dimensions, where it was thereafter retained for twelve to twenty-four hours. As in the case of Louisiana, the apparatus was aimed principally at yellow fever, and the

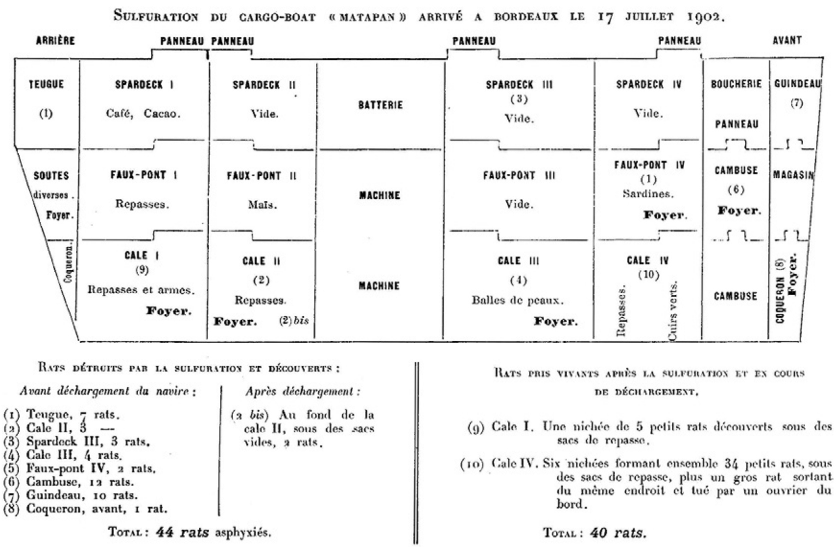

Figure 4.2

Diagram of the fumigation of the *Matapan*.

Source: A. Proust and Paul Faivre, "Rapport sur different procédés de destruction des rats à bord des navires," *Recueil des Travaux du Comité Consultatif d'Hygiène Publique de France et des Actes Officiels de l'Administration Sanitaire* 33 (1903): 341. gallica.bnf.fr / Bibliothèque nationale de France.

boat was kept in quarantine for five days, the disease's incubation period. As for the cargo, this was confirmed by Souchon to remain in the holds during fumigation, adding that "ships trading regularly with New Orleans have in each hold a special pipe to facilitate the introduction of the gas."[53] Asked whether merchandise have been observed to sustain any damage, Souchon replied that "no damage has been caused to the merchandise in a dry state. In the presence of humidity the anhydrous gas is converted into H_2SO_3 which has bleaching properties."[54] Souchon detailed that his station possessed two Clayton machines, one of which was operated by the side of the target boat with the help of a barge, while the other was fitted to a rail track running along the quay. Finally, asked about the price of the operation, Souchon replied that "The cost of complete disinfection of ships is 105 dollars (around 530 francs)."[55]

Comparing the three methods, the two doctors thus found sulphurization by burning sulphur in open air to be effective in killing rats: a simple, but inflammable method. But, as the process required unloading, so as not to harm the cargo, many rats were able to escape before fumigation even began. At the same time, unloading and reloading cargo was considered to be heavily reliant on labor. For example, in the case of the sulphurization of the Couldson in the Havre (June 28, 1902), the unloading and reloading of 2,000 sacs required the manpower of twenty-two. This had the added disadvantage that workers, generally averse to working in quarantine stations, required higher payment, while the crew had to sleep the night outside the boat; an arrangement described by its captain as most disagreeable. Finally, this gas was judged as having no penetrating properties in lack of pressure, so even if merchandise was present and left undamaged, the gas would fail to affect any but the top parts of the load. Thus the method of sulphurization by burning sulphur in open air was held to be unreliable as regards the total destruction of rats on a loaded hold. In these terms, Claytonization was considered to be a superior method, both for its ability to operate on a loaded hold, the noninflamability of the gas produced, as well as the rapidness and greater penetration force of the operation. When it came to comparing the Clayton with CO_2 methods, Proust and Faivre noted the importance of SO_2 being perceptible in terms of its odor by the vessel's crew. The example given was a man who had climbed on the vessel *La Marguerite* in a drunken state and slept there without being perceived by the Dunkirk harbor crew, who proceeded to fumigate the steamer. The man, who awoke from the smell of the gas, would have surely died had the boat been fumigated with odorless CO_2. Another major disadvantage of CO_2-based fumigation was judged to be the fact that, according to Drs. Catelan and Jacques' own confession, this could only be used in the hold proper, with application to other compartments of vessels necessitating "to modify the present mode of construction of ships."[56] However, what made the Clayton clearly superior was its ability to kill both microbes and so-called vermin, like fleas, which, as shown by Langlois and Loir's study, CO_2 was unable to do. It was only with SO_2 that the "double action" of disinfestation and disinfection was achievable. Proust and Faivre thus concluded: "The use of the Clayton apparatus, while suppressing these manipulations, brings into contact with the whole cargo of the ship a gas possessing more powerful bacteriological properties than those of other gases used up to that time. We are therefore logically led to give it in all respects the preference."[57]

Although, on the basis of this recommendation, on June 20, 1903, a circular would eventually announce to the chambers of commerce that the use of the Clayton machine under public health authority supervision had become obligatory, the two doctors were not oblivious to the limitations of the method. Indeed they had direct experience of the latter during operations undertaken on two additional empty and seven more loaded boats in Dunkirk. Though no cargo, including foodstuff, was reported as damaged by the process, the results were mixed insofar as in several cases surviving rats were found in the holds. This led Proust and Faivre to note that the results "undoubtedly leave much to be desired; however, they do not seem to us to invalidate the method, but the insufficient application which has been made of it."[58] The problem, in the opinion of the authors, seemed to be the duration of the fumigation process, which they estimated to be on average seven hours, inclusive of time taken for warming up the machine.

Responding to the report, Drs. Duriau and David hastened to remind the French medical community that the principal aims of fumigation should take into account the mutual interest of the public and seafaring capital. A "disinfecting product" should hence combine the following traits, all of which were met only by Claytonization:

> From the point of view of public hygiene [*salubrité*] it should destroy microbes, rodents (rats, mice, etc.), insect and in a complete manner vermin;
>
> From the point of view of navigation companies, it should not damage the ship, its furnishings, and should not necessitate the disembarking of the crew;
>
> From the point of view of the shipowner, it should not alter the merchandise;
>
> From the point of view of the insurance company, it should not cause fire;
>
> From a general point of view, it should be able to be employed without even partial unloading of cargo, to not delay but for a few hours commercial transactions, and, finally, to not be too expensive.[59]

These conclusions, and the optimism they carried with them regarding an effective application of fumigation in the control of germs and disease vectors, came in the aftermath of a major European crisis regarding deratization and its impact on maritime trade.

The Ottoman Deratization Crisis

The crisis concerned an Ottoman circular (No. 180, "Instructions Concerning Vessels which Have or Have Not Undergone Disinfection in View of

Destroying Rats and Mice on Board"), which was discussed by the Istanbul Quarantine Board over a period in 1901 and 1902. This originally demanded ships arriving in Istanbul or other Ottoman ports to be treated according to the sanitary conditions of the port of departure, regardless of the health of the passengers and crew, and the existence or not of dead or infected rats on board. However, in the course of its discussion, the Board ended up adopting an even more draconian measure, which made both the status of the port of origin and the sanitary status of the vessel irrelevant, necessitating constant deratization.

The Ottoman circular stated that the following drastic and costly measures had to be applied in the quarantine stations and lazarettos of Ottoman ports in the Black Sea, the Aegean, across the Mediterranean, as well as in Basra and the island of Kamaran to all vessels arriving from infected ports. Merchandise, provisions, and any object on board was to be removed from holds, underdocks, and the steward's room, so that baits consisting in cheese or other foods that attract rodents may be placed therein. The purpose of this was to attract rats from their nests and hiding places to the open. Then furnaces would be placed at a rate of six per hold/underdeck with two being additionally placed in the steward's room. Therein "sulphur in sticks" would be burnt "in the proportion of 30 grams of sulphur to 60 grams charcoal for each cubic meter of space, or 30 kilos (66 lbs.) of sulphur to 60 kilos (132 lbs.) of charcoal for 1,000 cubic meters (35,317 cubic feet) of space."[60] All spaces where this operation would take place would be hermetically sealed and remain fumigated for at least ten hours. Alternatively Pictolin could be used at a proportion of 1 kilo per $100m^3$ applied for three hours in a similarly sealed space. After reopening the holds, all rats found suffocated therein would be thrown into the ship's boiler furnace or otherwise burnt with the help of petroleum. The fumigated compartments would then be washed with water, and its walls scrubbed with raw carbolic acid, soap, and soda at 15 kilos each for 150 liters of water. As for other parts of the ship (toilets, drawing rooms, cabins, etc.) and any object contained therein, these would need to be disinfected by means of a 4 percent corrosive sublimate solution spray. Finally the water held in the ship's canteen would need to be disinfected with lime.[61]

Expressing the dismay of the British Board of Trade about the Ottoman circular, the UK Chamber of Shipping and the Liverpool Steamship Owners Association, the British delegate to Istanbul's Quarantine Council, Frank

Clemow, proposed as an alternative the principles contained in the 1901 British memorandum on "Ship-Borne Rats and Plague."[62] This stated that only when plague is present on a ship or where, upon suspicion of plague, rats are examined and found positive, should quarantine and disinfection measures be imposed: "For a boat arriving from an infected port no measure whatsoever is obligatory: and only in the cases where we have encountered an exceptional mortality amongst rats in that ship is the destruction of rats, according to this Regulation, desirable."[63] As Clemow was quick to stress before members of the Quarantine Council, objections to the Ottoman approach were also voiced by the German Health Council, as well as by foreign shipping companies in Istanbul.

In an effort to reach some sort of compromise, Clemow crafted a list of internationally binding regulations on maritime sanitation, which, while assuming a draconian tone, in fact largely restated British positions on the subject. However, this effort to mitigate the stringent regulations imposed by the Ottomans backfired as it was usurped by the Ottoman authorities: "Where my proposal tended to grant facilities to navigation," Clemow wrote on October 12, 1902, "they have been rejected; where they tended to add fresh restrictive measures (as, for example, in regard to ships on board of which an exceptional rat-mortality has been observed) they have been accepted."[64] Clemow appeared desperate, for in his mind his proposal had aimed to "maintain the principles established by the various International Sanitary Conventions" so that, "while admitting that at the date of the last conference (1897) the part played by rats in the distribution of plague was not fully recognized and had therefore not been dealt with in the conference, I nevertheless maintained that the principles accepted by the Powers in dealing with the spread of infection applied equally well to rats as the medium of infection as to human beings, merchandise or ships."[65]

Indeed Clamow's proposed regulations encouraged the most draconian among the Istanbul Quarantine Council's members, with Greece's delegate, Dr. Balilis, rising to be the champion of even stricter measures in the course of the Council's sessions in September 1902, where Clemow's objections to the new regulations were discussed. Bringing up the case of *Polis Mytilini*, Balilis suggested that the clean versus infected port distinction was moot, and that the only way to prevent plague from spreading was to destroy all rats on all boats every forty days.[66] This followed Balilis's hitherto-stated thesis that plague was a disease residing in the soil, wherefrom rats and fleas got infected: In a pamphlet on the subject of quarantine authored the previous year, he had confidently expressed the opinion that it was from the infected soil lying in the crevices of boats that rats acquired plague, leading to an epizootic process that, by rendering plague more and more virulent through inter-rat transmission, finally produced the disease among humans.[67] Here the old hypothesis of plague's attenuation in the soil and its recrudescence through rats (see chapter 3) was rehearsed once again, but with severe practical consequences.

Balilis's lengthy exposition on sanitary measures against plague to the Istanbul Quarantine Council hailed the way in which the rat and flea connection led to the "unveiling of the mysterious agent which operates stealthily in the soil" by tracing the "hitherto invisible thread" of plague propagation.[68] By thus connecting soil, rat, and flea in a tripartite plague-spreading chain of transmission, "all that was until recently mysterious and obscure becomes knowledge and light."[69] In short, Balilis maintained that the prime locus of infection was the soil, with rats functioning as in-betweens the soil of different regions or countries, leading to the infection of "indigenous rodents" and eventually of humans, who may also contract plague directly from the soil.[70] Merchandise or luggage could also be infected likewise by the attenuated soil-borne saprophytic bacillus. As this, and not human contagion, was seen as the means of spreading the disease, quarantines needed to be reclassified as merely secondary means of prevention (eight days for the surveillance of humans who may be incubating the disease was deemed adequate) giving priority to deratization as the principle means of protection from the disease.

Boats, in Balilis's opinion, thus functioned not only as ideal transporters but also as vital reservoirs of plague. For if plague in its supposed soil-borne, saprophytic state was believed to wither and die when exposed to light or fresh air, in the holds of the boats both these conditions were absent, providing an excellent environment for the preservation of the disease in an attenuated state. If humans had nothing to fear from this attenuated bacillus directly, the recrudescence believed to be brought about by the rat, and rat epizootics in particular, was thought to lead to cases of the disease even on boats not deriving from an infected port for a long time, or even ones who had never been in touch with an infected port. "It is therefore the ship, this mobile soil, which is the thread that connects contaminated countries to unharmed countries, which must occupy our full attention."[71]

This theory effectively rendered the status of origin ports irrelevant, making the ship itself the main object of epidemiological interest and concern. This was an opinion that Clemow (who attached Balilis's pamphlet in his report to London) considered "illogical," "dangerous," and "subversive of all hitherto accepted principles and measures."[72] However, to Clemow's great annoyance, his European codelegates appeared largely uninterested in his proposals, and the Greek motion carried the day. With strong support from France's delegate it was adopted as an amendment (Article 3) of Circular No. 180 by the Quarantine Council, hence instituting the most draconian system of deratization on the globe. Clemow lamented:

> This article forbids clean ships from clean ports from coming to the quays, if they have touched a contaminated port within four months and have no certificate of rat-destruction less than forty days old. I took the example of a ship which leaves a contaminated port, say on June 1st: she has her rats destroyed before leaving and obtains a certificate to that effect and out of date. She goes to a number of clean ports during three and a half months, and is every where [*sic*] received without any restrictions. Bur she arrives in a Turkish port, say on September 15th, without undergoing the enormous expense and loss of time of a fresh rat-destruction, she is forbidden to come up to the quays.[73]

In light of this development in the doctrine of "perfect disinfection" (in Balilis's terms), fumigation apparatuses became crucial not only in practical but also in political terms.[74] No longer simply technologies that guaranteed the feasibility of continuous deratization, they now formed part of a broader interimperial struggle for ascertaining the correct and most "economic" approach for disentangling maritime trade from plague, and for securing a minimization, if not abolition, of cargo-related quarantine and the economic losses it entailed.