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Research Paper

IMPACT OF BURNT BRICKS PRODUCTION ON SOIL BACTERIA AND FUNGI AT BRICK SITES IN BENUE STATE, NIGERIA

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Abstract

Despite the rich soil that favours massive production of burnt bricks in Benue State, there is dearth of information on the impact of burnt brick production on bacteria and fungi species in the State. This study was conceived with the objectives of identifying species of bacteria and fungi found at burnt brick sites, determining the effect of depth of soil excavation on the distribution of identified bacteria and fungi, and assessment of viable colony counts of bacteria at varying depths of soil excavation. Eight (8) Local Government areas (LGAs), notable for brick production, were purposively selected for the study. From each of the selected LGAs, two burnt brick sites were chosen for investigation – one as control for 0-5cm depth, and the others at 0-10cm, 10-15cm, 60-65cm, and 90-95cm depths. Thus, 128 composite soil samples were collected from 32 soil pits located in 16 brick sites within the study area. Another batch of 128 samples of composite soil were taken at 0-10cm depth at various locations of brick sites - burnt, vegetated, devegetated, and access road areas. Serial dilutions of each soil sample and analyses of microbes and fungi were done in the laboratory. Results showed that 19 bacteria and fungi species were found at various points of the brick production sites. Also, there are significant differences in the mean frequency of occurrence of bacteria and fungi species in all the soil excavation depths ($p<0.05$). The study also showed that the total variable colony count (TVC) values decrease significantly with increasing depth of soil excavation (at $p<0.5$). The study recommends the use of large permanent kilns for firing to reduce the effect of wood-based firing on soil bacteria and fungi, and afforestation of brick sites through the application of poultry droppings and cow dung to increase the organic matter content of soils to help reverse decreasing bacteria and fungi viable colony counts.

Key words: Burnt Brick, Bacteria, Fungi, Soil Excavation Depth, Total Viable Colony Counts.

INTRODUCTION

Bacteria are micro-organisms which are so minute that they can hardly be seen clearly even with the aid of a microscope. Bacteria are the oldest, structurally simplest and the most abundant forms of life on earth (Raven and Johnson, 2002)).Other forms of micro-organisms include: fungi, viruses and protists like protozoa and microscopic algae..

Environmental factors that affect the growth and distribution of bacteria and fungi as micro-organisms include: temperature and oxygen concentration. Temperature, for example, affects the growth and distribution of an organism in a particular environment. Micro-organisms also differ widely in their temperature requirements. The bacterium *Escherichia coli,* for example, can live in the gut of mammals as well as in the soil, and its optimum temperature for growth is 37˚C, while *Candida* yeast (a fungus) grows optimally at a temperature of 15˚C, but can also grow at temperatures lower than 5˚C. Similarly, micro-organisms differ in their requirement for minimum, maximum and optimum temperatures, but for most micro-organisms, the optimum pH value that favours their growth and distribution is 7.

Most bacteria and fungi (like *Penicillium*, algae and protozoans) are obligate aerobes, living only when oxygen is present. *Escherichia coli* is a facultative aerobe, requiring oxygen but can also live in an environment lacking in oxygen. The bacterium *Clostridium tetani* survives only under aerobic conditions where oxygen is available.

Bacteria and fungi have diverse uses to humanity.For example, infection with Clamydia was difficult to diagnose until the discovery of monoclonal antibodies in diagnosing the disease. Antibodies are also used in the diagnostic kit for streptococcal throat infections which are used by medical doctors in diagnosing and treatment of patients. The bacteria *Thiabacillus ferroxidons*, T. *thioxidons* and *Laptospirillum ferroxidons* are mainly responsible for the leaching of metal sulphates in the soil. These bacteria thrive mainly in acid conditions and can work at high temperatures. Bacterial leaching is now widely used globally as an additional technique for extracting copper, and uranium ores. (Taylor *et. al.*, 1997). Several species of the bacterium *Bacillus* are widely used in the commercial manufacture of biological washing powders which are vital in removing stains of biological origin such as blood, grass, and eggs formed from proteins and other materials. Yeast or bacteria cells have been used in conjunction with electrodes to measure alcohols, phenols, methane, vinegar, sugar and antibiotics. These cells facilitate the monitoring of conditions inside fomenters, which is particularly vital for continuous culture. Also an oxygen-detecting system which is about 100 times more sensitive has been developed which employs bacteria that become luminous when exposed to traces of oxygen.

Biological degradation is the process that leads to a decline in the humus content of soil through mineralisation (Solomon 1994). Decomposition of organic matter is enhanced by microbial activity. The bulk of organic matter is concentrated near the soil surface in the form of decaying leaves and stems. Therefore mining of soil for brick production and erosion of topsoil results in a rapid decrease in soil organic matter levels and therefore causes a loss of food for soil micro organisms. Once the organic matter layer is depleted, soil productivity and crop yields decline because of the degraded soil structure and depletion of nutrients.

Microbial biomass is pivotal to the stability of soil aggregates. Thus, elimination of soil micro organisms (by soil mining, erosion, burning etc.) causes physical damage to the soil ecosystem. These physical effects may in turn accelerate erosion, organic matter depletion, and further reduce microbial activity. All factors that favour the production and decomposition of organic matter tend to minimise the risk of biological degradation. The objectives of this study were to: (1) identify species of bacteria and fungi found at wood-based burnt brick sites and arrange them based on their frequency of occurrence in soil samples (ii) determine the effect of depth of soil excavation on the distribution of identified bacteria/fungi (iii) assess viable colony counts of bacteria/fungi at varying depths of soil excavation.

METHODOLOGY

The Study Area

This research was carried out in Benue State, Nigeria between April 2012 and December 2013. Benue State is made up of twenty three Local Government Areas which fall under three geo-political zones (A, B, and C). Commercial wood-based clay bricks are produced mainly in Zones A and B. Local Governments for the study were therefore selected based on this criterion. Out of the 14 Local Governments that make up Zones A and B, 8 were selected for the study based on their ranking in terms of abundance of clay deposits and massive production of burnt

bricks. The selected Local Governments included: Buruku (BK), Gboko (GB), Gwer West (GW), Konshisha (KN), Kwande (KW), Makurdi (MK), Ushongo (US) and Vandeikya (VK).

Field Study

From each of the selected Local Governments, two burnt brick sites were chosen for investigation. Two soil pits were dug at each of the sixteen brick sites selected and samples taken at uniform intervals of 0-5cm (as control),10-15cm, 60-65cm, and 90-95cm for each of the soil pits using labelled sterile Vacutainer bottles. Thus, a total of 96 soil samples were collected from thirty-two soil pits located in sixteen brick sites within the study area. All collected samples were taken to the laboratory on the day of collection and stored in the refrigerator to ensure that the samples' quality did not deteriorate.

From each of the soil samples collected, 1g was taken, weighed and 10mls of Normal saline added to it. These served as stock for each of the samples. Five (5) test tubes containing 9 mls of normal saline were arranged serially on a test tube rack for each of the samples.. From the stock solution, 1ml was dispensed into the 1st test tube, giving a dilution of 1/10.This was mixed and 1ml transferred to the second test tube, giving a further dilution of 1/100. Further dilutions were made up to the 5th tube, giving a dilution of 1/100000 (or $1x10^{-5}$). 1ml from the 5th test tube was dispensed into separate petri-dishes. Then 20ml of molten nutrient agar were dispensed into each of the petri-dishes..These plates were duplicated with duplicates using Sabourad dextrose agar for determination of yeast and dermatophytes, while the former was for determination of bacteria

The inoculated plates were then incubated at 37°C for 24-48 hours, while the second duplicate was incubated at room temperature (22-35°C) for dermatophytes and yeast. After incubation, growth of microbes were observed microscopically and characterised based on biochemical reactions and morphology.

RESULTS

Occurence of Bacteria Species at Brick Sites

A total of 19 species of bacteria were identified at various locations of the brick sites as indicated in Table 1.

TABLE 1: FREQUENCY OF OCCURRENCE OF BACTERIA SPECIES AT VARIOUS POINTS OF BRICK SITES IN STUDIED AREA

S/No	Bacteria Species	Frequency of sighting at Various Points of Brick Site				Total Frequency per Species
		Vegetated	Devegetated	Burnt	Road	
1	*Clostrodium*	31	26	21	22	100
2	*Bacillus*	24	25	25	24	98
3	*Actinomyces*	19	18	13	13	63
4	*Escherichia coli*	11	9	9	8	36
5	*Compylobacter*	5	13	8	9	35
6	*Enterococcus*	10	7	3	7	27
7	*Psodomonas*	12	7	3	4	26
8	*Aeromonas*	4	6	6	9	25
9	*Streptomyces*	6	4	4	9	23
10	*Serretia*	4	4	5	4	17
11	*Streptococcus*	5	4	1	1	11
12	*Agrobacterium*	3	2	-	-	5
13	*Staphylococcus*	2	2	2	1	7
14	*Listeria*	2	-	-	-	2
15	*Proteus*	1	1	-	-	2
16	*Bacteroides*	-	-	1	-	1
17	*Streptolyces*	-	-	1	-	1
18	*Morgenella morgenii*	1	-	-	-	1
19	*Peptostaphylococcus*	1	-	-	-	1
	Total Frequency	**141**	**128**	**102**	**111**	
	Mean No of Species	**8.42**	**6.74**	**5.37**	**5.84**	
	Total species observed	**17**	**14**	**14**	**12**	

The mean frequencies of occurrence of *Clostodium* at burnt, devegetated, road sitle(s) and vegetated areas were 21, 26, 22, and 31 respectively The frequency of occurrence of *Clostodium* varied significantly between burnt, devegetated, road sites and vegetated areas Similarly, the distribution of *Clostodium, Psodomonas, compylobacter, Enterococcus, Agrobacterium, Streptococcus, Bacteroides, Morgenella morgenii* and *Peptostaphylococcus*, varied significantly at burnt, devegetated, roaded and vegetated parts of brick sites. *Serretia, Staphylococcus, Strephtolyces. Listeria* and *Proteus* species did not show significant differences in distribution at vegetated, burnt, devegetated and roaded parts of brick sites.

The mean frequency of occurrence of species of bacteria at burnt, devegetated, roaded and vegetated parts of brick sites were 5.37, 6.74, 5.84 and 8.42 respectively. The mean frequencies of occurrence of bacteria species at burnt areas differed significantly with frequency of occurrence at devegetated, and access road areas. Also mean frequency of occurrence of bacteria species at devegetated, and access road areas differed significantly with frequency of occurrence of species at vegetated areas of brick sites.

Occurrence of Fungi Species at Brick Sites

The frequency of occurrence of fungi species in vegetated, devegetated, burnt and access road areas (Table 2) of bricks sites followed the same pattern as that of bacteria presented in Table 1.

TABLE 2: FREQUENCY OF OCCURRENCE OF FUNGI SPECIES AT VARIOUS POINTS OF BRICK SITES

Fungi	Point of Brick Site Assessed				
	Vegetated	Devegetated	Burnt	Road	LSD
Aspergillus	29.0±0.50^{e}	28.0±0.50^{f}	21.0±0.50^{e}	24.0±0.50^{e}	1.871
Mucor	17.0±0.50^{d}	19.0±0.00^{e}	21.0±0.50^{d}	16.0±0.50^{d}	1.210
Pennicillium	20.0±0.0^{e}	9.0±0.00^{d}	11.0±0.50^{c}	14.0±0.50^{d}	1.967
Nocardia	6.0±0.50^{c}	10.0±0.50^{d}	3.0±0.00^{ab}	10.0±0.00^{c}	1.957
Candida	4.0±0.50^{b}	6.0±0.50^{c}	5.0±0.00^{b}	3.0±0.50^{ab}	1.971
Rhodotorulla	2.0±0.50^{a}	2.0±0.50^{b}	2.0±0.00^{ab}	5.0±0.00^{b}	1.562
Trychophyton	4.0±0.50^{b}	2.0±0.00^{b}	0.0±0.00^{a}	2.0±0.00^{ab}	1.861
Epidomophyton	1.0±0.00^{a}	0.00±0.00^{a}	0.0±0.00^{a}	0.0±0.00^{a}	1.824
Mean±SEM	11.4±1.23^{b}	10.5.20±1.02^{ab}	7.68±1.42^{a}	9.25±1.37^{ab}	0.921

Means on the same column with the same superscript are not statistically different (p>0.05)

The most frequently occurring species of fungi within the vegetated areas of brick sites was *Aspergillus*, followed by *Pennicillium*. The highest number of fungi species (7) was observed in vegetated areas of brick sites while the lowest number (5) was observed at burnt areas of brick sites. Burning and access road construction decreased the frequency of occurrence of fungi species more than devegetation (without burning and road construction). The frequency of occurrence of fungi species was significantly higher at vegetated areas of brick sites compared to all other areas observed.

Occurrence of Fungi Species at Various Depths of Soil Excavation

TABLE 3: FREQUENCY OF OCCURRENCE OF FUNGI SPECIES AT VARIOUS DEPTHS OF SOIL EXCAVATION AT BRICK SITES

S/No	Species of Fungi	Frequency of Occurrence at various depth ranges (cm)				
		0-5cm (Control)	10-15	60-65	90-95	Total
1	*Aspergillus*	34^{cd}	30^{c}	22^{b}	17^{a}	103
2	*Mucor*	29^{bc}	25^{b}	5^{a}	5^{a}	64
3	*Pennicillium*	20^{bc}	18^{bc}	13^{b}	4^{a}	55
4	*Nocardia*	19^{bc}	17^{bc}	12^{b}	5^{a}	53
5	*Candida*	11^{bc}	$9b^{c}$	4^{b}	$-^{ns}$	24
6	*Rhodotorulla*	2^{ab}	1^{a}	1^{a}	3^{bc}	7
7	*Trychophyton*	3^{a}	2^{a}	$-^{ns}$	$-^{ns}$	5
	Total frequency	**118**	**102**	**57**	**37**	**314**
	Total species observed	**7**	**7**	**6**	**5**	**7**
	Mean frequency of occurrence of Specis	**16.86^{c}**	**14.57^{c}**	**9.50^{b}**	**6.80^{a}**	**47.73**

Table 3 indicates that within the 0-5cm depth range of soil excavation, *Aspergillus* species of fungi exhibited the highest frequency of occurrence (34) followed by *Mucor* species (29) while *Trychophyton* species of fungi exhibited the lowest frequency of occurrence (3). The highest frequency of sighting of fungi species was witnessed within the 0-5cm depth range of soil excavation for all species of fungi while the lowest frequency of occurrence was witnessed within the 90-95cm depth range of soil excavation. Mean frequencies of occurrence of fungi species for the soil excavation depth ranges of 0-5cm, 10-15cm, 60-65cm and 90-95cm were 16.86, 14.57,9.50 and6.80, respectively. There were significant differences in the mean frequency of occurrence of fungi species in all the four soil excavation depth ranges of 0-5cm, 10-15cm, 60-65cm and 90-95cm ($p<0.05$).

Occurrence of Bacteria Species at Various Depths of Soil Excavation

TABLE 4: FREQUENCY OF OCCURRENCE OF BACTERIA SPECIES AT VARIOUS DEPTHS OF SOIL EXCAVATION AT BRICK SITES

S/No	Species of Bacteria	Frequency of Occurrence at varying Depths of Soil Excavation				
		0-5cm (Control)	10-15 cm	60-65 Cm	90-95 cm	Total
1	*Bacillus*	32^{b}	31^{b}	26^{a}	26^{a}	113
2	*Clostridium*	31^{c}	28^{bc}	25^{ab}	22^{a}	106
3	*Psodomonas*	18^{ab}	16^{ab}	12^{a}	11^{a}	57
4	*Escherichia coli*	30^{bc}	26^{b}	2^{a}	1^{a}	59
5	*Actimomycetes*	21^{ab}	19^{ab}	14^{a}	14^{a}	68
6	*Compylobacter*	17^{ab}	14^{b}	8^{ab}	3^{a}	42
7	*Enterococcus*	15^{b}	14^{b}	4^{a}	3^{a}	36
8	*Streptomycetes*	7^{ab}	5^{a}	5^{a}	10^{c}	27
9	*Aeromonas*	6^{ab}	4^{ab}	3^{a}	2^{a}	15
10	*Serretia*	5^{ab}	4^{ab}	2^{a}	2^{a}	13
11	*Agrobacter*	3^{a}	2^{a}	1^{a}	2^{a}	8
12	*Staphylococcus*	5^{a}	3^{a}	0.0^{ns}	0.0^{ns}	8
13	*Streptococcus*	3^{a}	2^{a}	0.0^{ns}	0.0^{ns}	5
14	*Fusabacterium*	2^{b}	1^{b}	1^{b}	0.0^{na}	4

15	*Listeria*	1^{a}	1^{a}	0.0^{ns}	0.0^{ns}	2
16	*Bacteroides*	1^{a}	1^{a}	0.0^{ns}	0.0^{ns}	2
	Total frequencyof occurrence	**197**	**171**	**84**	**72**	**524**
	Total species observed	**16**	**16**	**12**	**11**	**14**
	Mean Frequency of occurrence	**12.31^{b}**	**10.69^{ab}**	**7.00^{a}**	**6.55^{a}**	**37.43**

Means on the same column with the same superscript are not statistically different (p>0.05); ns= no significant difference

From Table 4, a total of 16 species of bacteria were identified at the four depth ranges of soil excavation investigated (0-5cm, 10-15cm, 60-65cm and 90-95cm). Within the 0-5 cm depth range, *Bacillus* species of bacteria exhibited the highest frequency of occurrence (320 closely followed by *Clostridium* (31). *Listeria* and *Bacteroides* specie of bacteria both had a frequency of occurrence of 1 which was the lowest frequency observed. Mean frequencies of occurrence of bacteria species at soil excavation depth ranges of 0-5cm, 10-15cm, 60-65cm and 90-95cm were 12.31, 10.69, 7.00 and 6.55 respectively. There were significant differences in the mean frequencies of occurrence off bacteria species between all the observed depth ranges (p<0.05).

Viable Colony Counts Of Bacteria At Varying Depths Of Soil Excavation

The effect of various burnt bricks activities on total bacteria viable colony count (TVC) in all studied Local Government Areas (LGAs) is depicted in Table 3. These TVC values were significantly higher than all TVC values at the soil excavation depth range of 90-95cm. This shows that the TVC values decreases significantly with increasing depth of soil excavation (p<0.05). Within the 0-10 cm depth, burnt areas of brick sites had the lowest mean TVC values. Vegetated areas had the highest TVC values which were significantly higher than TVC values at devegetated, burnt and access road areas (p<0.05).

TABLE 3: EFFECT OF VARIOUS ACTIVITIES ON THE BACTERIA TOTAL VIABLE COLONY COUNTS (TVC) AT BRICK SITES BY LOCAL GOVERNMENT AREA IN BENUE STATE

S/No	Activity	Soil Depth (cm)	Mean Bacteria Total viable counts (TVCs) by Local Government Area (Cfu/M)x10^{7}							
			BK	GB	GW	KN	KW	MK	US	VK
1	Burning of bricks	0-10	0.7875	0.4200	07350	41.25	0.3975	0.4350	0.4300	0.3600
2	Vegetation	0-10	1.2850	1.7800	1.8150	0.9150	1.0100	0.9850	2.0230	0.7925
3	De-vegetation	0-10	1.0250	1.2700	1.0450	0.5000	0.7125	0.5950	0.9700	0.5925
4	Transportation (Access Roads)	0-10	0.6600	0.7900	0.9150	0.4525	0.5125	0.4800	0.5375	0.4125
5	Soil excavation	10-15	2.1100	1.7775	2.2150	1.4025	2.4150	0.7975	1.3975	1.3650
		60-65	1.2275	0.89.25	1.9975	0.9525	1.8250	0.6800	1.0825	0.8450
		90-95	0.6600	0.8500	0.9625	0.4225	0.9700	0.6125	0.7975	0.5700

BK=Buruku; GB=Gboko; GW=Gwer-West; Kn= Konshisha; Kw= Kwande; Mk=Makurdi; US= Ushongo Vandeikya= Vandeikya

Source: Field Survey, 2013

DISCUSSION OF RESULTS

The mean frequencies of occurrence of Bacillus at burnt, devegetated, and access road areas were significantly lower than at vegetated areas. Frequency of occurrence of *Bacillus* was significantly lower at burnt, devegetated, aceess road areas than at vegetated areas. Similarly, the distribution of *Clostodium, Psodomonas, compylobacter, Enterococcus, Agrobacterium, Streptococcus, Bacteroides, Morgenella morgenii* and *Peptostaphylococcus*, varied significantly at burnt, devegetated, roaded and vegetated parts of brick sites. *Serretia, Staphylococcus, Strephtolyces. Listeria* and *Proteus* species did not show significant differences in distribution at burnt, devegetated, access road and vegetated parts of brick sites. Brick firing, devegetation, and construction of access roads are all capable of significantly altering the micro-climate for micro-organisms. Observed differences in the frequency of distribution of microbes at different locations of brick sites may be closely linked to associated changes in their micro-habitat as a result of bricks production activities (firing, access road construction, soil excavation).

Soil micro-organisms play an important role in nutrient cycling and energy flow, and they are extremely sensitive to environmental changes. Soil micro-organisms have numerous functional roles in ecosystems, including serving as sources and sinks of key nutrients and catalysts of nutrient transformations; acting as engineers and maintainers of soil structure; and forming mutualistic relationships with roots that improve plant fitness (Hart *et al*., 2005). Fire can significantly alter the distribution and frequency of sighting of microbes that affect large-scale processes such as nutrient cycling. The immediate effect of fire on soil microorganism is a reduction of their biomass. The intense fire can reduce a significant amount of biomass of microorganism. In fact peak bricks kiln temperatures often considerably exceed those required for killing most living beings (DeBano *et al*., 1998).

Few studies conducted on soil bacteria after fire suggest that bacterial community structure is significantly changed after fire events. Community structure of soil bacteria in post-fire can climax forest several years after fire can be more heterogeneous compared with that in unburned climax forest (Otsuka *et al.,* 2008). They observed that aerobic heterotrophic bacteria, including the acidophilic and sporulating ones, were stimulated by fire while cyanobacteria, was clearly depressed. Long-term positive effects of fire on bacteria were nullified except the sporulating ones which reached the unburned soil values, cyanobacteria also increased. Soil incubation improved the beneficial and diminished the negative fire effect on the micro biota (Vázquez *et al*., 1993), whereas Jaatinen et al. (2004) studied that there is no siginficant effect of forest fire on methane oxidizing bacteria. They suggested that fire increased CH_4 oxidation rates, but the increased pH after the fire and ash probably do not cause any alterations in methane oxidizing bacteria.

Woody biomass ash contains heavy metals and other toxic substances that may cause harm to the environment and human health if indiscriminately released; the ash must be handled carefully to avoid releasing toxic pollutants that might otherwise have been containable (Ljung and Nordin 1997). Although biomass ash is often treated as a hazardous waste, such disposal fails to take advantage of the beneficial components of ash, such as valuable nutrients. Because these nutrients are vital to long-term forest health, biomass ash holds promise as a soil supplement for harvested forests.

Mycorrhizal fungi maintain overall ecosystem health, as they play a crucial role in nutrient uptake, extended root life and protection against root pathogens. Stendell et al. (1999) studied that the total ectomycorrhizal biomass in the unburned plots did not differ for any core layer, while in the burnt site, the destruction of the litter organic layer resulted in an eight-fold reduction in total ectomycorrhizal biomass. Mycorrhizal biomass in the two mineral layers was not significantly reduced by the fire. Fire can affect soil arbuscular mycorrhizal (AM) fungi by changing the soil conditions and by directly altering AM proliferation (Rashid *et al.,* 1997). Compared with a nearby control area, the burnt site had a similar number of total spores but a lower number of viable AM fungal propagules (Rashid *et al*., 1997).

CONCLUSION AND RECOMMENDATION

Firing of bricks more than any other brick production activity, decreased bacteria total viable counts (TVCs) between 0-10cm soil depth. Burnt bricks firing decreased the frequency of occurrence (and thus the frequency of sighting) of both bacteria and fungi species in sampled soils throughout the study area. The depth of soil excavation was also negatively correlated to the frequency of occurrence/sighting of bacteria and fungi as well as the total viable bacteria and fungi colony counts (TVCs). Decreases in both frequencies of occurrence/sighting and TVC counts with increasing depth of soil excavation also implied a reduction in biomass of both bacteria and fungi. The diversity of both bacteria and fungi species also decreased with increasing depth of soil excavation.

The study therefore recommends the use of large permanent kilns for firing bricks to reduce the adverse effects of open-cast brick kilns, commonly found in brick producing areas, as well as to reduce the adverse effect of wood-based firing on soil bacteria and fungi. Also recommended is the afforestation of brick sites through the application of cow dungs and poultry droppings to increase the organic matter content of the soil, so as to help reverse the decreasing bacteria and fungi viable colony counts in the area.

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