

1 Article

## 2 Identifying modern slavery through occupational 3 hygiene conditions of nineteenth-century slaves

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11 **Abstract:** The Brazilian economy, the rural in particular, was until the end of the 19th century based  
12 on slave labour. In this research, it was intended to obtain, through a review of historical descriptive  
13 studies, a detailed picture of the occupational hygiene conditions related to the slaves' work and  
14 their interactions with climatic and environmental conditions. The search was done in the following  
15 databases: Science Direct, Scopus, Web of Science, Criminal Justice, Ebsco, Business Source  
16 Supplement, as well as original historical documents. Descriptive studies, without the restriction of  
17 language, were selected that involved the rural work of slaves in colonial and imperial Brazil.  
18 Working environmental conditions have been evaluated: environmental and occupational hygiene  
19 conditions to which the captive workers were exposed, as well as their accommodation and  
20 clothing. The analysed studies registered the existence of accommodation and similar dresses all  
21 over Brazil, regardless of the region's climate. In addition to these accommodation conditions, slaves  
22 were still exposed in a similar way to physical, chemical and biological agents throughout the  
23 country. Finally, it was also possible to identify a clear similarity with the occupational exposure  
24 conditions of the modern slaves in the 21<sup>st</sup> century.

25 **Keywords:** Brazil; slavery; modern slavery; occupational hygiene; rural.

26

### 27 1. Introduction

28 A Country of strong economic participation at the global level, Brazil has a very diversified  
29 economy, but with a substantial contribution from the primary sector. Livestock farming accounts  
30 for more than 20% of gross domestic product – GDP [1]. This sector is also the largest generator of  
31 work and income, and its socio-economic importance contributed actively to Brazil's independence  
32 and has been its main driving force.

#### 33 1.1 *Slave labour in the 18th and 19th centuries*

34 Throughout the colonial and imperial period, Brazil had an economy based mostly on  
35 agriculture. Agricultural products such as sugar cane, cotton and coffee, that were primarily destined  
36 for export had the captive population as the primary labour force [2].

37 In this historical period, the enslaved workers carried out a large part of their tasks, counting  
38 only with manual tools such as axes, sickles, and hoes, due to still incipient mechanisation. Almost  
39 all main tasks such as deforestation, excavations, planting, weedings, and harvests, were executed  
40 using only the human force. Even the mills of that period, when they were not moved with running  
41 water, were often moved by the use of pack animals or slaves [3].

42 Until 1888, when slavery was abolished in Brazil [2], the captive workers were, at the same time,  
43 labour force, and patrimonial property on which its owner exercised the full right of usufruct. As  
44 such, the capital invested in these assets should be amortised and still generate profits to ensure an

45 economic return to its owner [4], which implied the recovery of the investment in the slaves'  
46 acquisition in a few years.

47 In order to ensure the recovery of the invested capital, this working force was subjected to long  
48 working hours in precarious conditions, with insufficient and low-quality food. To these conditions  
49 were added the barracks and inadequate or non-existent health care. As they were considered a  
50 means of production, it was necessary to obtain from slaves, with a minimum cost, the highest  
51 possible profitability. Under these conditions, the safety and health of this population were very  
52 precarious.

53 A study on slaves health in São Paulo in the 19th century [5] leaves no doubt to the relevance of  
54 work accidents as the leading cause of death in this population. In men aged between 15 and 49 years  
55 old, death by accident accounted for approximately 20% of the causes of death.

56 Another study on slave's health in the Vassouras region between 1830 and 1870 [6], points out  
57 that «the main group of diseases affecting the slaves was trauma," or traumas in soft or bony tissues,  
58 with more than 35% of that population affected. Between 1790 and 1807, in Rio de Janeiro, it was  
59 found that 46.4% of the slaves were affected by traumatic injuries, caused by violence and heavy  
60 work [7].

## 61 1.2 *Neo-slavery labour*

62 Compared with the eighteenth and nineteenth centuries, in the second half of the twentieth  
63 century and the twenty-first century, working conditions have been improved socially and  
64 economically, particularly, concerning Occupational Safety and Health (OSH) concerns. However,  
65 the degrading working conditions and days with the excessive effort, which raised concerns in the  
66 days when slavery was legal, are far from over. On the contrary, they remain a reality. Slave labour,  
67 or under similar conditions of slavery, persists in many countries, more than one hundred years after  
68 the universal abolition of slavery [8].

69 People submitted to modern slavery suffer daily accidents and acquire occupational diseases  
70 without any control by the OSH authorities, mainly due to the current illegal and occult nature of  
71 this kind of "employment" relationship. Nowadays, neo-slavery causes extensive damages not only  
72 to the people in these conditions but also to society, the economy and the environment. Under these  
73 conditions, workers are exposed to the specific occupational risks of each activity, worsened by the  
74 precarious conditions in which their work is accomplished, and by a long and tiring daily work.

75 Slave labour is considered a severe violation of human rights in international treaties, pacts,  
76 declarations and conventions due to the dangerous and degrading conditions of human existence in  
77 which it is developed [9]. However, even condemned at the highest international levels, the  
78 International Labor Organization (ILO) estimates that the number of people enslaved in the world  
79 exceeds 40 million [10].

80 In general, all recognised national governments declare rejection of slave work. Some countries,  
81 such as Brazil, do so in the constitution itself, others in different levels of legislation, all this in  
82 addition to the international agreements that most states have signed.

83 According to Brazilian Law, there are four aggravating factors, that isolated or together, may  
84 lead to the characterization of a condition analogous to slavery: (i) subjection to forced work; (ii)  
85 subjection to exhaustive working days; (iii) subjection to degrading working conditions; (iv)  
86 restriction of circulation, by any means, due to debt contracted with the employer or his  
87 representative.

88 However, such situations are also described in the Safety and Health Regulatory Standards, as  
89 a minimum requirement of working conditions. So, for this very reason, these situations tend to be  
90 regarded as minor violations of these norms and not as a crime. This is why they are often punished  
91 with a simple fine. Under this context, the users of neo-slave work can avoid the legal penalties  
92 foreseen for these situations [9], even in countries such as Brazil, where there is specific legislation on  
93 neo-slavery based on the ILO Declaration of Rights and Fundamental Principles of labour. Which,  
94 for its part, is based on several ILO standards (Conventions 29, 87, 98, 105, 138 e 182), signed by most  
95 countries.

96 The lack of technical and scientific support, able to be used as a comparison parameter between  
97 slave working conditions in the period when this practice was legal, and the working conditions of  
98 the contemporary neo-slavery, allow, as already mentioned, the characterisation of this practice as a  
99 simple violation of the regulatory working standards.

100 Although there are several studies on slave labour, they do not seek to clarify this issue from an  
101 occupational safety and health (OHS) perspective. Thus, the work on this literature review is justified  
102 as a further step to study and understand the conditions of OHS of the captive workers in Brazil at  
103 the time of legalised slavery but in a current OHS perspective. So, it is expected to contribute to the  
104 distinction between neo-slavery and the single violation of labour standards. It is also intended that  
105 this work help to raise clues and contribute to the development of methodologies to identify this  
106 problem in the different corners of the world where these practices are still a reality.

## 107 2. Materials and Methods

108 The initial phase of this study was a review based on the Preferred Reporting Items for  
109 Systematic Reviews and Meta-Analyses (PRISMA) [11], where descriptive studies covering the  
110 conditions of rural slaves labour in colonial and imperial Brazil were selected.

111 This first phase served to select the recent historiographic researches dealing directly or  
112 indirectly with the subject. The following electronic databases were searched: Science Direct, Scopus,  
113 Web of Science, Criminal Justice, Ebsco, Business Source Complete with temporal record started in  
114 2014. In all databases, the same Combination of keywords: *slavery* and *work*, was used. No language  
115 restrictions were imposed, and duplicate references were eliminated.

116 In the second phase, screening, the potentially relevant articles were selected from the titles and  
117 abstracts, where were excluded the works without descriptions of the slaves' labour activities. As  
118 selection criteria were established, the existence of direct descriptions of the subjects related to the  
119 study, dealing with the Brazilian slavery of the nineteenth century, and recognition as a reliable  
120 source. Thus, only those works that, after reading the complete texts, enable the extraction of relevant  
121 information (full reference, country region, environmental conditions, climatological, occupational  
122 hygiene, accommodation, and clothing) were included.

123 The bibliographical references of all the selected articles were read without distinction of  
124 publication type, which allowed the analysis of theses, dissertations, books and rare books (original  
125 publications dating from the 18th and 19th centuries) complementing this second phase. Primary  
126 sources (rare books) were the richest in detailed descriptions of slave labour and the conditions under  
127 which it was performed.

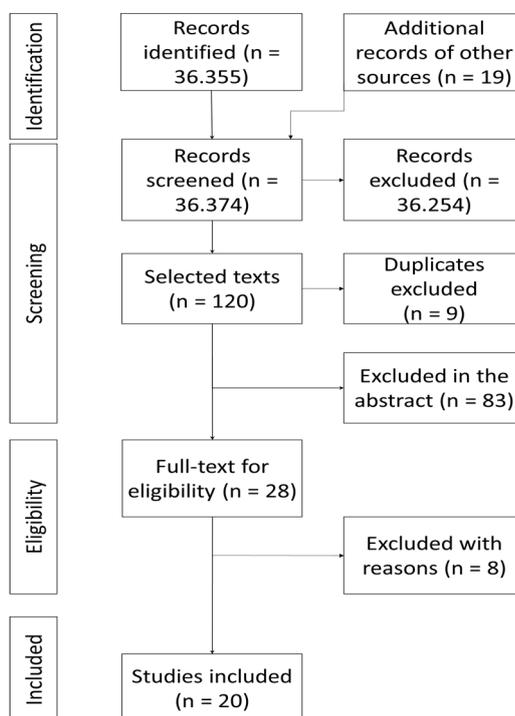
128 In the third and last phase, the data were collected, focusing the attention on the climatic  
129 conditions and occupational hygiene to which the captive worker was exposed, their usual  
130 accommodation conditions, and clothing. Subsequently, the historical data found were compared  
131 with data from the free poor workers of the same period, to highlight only the usual exposure  
132 situations related to captive workers.

133 In the next step, the historical data were compared with the use of similar techniques in current  
134 situations, in order to allow a relative quantification of the exposure of the nineteenth-century slaves  
135 to some agents to which they were habitually and demonstrably exposed. Finally, it was considered  
136 a dynamic exposure to contaminants, combining the climatic and occupational hygiene issues of the  
137 time, with potentially aggravating situations caused by housing and clothing conditions.

## 138 3. Results

139 The search in the six databases initially provided 36,355 references. After applying the exclusion  
140 criteria, nine references were selected to read the full text. The defined time frame has eliminated  
141 28,498 references. A total of 4,312 were withdrawn after the requirement of publication in periodicals.  
142 Finally, after reading the title and abstract 3,536 works were excluded because they were out of  
143 subject remaining nine works. From these, a further 19 papers were selected from the respective  
144 references or obtained from other sources, resulting in a total of 28 works selected for full-text  
145 reading. After analysing these 28 works, eight were excluded because they did not meet the defined

146 inclusion criteria. In the end, 20 works were included in the systematic review: seven articles, four  
 147 books, and nine rare books. The flowchart of figure 1 summarises the path and the results of the  
 148 performed bibliographic search.



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 150

**Figure 1:** Flowchart of the articles selected for the thematic review (adapted [11]).

151 The data in table 1 show the climatic variations, along the territorial extension of Brazil. There is  
 152 a predominance of heat in the northeastern states ( closer to the equator) [12-19], and the report of  
 153 exposure to heat and cold in the southeast region [2,20]. The exposure to the storms was usual, with  
 154 the slaves especially susceptible to the more abrupt weather variations.

155 Regarding the environmental conditions related to occupational hygiene (table 1), some  
 156 descriptions related to the respirable chemical agents such as dust, vapours, gases, and fumes were  
 157 found. The machines and mills were great generators and responsible for the atmospheric dispersion  
 158 of chemical agents in the working environment of the slaves. A real indicator of the very high  
 159 concentration of these agents in the slaves' working environment, is the fact that some authors have  
 160 pointed them out, even knowing all the other daily risks to which the slaves were subjected. Exposure  
 161 to poisonous snakes, mosquitoes, and other disease vectors was considered intrinsic to fieldwork.  
 162 However, the relevance given to them in historical reports reveals their major relevance, which is  
 163 justified by a large number of slaves affected by health problems related to these agents, especially  
 164 during deforestation of native forest and in planting operations and sowing during rainy periods.

165 The poor conditions of housing and clothing are also evident in Table 1. These are closely related  
 166 to the exposure and dissemination of contaminating agents among the population of slaves on  
 167 Brazilian farms, both for their material insufficiency and for the sanitary conditions in which they  
 168 lived.

169 Table 1 also shows the environmental conditions of work to which the slaves were subjected,  
 170 distinguishing the climatic conditions (figure 2) from those of occupational hygiene, for each  
 171 geographical region. It also presents the usual accommodation and clothing conditions for this  
 172 population.

Table 1. Environmental, accommodation and clothing conditions.

Ref.	Region	Environmental conditions		Accommodation conditions	Clothing conditions
		Weather	Hygiene		
[2]	Southeast of Brazil	Under storm, Cold, rain, and sun	Dust and humidity	The <i>senzalas</i> were rectangular and elongated sheds divided into several cubicles. A second model of <i>senzalas</i> was formed by small independent huts, made of clay walls and covered with leaves or tiles.	The mills provided ready-made clothes and tissues twice a year. In the coffee plantations, they provided three shirts, three pairs of trousers and coats, a hat and two blankets per year. The women were given skirts and shawls of coarse cotton.
[18]	Maranhão	Heat	Animal vectors of diseases	-	Very little clothing was provided to the slaves.
[22]	All of Brazil	Coastal region, rarely below 25°C	-	-	-
[20]	Southeast of Brazil	Heat and rains	Toxic vapours	-	Sunday should wear clean clothes and washed the dirty on Tuesday. Must change the wet clothes from rain, returning to wear it after drying.
[23]	All of Brazil	-	-	<i>Senzalas</i> * are described as small huts (built of wood and clay) covered with leaves.	-
[24]	Minas Gerais	Under storm, Cold, rain, and sun	Dust and humidity	As <i>senzalas</i> * were precarious, uncomfortable and unhealthy housing.	Insufficient, inadequate and filthy
[12]	Maranhão	Heat and rains	-	-	2.5 rolls of thick cotton cloth to wear by 50 slaves per year. That is 5.25 meters per slave per year.
[25]	All of Brazil	Hot and humid with lots of rain	Animal vectors of diseases	-	Usually mistreated and exposed to the storms.
[26]	All of Brazil	-	-	-	Providing few clothes, slaves walked almost naked.
[5]	São Paulo	Under Heat, humidity, and cold	Stagnant water and mosquito vectors of diseases	-	-
[13]	Maranhão	Hot and humid with lots of rain	-	-	In general, they walk naked or dressed in a small thing.
[14]	Maranhão	Hot and humid	-	-	Clothes from thick cotton tissue, the same as filling cotton feathers.
[4]	All of Brazil	Under storms	-	Large constructions in clay and wood, covered with leaves, with internal divisions where they stood pallets with mats and straw pillows. The couples lived separately from the other slaves, in small sheds with the same constructive model.	Few pants, shirts and a long vest per year, in the milder climate regions. All in thick tissue. In the fields, especially in the summer, rags covered them.
[15]	Maranhão	Hot and humid	-	-	-
[27]	All of Brazil	-	-	-	Clothing inadequate for protection against climatic variations
[16]	Bahia	Hot and humid	Humidity, the heat of furnaces, gases, and fumes	They could be separate huts or buildings divided into compartments, each one occupied by a family. Usually with clay walls and roof of leaves.	The men used long johns down to their knees, without a shirt and a band on their foreheads. Each slave received a quantity of coarse tissue relative to its size
[3]	All of Brazil	Varied climates	-	In the <i>senzalas</i> * the sleepers should be lifted from the ground in the dark over strings. Suggested cleaning inspection every Sunday.	Supply of cotton fabric for clothing and blankets.
[17]	Pará	Rains in the first months of the year.	-	-	-
[19]	Maranhão	Hot and rainy, with 4-6 dry months a year	-	-	slave clothes were made of thick cotton cloth
[28]	Rio de Janeiro	-	-	-	The domestic slaves of the farms were better dressed

\* *Senzalas* were the accommodations that were intended to house the slaves of Brazil between the 16<sup>th</sup> and the 19<sup>th</sup> centuries.

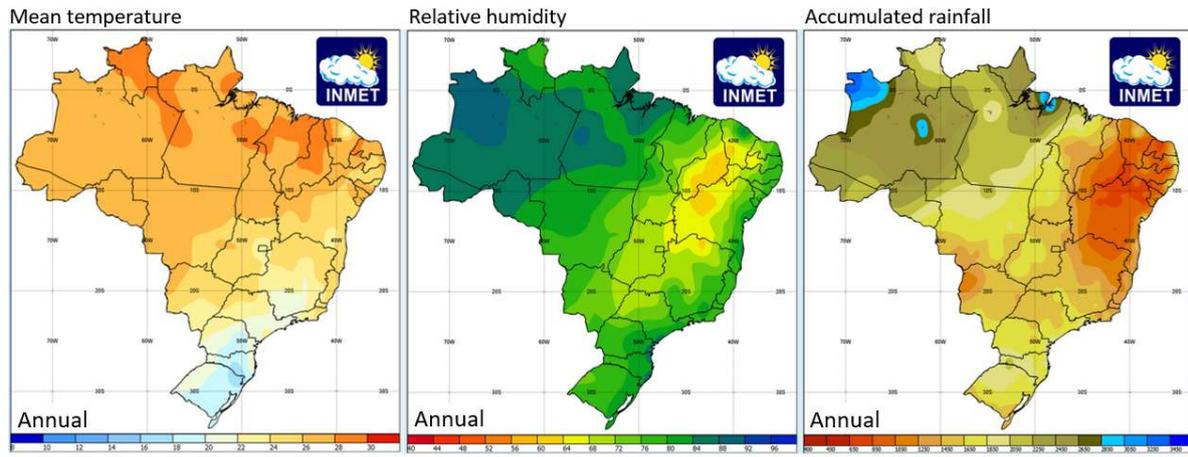


Figure 2: Maps 1, 2 e 3: Brazilian climatological data, period 1981 – 2010 [21].

## 4. Discussion

### 4.1. Occupational hygiene in slave labour

This work gathered information on the general conditions of exposure to physical, chemical and biological agents in labour environments and accommodation (*senzalas*) of enslaved workers from colonial and imperial Brazil. This information came from scientific articles and other texts, including original reports of the period. A considerable portion of the data was found in rare books of the 19th century (table 1) dating from the period of legalised slavery in Brazil, identified through cross-references.

The 20 studies included presented descriptions with a degree of objectivity considered by the authors as reliable. The necessary data for this work were extracted, summarised and systematised in Table 1. However, neither work aimed to study, analyse or describe aspects related to OHS. For this reason, although the studies included good descriptions, they were included in a complementary way to the report about the work done by the slaves.

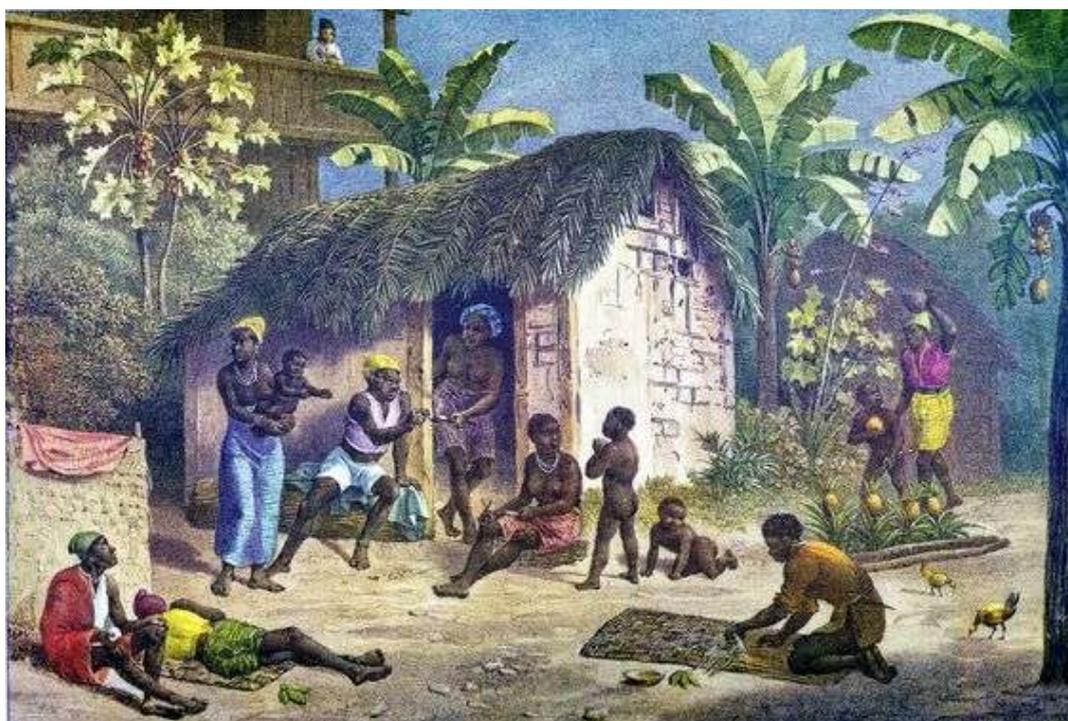
Some of the analysed studies present more superficial descriptive elements, with sentences or paragraphs which do not contain profound descriptions, but they help in the general description and reinforce the items obtained from other sources with more detailed elements and greater descriptive accuracy. Some of the rare 19th-century publications about the slaves' management were highlighted [3, 20] due to their technical and scientific character facing the economic needs of the farmers at the period, and detailing technical and climatic aspects of the activities carried out by the slaves. Even the ways of avoiding diseases and death, to achieve the maximum possible economic incomes in the face of the invested capital in their acquisition were presented.

The most profitable agricultural products of the time were those of hot climate, whose production was destined for export. The production of cotton, rice, coffee, and sugar cane made the majority of slaves work in coastal and tropical areas where the large farms were located. [16]. Nineteenth-century books [12, 13, 15, 20, 25] describe rainy hot weather conditions, with temperatures often above 30 °C, sometimes above 40 °C. These temperatures were accompanied by rainfall that could last several days, with pluviometry indices easily exceeding the 300 mm monthly in rainy seasons, more particularly in the regions used for crops of agricultural products for exportation [29]. The same hot and humid climate that is so conducive to tropical agricultural export crops also promoted the proliferation of insect vectors of diseases and other poisonous animals [18, 25], especially malaria and yellow fever mosquitoes that reproduced easily in the standing waters of the plantations [5]. In addition to these natural factors, dust, gases, smokes, and heat also contributed to the precarious general conditions of occupational hygiene, resulting from activities such as burning forests and furnaces for the processing of sugarcane in sugar mills [2,16,18].

Because of the intense heat and humidity, the enslaved worker was always wet with sweat or rain, since these storms were not considered as obstacles to carrying out the tasks. The exposure to

214 contaminants from other farms, such as liquids and aerosols (dust, vegetable fibres, gases, and  
215 fumes), generally also took place without any physical or administrative protection measures being  
216 taken [3].

217 When the slave went to sleep for 5 or 6 hours until the next morning for a new working day, he  
218 did it with his body and clothes not only impregnated with sweat but also with remnants of other  
219 body fluids, and often also contaminants chemicals such as dust and fumes. They slept with their  
220 working clothes, day after day on decks and mats inside large or small wooden and clay shacks,  
221 walled with raw clay and covered with leaves. These huts known as *senzalas* had no windows, only  
222 small openings near the roof of leaves that guaranteed the circulation of air for their many  
223 inhabitants. They used to be the worst structures of the farms, the least resistant. However, it was  
224 still usual to lock the door. Couples used to have the right to live in a small separate shack (Figure 3)  
225 constructed similarly, a kind of mini "Senzala" [16].



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Figure 3: Housing and clothing of the 19th Century slaves [23].

228 The reduced ventilation of the *senzalas* did not allow the dispersion of the contaminants  
229 impregnated and emanated from the clothes and the bodies. Due to the habit of keeping the *senzalas*  
230 door locked at night to make it difficult to escape, the captives ended up making their physiological  
231 needs within those spaces. For this reason, *senzalas* were commonly described as fetid and unhealthy  
232 [16], being a biological severe risk factor. Under these conditions, *senzalas* were by themselves a  
233 factor for the propagation and spread of various chemical and biological contaminants among slaves.

234 In addition, the foul-smelly slave's clothes, besides wet with sweat and charged with chemical  
235 and biological contaminants, they were few and insufficient to protect against climatic variations,  
236 namely temperature falls. These clothes of coarse and cheap tissues were distributed one or two times  
237 a year, always with an insufficient quantity to the needs. In the coffee plantations of southeastern  
238 Brazil, with a non-tropical climate and therefore with higher needs of protection against the cold,  
239 only three shirts, three pairs of trousers and jackets, a hat and two blankets were delivered each year  
240 [2]. In regions with a warmer climate, the quantity of clothing supplied was significantly lower. In  
241 Maranhão, a little number of clothes were provided to slaves that, in general, walked naked or  
242 dressed in a small thong [13, 18]. They could also wear long johns below the knee, without a shirt, as  
243 was common in Bahia [16].

244 In farms with a more technical administration, slaves should change dirty clothes for clean once  
245 a week on Sundays [20]. However, no evidence was found that this practice was widespread among  
246 farmers and, due to the recurrent information by the different authors of that period regarding the  
247 insufficiency of clothing supply, probably this was not a common practice.

248 The continued use of few and dirty pieces of clothing added to the high mechanical and chemical  
249 wear to which the same pieces were submitted as a result of the heavy work routine in the fields and  
250 also in the mills, ended up exposing the slaves, even more, when storms occurred. The clothing  
251 usually provided was not sufficient because it could not have the necessary durability for the time  
252 interval between two clothing supplies. In the last months before the new clothes delivery, the slaves  
253 were dressed with the tatters that remained [4].

254 The most common routine among the slaves on the farms can be considered as heavy work by  
255 the current criteria (ISO 7243:2017) [30] for a hot and humid climate [3, 29]. Nevertheless, in hot  
256 climatic conditions and with the metabolic demands at work, scarcity of clothing became less  
257 damaging, since worker clothing influences thermal stress. Its use implies an increase in the  
258 correction values to the WBGT index, depending on the type of used clothing [30-32].

259 However, both in the accomplishment of activities in milder climatic conditions or during the  
260 night with lower temperature, the slaves were thermally unprotected [27]. The scarcity of clothes  
261 involved a great heat dissipation via a deficient or no thermal insulation and permeability of their  
262 cotton clothes already soaked with sweat.

263 In general, the difficulty of having clothing other than those provided by the slaveholder made  
264 this population much more exposed to climatic variations than the free poor population, although  
265 the type of clothing did not differentiate much between both groups [18].

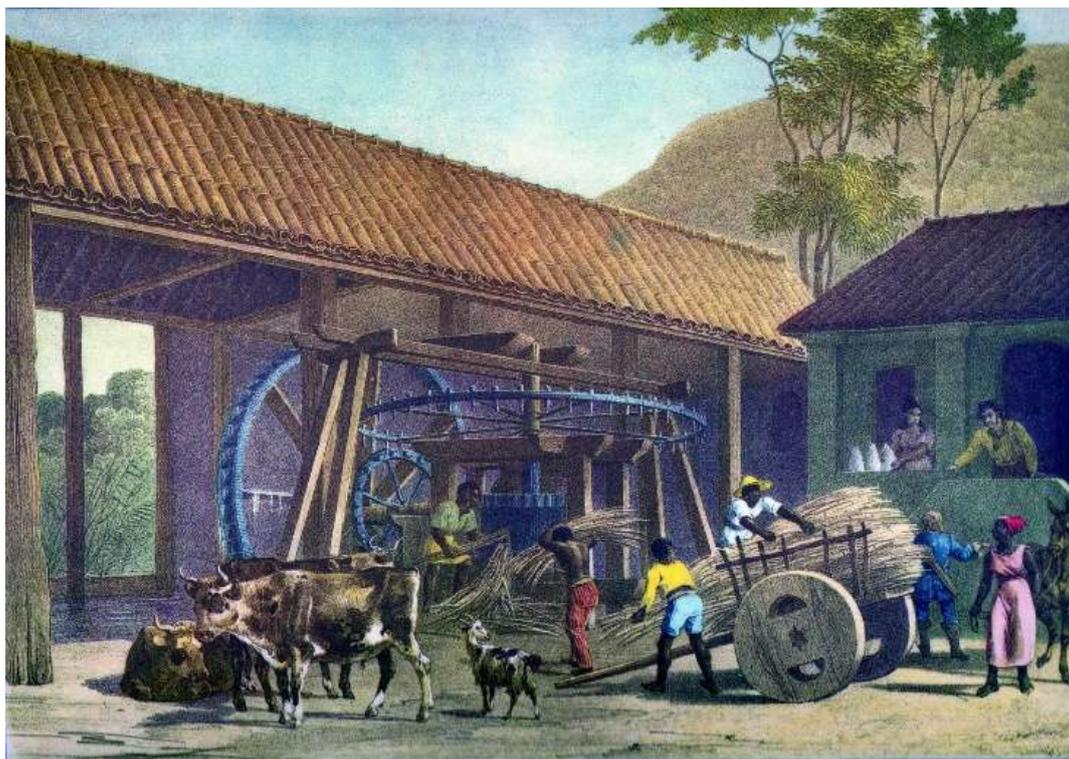
266 The use of equipment (machines and mills) by slaves was a common source of chemical risks,  
267 namely fibrogenic and non-fibrogenic aerosols resulting from the beneficiation processes carried out  
268 in the devices. The heat from furnaces and controlled burning of forests was also a regular source of  
269 risks for this population [16].

270 The available machines for agriculture at that period were widely used in the most significant  
271 properties, and their operating mode was detailed in several works [3, 16, 18, 20, 33]. There were mills  
272 for various purposes, such as ginning cotton, processing sugar (Figure 4) and grinding grain, an  
273 animal or human has changed in most farms for the use of hydraulic power. Subsequently, with the  
274 appearance of steam machines, some farms joined the use of this new driving force.

275 By checking the details of each stage of sugarcane mills production process, it was possible to  
276 extract details about the occupational hygiene conditions such as the presence of fumes, vapours,  
277 gases, furnace heat and humidity [16].

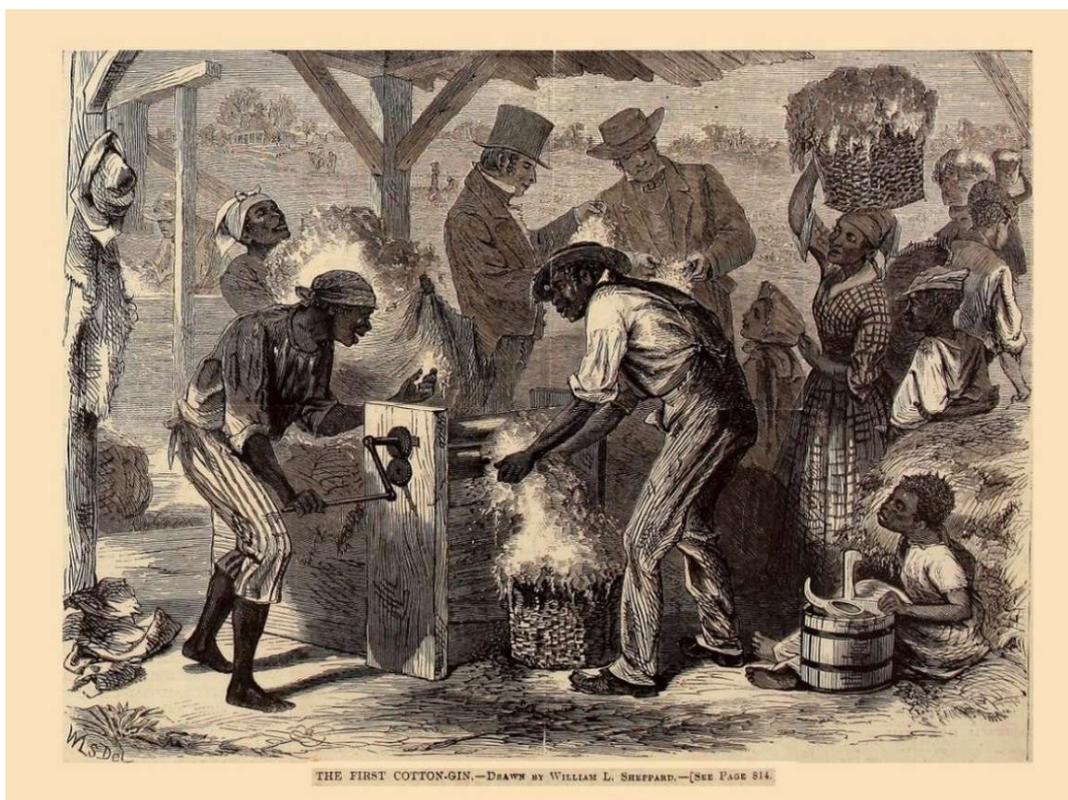
278 The processes of heat generation with the burning of firewood and other materials, such as  
279 sugarcane bagasse, were used in the 19th century in several activities, such as cooking food, pottery  
280 and steam generation in pressure boilers. However, It was in the sugar-producing plants that the use  
281 of heat was more intense. Although the smoke produced there is less damaging if considering only  
282 the respirable fraction (mean of 1.3% by volume) when compared to the smoke from sugar-cane  
283 leaves [34], the exposure of slaves to this chemical agent was intense at the periods of the year in  
284 which these activities were carried out. Exposure to the gases resulting from the firewood burning to  
285 the vapours, and dust resulting from sugar-cane processing was more pronounced and continuous  
286 throughout the sugar production period. This production lasted several months a year, with at least  
287 14 hours of daily work. [16].

288 Cotton ginning mills (Figure 5) were usually driven by human pull through large cranks. They  
289 were machines of simple construction and operation, but they were highly productive compared to  
290 the manual cottonseed removal. Although it is considerably simpler than sugar production and does  
291 not produce fumes or vapours [12,16], cotton processing produced vegetable fibres that, when  
292 dispersed by the working environment, ended up being inhaled by the slaves. Occupational exposure  
293 to cotton dust, in its breathable fraction, is associated with an increased prevalence of respiratory  
294 symptoms and disorders among directly exposed workers [35, 36].



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**Figure 4:** Slaves in sugar-cane mill [23].



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**Figure 5:** Slaves operating a cotton ginning mill [37].

299 Vegetable dust also occurred in rice processing, an agricultural crop which was also used,  
300 mainly for export and which was often cultivated on the same farms as cotton [38]. Rice processing  
301 was particularly problematic for the slaves because of the shell that, when unleashed from the grain  
302 tended to adhere to the soaked bodies with sweat and generate irritation and dermatitis. Slaves were  
303 exposed to the risk of death when they slept in warehouses, where rice was stored because of the

304 deadly gases generated by this agricultural product [20]. The current version of these warehouses are  
305 the grain silos. These structures present the same risks already known to 19th-century rice farmers.  
306 The deadly vapours are toxic and asphyxiating gases, mainly nitrogen dioxide (NO<sub>2</sub>) and carbon  
307 dioxide (CO<sub>2</sub>), produced by the grains after harvest and that can reach high concentrations in low  
308 ventilation environments [39].

309 Contaminants with atmospheric dispersion generated by the different agro-industrial processes  
310 tended to impregnate the bodies, hair and clothes of the slaves, and then contaminated the other  
311 slaves, products that, later, would contaminate the other slaves during the night, in the closed  
312 environment of the *senzalas*. This process of indirect dispersion of the contaminants had as next cause,  
313 the deficient personal hygiene and the uncommon exchange of clothes practised in the slavery  
314 system. Although this shared indirect contamination during the night was significantly lower than  
315 that of the directly exposed captives, it contributed to the increase of the diseases related to these  
316 chemical agents.

317 Technical-scientific works [3, 20, 25] directed at farmers of the first half of the 19th century  
318 attempted to alert about the risks associated with the slaves' exposure to environmental  
319 contaminants. This concern shows clearly that the concentrations of these agents were so high that  
320 they could stand out, even at high risks and daily aggressions of the forced labour. However, farms  
321 reality showed that little importance to these alerts was given. Authors like Taunay, do Alferes and  
322 Imbert related several environmental issues such as exposure to some contaminants - including those  
323 generated in the processes of upgrading with machines and mills, inadequate protection of climatic  
324 conditions and the precariousness of the accommodations, with the consequent illness and deaths of  
325 slaves. These facts show that, in the view of these authors, this type of conditions would contribute  
326 to the lack of profitability of rural properties.

#### 327 4.2. Occupational hygiene in modern slavery

328 In the period when slavery was a legal practice in Brazil, there was a need to guarantee a  
329 minimum lifespan to the slaves, in order to guarantee the amortisation and the return of the  
330 investment. The cost of a slave in the nineteenth century had an average value, per individual,  
331 sometimes greater than 1 kg of gold [41-44].

332 In neo-slavery or modern slavery, this concern with capital recovery becomes secondary or  
333 almost non-existent because the financial cost of acquiring the neo-slave worker is often restricted to  
334 transportation to the farm and the commission to the seducer. In this scenario, concerns over the  
335 lifespan of such workers cease to exist. The concerns are focused on hiding the traces of such practices.  
336 One of the known methods is to promote a high turnover of these workers who, after having worked  
337 without any safety or health measures exercising high-risk functions, are replaced by others after  
338 periods that may not exceed one year [40].

339 Thus, despite all the social and technological evolution that has taken place during the last two  
340 centuries, the environmental labor conditions observed in the slave labor of the 19th century end up  
341 replicating in a very similar way, or in some cases even worse, in the 21st century's neo-slavery, since  
342 the initial investment is substantially lower.

343 As an example, the activity of sugarcane manual cutting, which is still done in the same way and  
344 with the same type of environmental exposure as in the 19th century, was observed. This activity is  
345 one of the most frequently classified as analogous to slavery by official labour inspection organisms.  
346 The burning of the sugar cane consists of burning the leaves of the canes before the beginning of the  
347 harvest. After the combustion, the stem of the cane remains without leaves and, therefore, it is easier  
348 to be harvested. This process is still widely used in the 21st century despite the greater mechanisation  
349 of agricultural labour. This burning was and is still especially damaging since the smoke generated  
350 in the process is mostly (~96% by weight) within the respirable fraction (aerodynamic diameter <4  
351 µm) [34].

352 Another common activity carried out by the neo-slaves in a similar way to that of the nineteenth  
353 century is the controlled burning of forest areas to open new agricultural fields, or in planting areas  
354 to facilitate sugarcane harvesting. In these activities, exposure to wood-burning smoke is less

355 damaging in terms of the breathable fraction (mean 1.3% by volume) when compared to smoke from  
356 cane leaves [34]. However, forest fires show very high mean values of exposure to fine particulate  
357 matter (PM<sub>2.5</sub>) and carbon monoxide (CO) for those dealing with their extinction or control [45, 46].

358 Neo-slaves accommodation system is usually made up of improvised and unsafe structures,  
359 usually consisting only of a plastic tarpaulin over a green wood structure cut in the nearest forest.  
360 These places without rooms or even external walls, offer even more inadequate protection against  
361 weather changes than the old *senzalas*. In the working activities, the modern slave worker uses his  
362 clothes until they become unusable [40, 47]. The owners of these neo-slaves do not supply new  
363 clothes. The neo-slave is obliged to use old and dirty rags without conditions to protect against  
364 weather variations as well as the 19th-century slaves.

365 The unprotected exposure to organic dust, which severely damages the respiratory system [48-  
366 50], is frequent in most cotton ginning operations in small agro-industries of developing countries in  
367 the 21st century. In this operation, the roller mills [51] are still used, operating similarly to the ones  
368 of 19th-century cotton farms.

369 These activities, although not officially characterised as analogous to slavery, they have  
370 occupational hygiene conditions similar to the manual mills operated by the Brazilian slaves of the  
371 19th century. In general, these activities are developed visibly in very dusty environments and the  
372 workers directly involved in this kind of cotton processing, show high rates of respiratory problems  
373 characteristic of unprotected exposure to inhalable vegetal fibres [36].

374 On average, the operators of these mills are exposed to concentrations ranging from 2 mg / m<sup>3</sup>  
375 to 5 mg / m<sup>3</sup> of inhalable cotton fibre dust [51-53]. For many times, exceeding the tolerance limit of  
376 0.2 mg / m<sup>3</sup> suggested by the American Conference of Governmental Industrial Hygienists (ACGIH),  
377 British Occupational Hygiene Society and Occupational Safety and Health Administration (OSHA).

## 378 5. Conclusions

379 This work starts as a literature review based on the PRISMA Statement methodology, which  
380 presents as a strong point the reproducibility of the processes of identification, extraction, selection,  
381 and systematisation of the information. It was possible, in this research, to identify detailed and  
382 concise descriptions of the daily activity of the slaves' populations, both in current scientific literature  
383 and in rare books of the 19th century. The general perception of the climatic, environmental and  
384 occupational hygiene contexts to which the captive worker was exposed as a result of the equipment  
385 used, of the clothing characteristics and housing conditions, as agents that generate and disseminate  
386 contaminants, allow comparisons with the current occupational hygiene conditions relative to the  
387 neo-slavery.

388 The slaves were exposed in an aggravated manner to bad weather conditions and the physical,  
389 chemical and biological agents generated, generally, in an uncontrolled way in each developed work  
390 activity. These contaminants had several origins, such as controlled burns, furnaces or vectors of  
391 infectious diseases that spread in the plantations in a poorly controlled manner.

392 Due to the organisational dynamics applied to enslaved workers, with a reduced number of  
393 daily hours to sleep or rest, and depending almost exclusively on what was supplied to them by the  
394 landlord, the exposure to harmful agents was significant even when they were not working. The  
395 insufficiency of garments and the few conditions for personal hygiene forced them to wear the same  
396 dirty and contaminated clothes for several days and nights. All this was added to the constructive  
397 and organisational model of the *senzalas*, where the sleeping conditions have also become a source of  
398 contamination and spread of disease among all slaves. Not only through the products that  
399 impregnated their bodies and clothes, but also through the contact with insects and other animals  
400 potentially vectors of diseases.

401 The working conditions analysed are similar in all regions of Brazil, which can be observed in  
402 the geographical origin of the descriptions summarised in table 1, despite the country's continental  
403 dimensions and the climatic differences and the agricultural products adopted. Thus, it was possible  
404 to demonstrate the homogeneity with which the production, exposure and dissemination of  
405 contaminating agents in slave labour occurred in nineteenth-century Brazil, based on consistent

406 reports from primary and independent sources, from different periods and regions of a country as  
407 large and diverse as Brazil.

408 In the twenty-first century's neo-slavery, the financial value involved in acquiring human beings  
409 is often inferior to that of the nineteenth century, which significantly reduces the concern with the  
410 health and safety of the neo-slave workers.

411 Despite the social and technological development of the last two centuries, in the rural neo-  
412 slavery of the twenty-first century, the conditions of climatological exposure and environmental and  
413 occupational hygiene occur in a very similar way to that of the captive workers of the nineteenth  
414 century. The conditions of exposure to abrupt weather variations and storms remain, the physical,  
415 chemical and biological agents did not vary, and accommodation and clothing conditions were not  
416 significantly modified.

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