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Assessment of Carbon Dioxide and pH Concentrations In Water Bodies Adjourning Fuelwood-Based Burnt Brick Sites: Implications for the Aquatic Environment in Benue State, Nigeria.

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ABSTRACT

Burning wood emits many gases including carbon dioxide , carbon monoxide and nitrous oxide which could dissolve in adjourning water bodies during wood-based brick firing. This study investigated the effect of fuelwood-based bricks firing on water pH and carbon dioxide (CO_2) concentrations in water bodies adjourning brick sites. The Randomized Complete Block Design (RCBD) was adopted as experimental units in this study. CO_2 and pH concentrations were assessed in eight LGAs of Benue State at three stations along the water courses, namely at point of burnt brick production (PBP), downstream of the point of brick production (DBP) and upstream of the point of brick production (UBP). The Cambo Waterproof Tester brand of HANNA digital instrument was used in taking direct measurement of hydrogen ion concentration (pH), while determination of free carbon dioxide concentration was achieved through titration method. Results indicate that there are significant inter-Local Government differences in both CO_2 concentration and pH of water bodies adjourning brick sites. The period of burnt brick production (November to March - dry season) also coincide with higher concentrations of CO_2 in water bodies; the concentrations of CO_2 were lower for all Local Government Areas during the wet season. This implies that the increased CO_2 concentrations were attributable to wood-based brick firing. Mean pH values at the sampling stations were not significantly different during the dry and wet seasons. Greener alternative energy sources (solar, hydro wind, liquefied hydrogen gas) are recommended for use in firing bricks to reduce CO2 emissions into water bodies.

Key words: Burnt bricks, Carbon Dioxide, pH, Water Quality, Flora and Fauna,

INTRODUCTION

Hand-made bricks production in Benue State has historically adopted firing in traditional open brick clamps. The clamps are composed of a large quantity of dry green bricks (not fired) carefully constructed on a foundation of green dry bricks. Fuelwood is fed into tunnels at the basement of the clamps. Some of the fuelwood tree species commercially utilized in firing bricks in Benue State include *Khaya senegalensis,* (Desr.) A. Juss, *Khaya grandifoliora,* (A. Juss) *Prosopis africana* (Guilol. and Perri) Taub and *Vitellaria paradoxa* (C.F. Gaertn) **(**Dagba, 2005; Agera, 2016**)**.

The use of fire in brick production can influence the hydrological cycle, shifts in animal and plant populations as well as soil chemistry by transferring heat into the soil (Brady and Weil, 1999). Man-induced alteration in water properties can be beneficial or detrimental, short-term or long-term, reversible or irreversible, depending on the specific properties altered and its interaction with the soil-water-fauna-flora-climate systems. In his attempt to increase net community productivity, man introduces ecological instability through his exploitative activities. The creation of excessive ecological instability, driven by short-term economic gains, is an act of short-sightedness. It is possible to increase the productivity of ecosystems and yet cause acceptable levels of negative effects through sustainable natural resource management and exploitation (Ivbijaro, 2002).

Fire can cause immediate changes in the water chemistry of forest streams and ponds, both as a by-product of heating and from smoke and ash inputs during the fuelwood burning process (Spencer and Hauer 1991). Elevated water temperatures can reduce the solubility of dissolved gases like carbon dioxide.

One important factor for measuring the health of a water body is pH, which assesses whether the water is acidic or alkaline. Carbon dioxide is one of many compounds that dissolves in water and can affect the pH of the ecosystem. Too much dissolved carbon dioxide can make the water acidic and unhealthy for plants and fish. Pure water has a pH of 7. The nominal pH range for healthy aquaculture is between 6.5 and 9.0 because fish have a natural blood pH of 7.4 (Coop, 2014).

In India, the brick industry produces about 22% of the carbon dioxide (CO_2) emissions of the construction sector, and requires about 27% of the energy used in building materials production (PA, 2007). This is because the small and medium scale sectors are predominant, and are generally more polluting than modern large-scale industries. The informal clay brick makers lack formality in terms of the licensing laws, tax laws, labour laws and environmental health regulations. These informal operations are small scale, mostly family or household-based enterprises that are unregulated by government institutions (Swiss Agency for Development and Cooperation, 2014). With fire's inherent sensitivity to climatic conditions, and with the prospect of rapid future climatic change, it is therefore important to investigate the influence of burnt brick fires on the aquatic environment. This study is therefore set out to investigate the effect of fuel wood-based brick firing on carbon dioxide and hydrogen ion (water pH) concentrations of adjourning water bodies and brick sites.

The Study Area

The study was carried out in Benue State, Nigeria, between April and and to October for wet season, and November to March for dry season. Benue State is made up of twenty three Local Government Areas (LGAs) that make up the geo-political zones (A, B, and C). Zones A and B are homes for the commercial wood-based clay bricks production because of the abundance of clay deposits there. Out of the 14 LGAs that make up Zones A and B, 8 were selected for this study, based on their ranking in terms of abundance of clay deposits as well as massive production of burnt bricks. The selected LGAs include Buruku, Gboko, Gwer West, Konshisha, Kwande, Makurdi, Ushongo and Vandeikya (Figure 1).

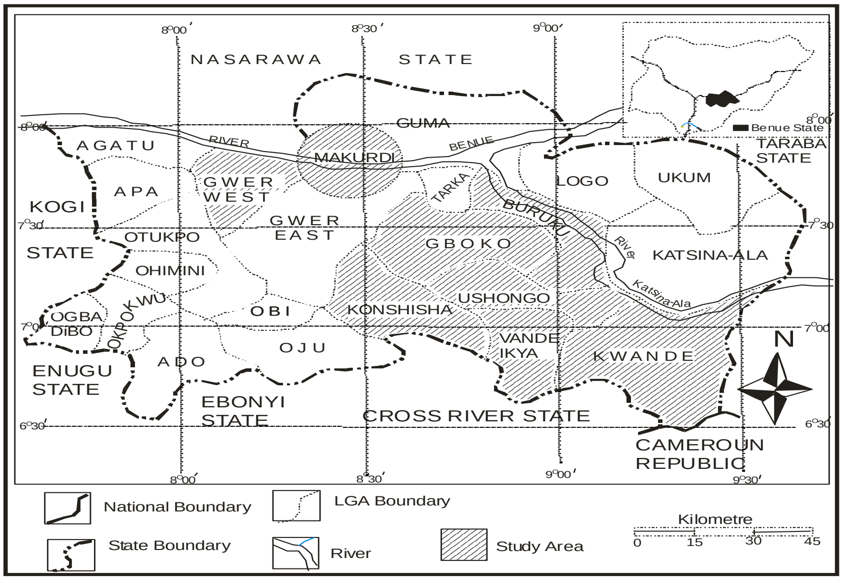

Fig. 1: Map of Benue State showing the studied Local Government Areas

METHODOLOGY

The Randomized Complete Block Design (RCBD) was adopted for this study, since the experimental units were not homogenous (Adesoye, 2004). Hydrogen ion (pH) and carbon dioxide (CO_2) concentrations were water quality parameters that were investigated at brick sites near rivers and streams.

The following rivers and streams were purposively selected for the assessment of water quality parameters at brick sites in eight Local Government Areas (LGAs) of Benue State: they are: Dura River (in Buruku LGA), Ngo and Ambighir streams (both in Gboko LGA), Nak stream (in Gwer West), Amire Tamen River (in Kwande LGA), Uavande and Sambe Rivers (in Konshisha LGA), River Mu and River Benue (both in Makurdi LGA), Sohonor Stream and Amire Kiriki River (both in Ushongo LGA) as well as Aya River (in Vandeikya LG.A.).

Water samples for assessment were collected at three stations along the water courses, namely (a) point of burnt brick production (PBP), (b) downstream of the point of brick production (DBP) and (c) upstream of the point of brick production (UBP) at both wet and dry seasons. The stations, DBP and UBP, were each selected at approximately 1000m away from PBP. The Cambo Waterproof Tester brand of HANNA digital instrument Model HI 96129 was used in taking direct measurement of hydrogen ion concentration (pH), and the determination of free carbon dioxide concentration was achieved through titration method

RESULTS

Table 1 shows the mean water quality concentrations of CO_2 and pH in the study areas by LGAs.

Carbon dioxide (CO_2) Concentration

From table 1, the mean annual CO_2 concentration of rivers surveyed ranged from 8.80±0.59ppm to 11.08±0.80ppm. The annual mean CO_2 concentrations of rivers in Gwer West and Kwande LGAs do not differ significantly. (CO_2) concentrations in rivers in Konshisha LGA differ significantly with that for rivers in Gwer West and Gboko LGAs. The CO_2 concentration for Konshisha LGA also differs significantly with that for rivers Buruku, Gboko, Makurdi, Ushongo and Vandeikya LGAs. The annual mean values of CO_2 for rivers in Buruku, Gboko, Makurdi, Ushongo and Vandeikya vary significantly with that in other LGAs. Also, in table2, the annual mean CO_2 concentrations at sampling points - UBP, PBP and DBP, the Coefficient of Variation and Fisheries LSD values for these sampling points, and the mean dry and wet season concentrations of CO_2 for all the rivers sampled in the study area (table 3), differ significantly from each other.

Hydrogen ion Concentration (pH)

From Table 1, the rivers in Gwer West have the lowest annual mean pH value of 6.62±0.16 while rivers in Makurdi LGA have the highest pH of 7.51±0.12. The mean pH of rivers in Gwer West differs significantly from that of other LGAs. The annual mean pH value of rivers in Buruku, Gboko, Konshisha, Kwande, Ushongo and Vandeikya LGAs do not differ significantly even though they differed significantly with pH values of rivers in Gwer West LGA as well as for Makurdi LGA. pH values for rivers in Makurdi LGA have an annual mean of 7.51±0.12 which differ significantly from those of other LGAs studied. The water sampling points UBP, PBP and DBP have annual mean pH values of 7.11±00, 7.13±00 and 7.14±0.07 respectively (Table 2) that do not exhibit any significant difference. The Coefficient of Variation and Fisheries LSD for the three sampling points were 0.42 and 0.17 respectively. The seasonal mean pH values for dry and wet seasons were 7.19±0.05 and 7.06±0.06 respectively (Table 3). These pH values differ significantly between the seasons. Mean seasonal values of pH and carbon dioxide concentrations are also presented in bar charts as Figures (2) and (3) respectively.

Table 1: Mean Water Quality Concentrations of (CO_2) and pH in the Study Areas by LGAs.

Local Government Areas	**Water Quality Parameters (ppm)**	
	CO_2	**pH**
	Mean ± SE	Mean ± SE
Buruku	9.78 ± 0.47^{b}	7.26 ± 0.05^{b}
Gboko	11.08 ± 0.80^{b}	7.21 ± 0.05^{b}
Gwer West	8.80 ± 0.59^{a}	6.62 ± 0.16^{a}
Konshisha	9.44 ± 0.44^{ab}	6.91 ± 0.04^{b}
Kwande	9.23 ± 0.50^{a}	7.30 ± 0.03^{b}
Makurdi	10.19±0.45	7.51 ± 0.12^{c}
Ushongo	9.81 ± 0.44^{b}	7.01 ± 0.07^{b}
Vandeikya	10.03 ± 0.51^{b}	7.18 ± 0.04^{b}

Means on the same column with the same superscript are not significantly different ($p<0.05$)

SE= Standard error of the means: pH= Hydrogen ion concentration

Table 2: Mean Water Quality Concentrations in the Study Area by Sampling Points

Sampling Point	**Water Quality Parameters (ppm)**	
	Carbon dioxide	pH
	Mean ± SE	Mean ± SE
UBP	7.69±0.25[a]	7.11±0.05[a]
PBP	11.87±0.27[c]	7.13±0.05[a]
DBP	9.82±0.25[b]	7.14±0.07[a]

*Means on the same column with the same superscript are not significantly different (p=0.05)
UBP= Upstream of point of brick production: PBP= Point of brick production:
DPB= Downstream of point of brick production
SE= Standard error of the means: pH= Hydrogen ion concentration**.**

Table 3: General Mean Carbon dioxide Concentration and pH of Sampled Water Bodies in Benue State by Season

Season	**Carbon dioxide(ppm)**	**pH**
	Mean ± SE	Mean ± SE
Dry	10.80±0.26[b]	7.19±0.05[b]
Wet	8.78±0.25[a]	7.06±0.06[a]

Means on the same column with the same superscript are not significant

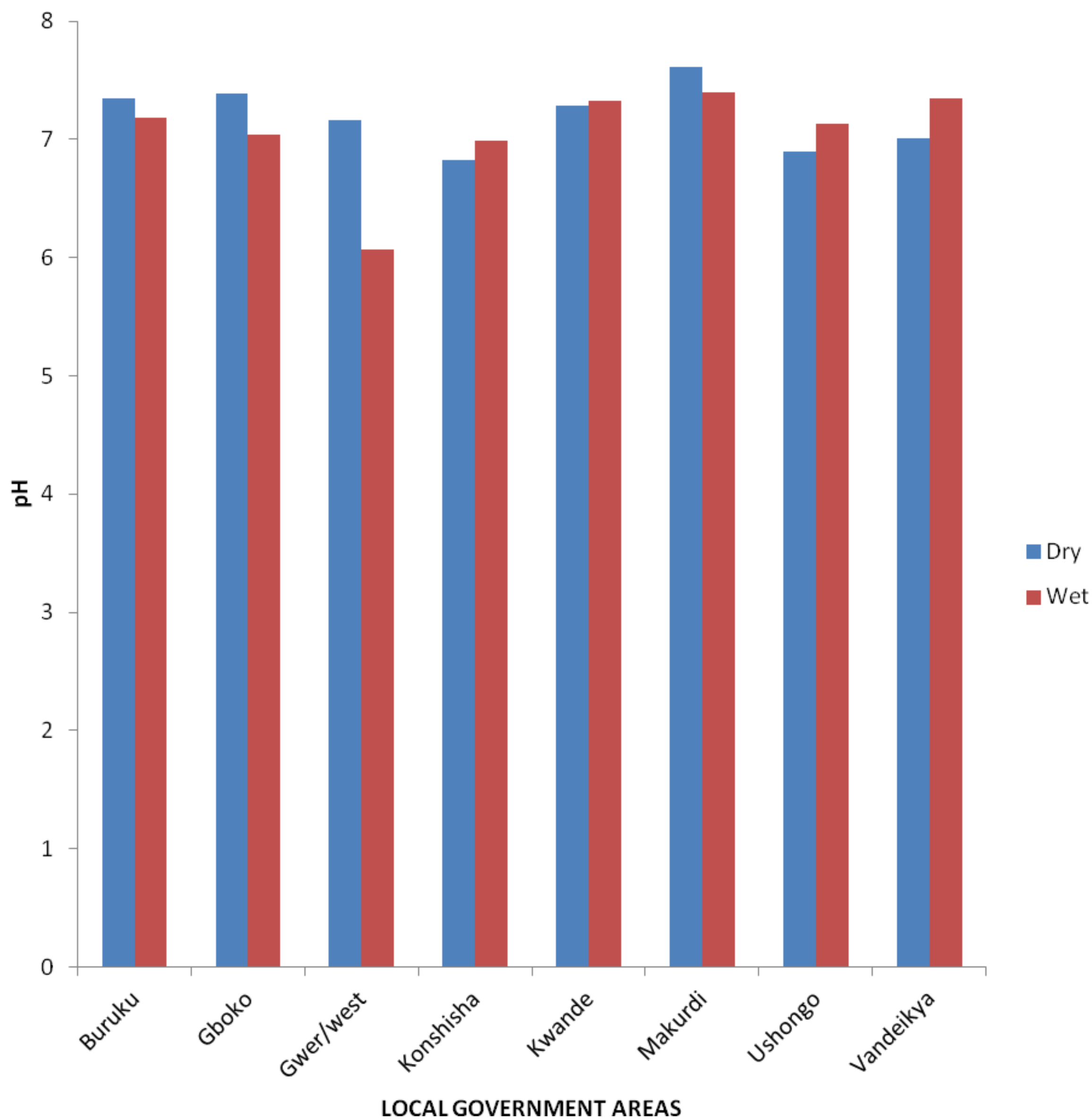

Figure 2: Mean pH Values of Fresh Water Bodies in Benue State by Season and Local Government Area.

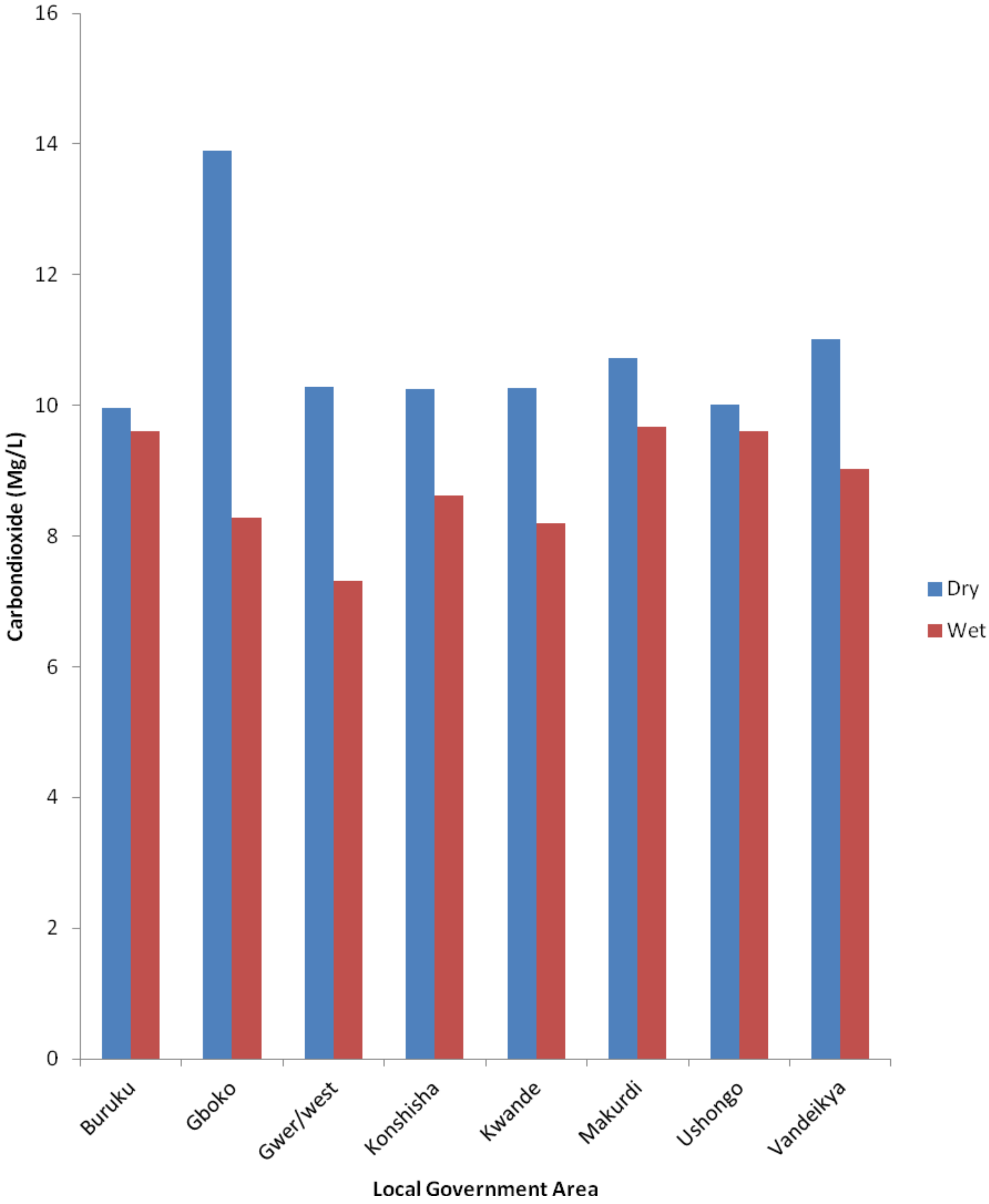

Figure 3: Carbon Dioxide Concentration in Rivers within the Study Area by Local Government Area by Season

DISCUSSION

Generally, the concentrations of CO_2 were higher during the dry season months of November to March, just as wet season concentrations of CO_2 were lower than that of dry season figures. The concentration of carbon dioxide (CO_2) was highest during the Harmattan period which coincided with the coldest dry season months (December to early February). At room temperature, the solubility of carbon dioxide is about 90 cm^3 of CO_2 per 100 ml water (cl/cg = 0.8) (AL-Amin, 2014). This explains why any water-soluble gas becomes more soluble as the temperature decreases. All these have significant implications for survival of flora and fauna, and their habitats.

The pH values of water bodies assessed fell within the range of 6.62±0.16 and 7.51±0.12 which were ideal for survival of flora and fauna species, as very high (>9.5) or very low (<4.5) pH values are unsuitable for most aquatic organisms (Encyclopedian Dictionary, 2007). Young fish and immature stages of aquatic insects are extremely sensitive to pH levels below 5 and may die at these low pH values. This is in line with a study by George (2009) where he observed that the size in length of each grass shrimp, *Palaemonetes pugio,* was inversely correlated with heart rate and beats per millimeter of length. He found out that the average heart rate of P. pugio at a pH of 6.5 was significantly lower than at a pH of 7.5.

pH also has a direct or indirect effect on photosynthesis and growth of water plants. Water with low pH, experiences decreased iron phosphate dissolution and vice versa. Changes in water pH may directly or indirectly have adverse effect on fish and other organisms. Low water pH can cause mucus to form on the gills of fish and prevents the fish from absorbing oxygen. If pH further increases, the fish will suffocate and die (Gado, 1999). According to him, low pH can alter the balance of salts in the tissue of organisms, noting that calcium ion levels of some fish cannot be maintained due to changes in pH which results in poor reproduction.

Fire can cause direct and immediate changes in the water chemistry of forest streams and ponds, both as a by-product of heating, and from smoke and ash inputs during the burning process (Minshall *et. al*. 1997). Elevated water temperatures can reduce the solubility of dissolved oxygen. Pulses of inorganic nitrogen and phosphorus into nearby water courses and water bodies are most commonly noted after forest fires (Spencer *et al*. 2003). Departures from baseline can kill aquatic invertebrates, amphibians, and fish.

CONCLUSION

Wood-based burnt brick production significantly increase the carbon dioxide concentration of water bodies adjourning the burnt brick sites in Benue State (especially during the Harmattan period of the dry season) when the bricks were fired, as well as insignificant increase in water pH during the dry season. All these have significant consequences for the survival of flora and fauna as well as the sustainability of their habitats.

RECOMMENDATIONS

From the results obtained in this study and the discussions, the following recommendations are suggested:

i. The proliferation of brick industries and polluting potential of wood-based brick industries around water bodies and agricultural lands should be checked by establishing larger brick factories away from water bodies.
ii. Greener alternative energy sources (solar, hydro, wind, and liquefied hydrogen gas) should be used in firing bricks, and
iii. Brick kilns that burn wood more efficiently need to be established to minimize pollution of water bodies near brick sites.

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