BLACK CARBON from BRICK KILNS

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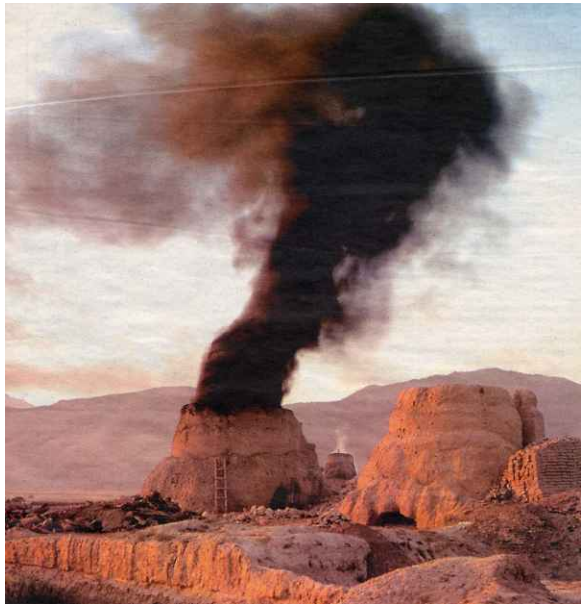


Brick making summary

- Brick kiln emissions information is quite limited and does not yet include BC/OC measurements.
- Many recent images of brick kilns across several countries show that BC emissions from typical brick kilns can be significant.
- Primary fuels are coal, local biomass and any available low-cost fuel or scavenged fuel (waste oil, tires, battery cases, dung, etc.).
- Brick production levels are not well documented, but are substantial and appear to be growing rapidly in many developing countries.
- BC emissions can be reduced by upgrading kiln technology and possibly adding emissions control devices.
- Upgrading kiln technology will reduce fuel consumption and CO2 emissions.
- China dominates global brick production (~54%)

Brick industry

- Industry of the poor
- Many brick workers are in virtual or actual slavery
- Only a very small fraction (less than 10%) of global brick production uses modern mechanized technology
- Very primitive brick kiln technology continues to be widely used in developing countries
- Brick making typically causes significant air pollution and land use problems
- Developing country government action attempting to reduce brick kiln air pollution and other land use/environmental impacts has had only limited success
- Western development agencies have had only limited success in attempts to upgrade developing country brick kiln technology

Brick kiln taxonomy

- Intermittent kilns – bricks fired in batches
  - Clamp, Scove & Scotch
- Continuous kilns – firing occurs all the time
  - Hoffman (several variations)
  - Bull's Trench (BTK)
  - Vertical shaft (VSBK)
  - Habla
- Efficient and potentially clean –
  - Hybrid Hoffman
  - VSBK
  - Habla
- Tunnel (modern – several variations)

Brick Production

- ~300,000 kilns worldwide

- Brick production is highly concentrated in four counties (~75% global production):
  - China 54% ~700-800 billion/year
  - India 11% ~140 billion/year
  - Pakistan 8% ~100 billion/year
  - Bangladesh 4% ~ 50 billion/year

Brick production: China & India

- China:
  - ~900 billion bricks/year (2004 estimate)
  - 90% Hoffman kilns with open air drying
  - ~100 million tons coal/year
- India:
  - ~140 billion bricks/year
  - ~100,000 kilns
  - ~70% production from 3000 Bulls Trench Kilns
  - ~15-20 million tons of coal per year

Brick Production Drivers

- Brick production is driven by population growth and **urbanization** in most countries:
  - India: Production is increasing **5-10%** a year (2009 estimate)
  - Bangladesh: Production is increased by about **5.6%** annually - tracking urbanization rate of 6% (2008 estimate).
  - Vietnam: Production increased **17%** annually from 2000 to 2006.

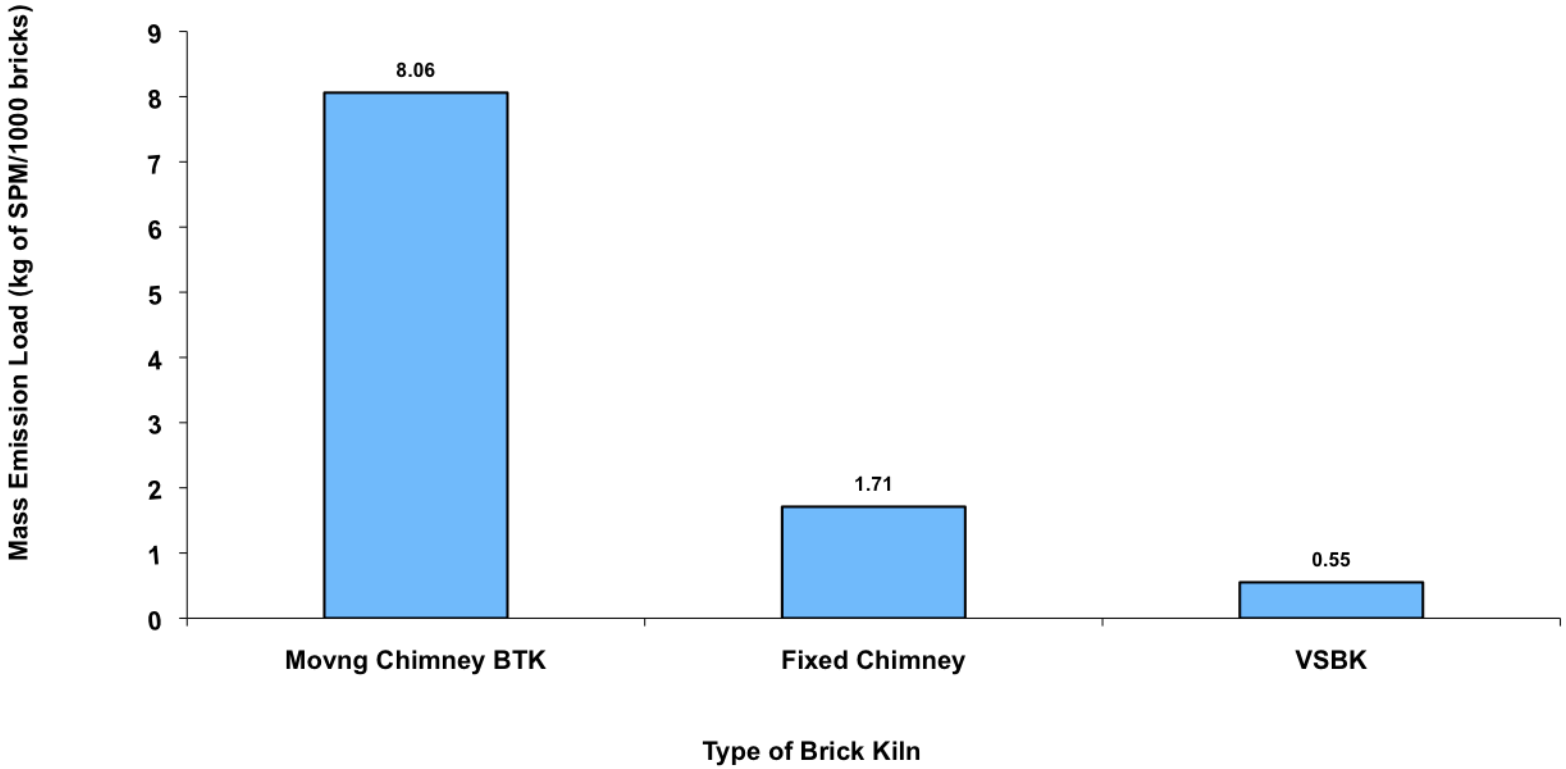
- China: difficult to project
  - Dramatic urbanization and modernization = much construction
  - However, steel, cement and wood are replacing bricks as dominant construction materials
  - China is attempting to moderately reduce solid brick production

CLEAN AIR TASK FORCE

Brick Kiln Emissions

- Brick kiln air pollution is of great concern in many counties/regions
- Very few emissions measurements exist
- Measured particulate emissions are high
- No BC/OC measurements have been identified
- Black plumes from brick kilns are common
- Some evidence of brick kilns fired at night to mask pollution plumes
- Most bricks continue to be made in “primitive” kilns
- As coal is the dominant fuel used to fire brick kilns, understanding the climate response from mitigation will also demand knowledge of SO_2 emissions.

Particulate emissions by Kiln Type



Source: Tuladhur, Acharya and Raut, Co-Benefits of Financing Vertical Shaft Brick Kilns in Nepal, Presentation at BAQ, 2006

Kiln Energy Consumption/Emissions

Kiln Type	Specific Energy (MJ/100 kg of fired bricks)	Fuel (tons of coal/100,000 bricks)	SPM (mg/ NM3)	India standards (mg/NM3)
Clamp	1.9-3	30-48	NA	NA
Moving Chimney	1.25-1.5	20-24	1021	750
Fixed Chimney	1-1.25	16-20	380	750
VSBK	0.7-0.9	5-8	70	300

Source: Development Alternatives, India

Nepal Air Pollution Study

Air pollution in Tikathali before and during brick kiln operation

PM_{10} ($\mu g/m^3$)		TSP ($\mu g/m^3$)		SO_2 ($\mu g/m^3$)		NO_x ($\mu g/m^3$)	
Before	**During**	**Before**	**During**	**Before**	**During**	**Before**	**During**
217.95	602.16	265.49	633.78	25.47	48.31	33.97	39.49

Source: Raut Anil K. Health Impact Assessment of Brick Kilns in Tikathali, 2003

Baseline projections

- High growth tied to urbanization in key developing countries.
- Some incremental reduction in emissions/per unit of brick production will likely occur as kiln technology is slowly upgraded.
- China *may* see moderate to significant shifts in technology and associated emissions reductions.
- Integrated urban expansion models under development for China may be capable of useful China brick production projections.

BC Emission Control Options

- Upgrade to cleaner, more fuel-efficient kilns
  - Development agency projects: convert to VSBK (Vietnam, India and Pakistan)
  - Government regulation (banning certain kiln types/shifting construction away from traditional bricks/emissions standards)
- Apply appropriate air pollution control technologies to kilns
  - Possible example - add gravity-settling chambers to fixed chimney BTKs
- Use cleaner fuels
  - Egypt CDM project switching Hoffmann kilns from mazot (oil waste) to natural gas
- Process changes
  - Hollow bricks
  - Fly ash bricks, etc.
- Shift market
  - China has taken several actions to reduce use of solid bricks

BC Emissions Control Experience/Issues

- Government regulation
  - Limited effectiveness to date, except possibly in China
  - Can complement financial incentives programs
- Carbon and BC/climate benefit driven financial incentive programs
  - Considerable experience has been gained through Western development agency programs and the CDM process (neither of which have driven significant kiln upgrading to date)
  - This experience does suggest that a well designed program
- China may be a “special case”
  - Cooperative government/industry action may be able to drive major shifts in brick making technology over a relatively short period of time
  - CO2 emissions reductions and *recognition of BC emissions reduction climate benefits* may be important to driving technology change in China

Next Steps?

- BC/OC/SO2 emissions measurements!!!!
  - By kiln/fuel type
  - With and without emissions control devices (where appropriate)
- Useful estimates of non-coal fuels consumption
- Better/current information on China brick production by kiln type and production growth rates

Measuring Brick Kiln Emissions

- CATF has teamed up with Dr Sameer Maithel, of Greentech Knowledge Solutions, New Dehli. India. Dr. Maithel has had extensive experience measuring pollution from brick kilns and has in place, systems (i.e. technicians, platforms for measurement) and labor to measure black carbon and other climate relevant emissions. He is a co-author of Brick by Brick: the Herculean Task of Cleaning Up the Asian Brick Industry
- Black carbon, organic carbon, and other pollutants (CO, CO_2, SO_2, and mineral matter) will be measured from eight brick kilns, including both primitive and improved designs, in five geographical locations.
- The kilns selected for testing include a range of different production capacities and fuel types and represents a comprehensive sample of brick kilns in operation.

Step two: Country level activity data to produce roadmaps for replacements and kiln improvements

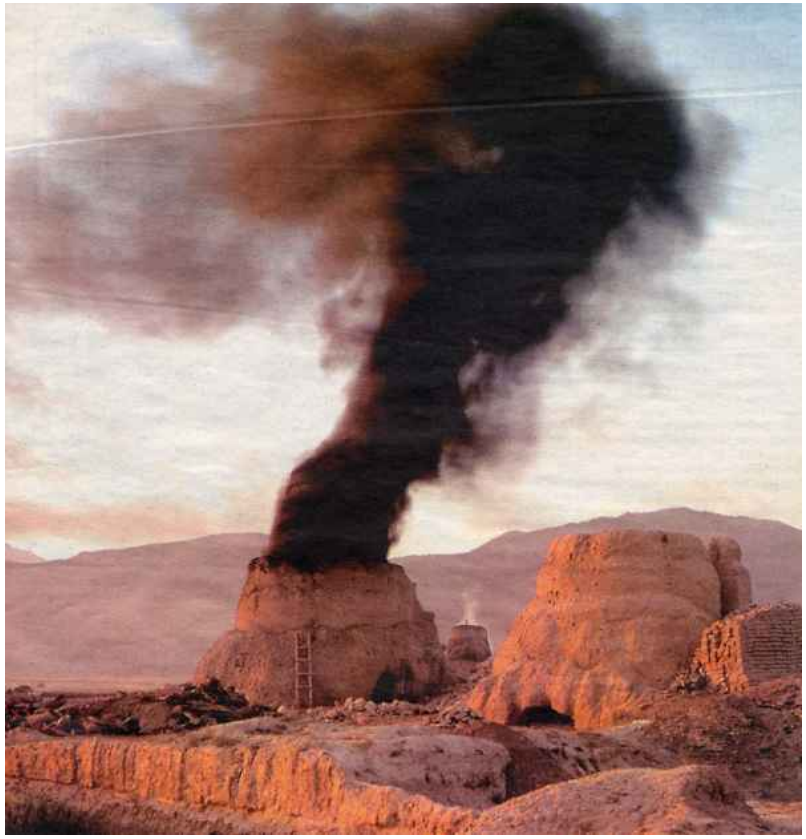
- Additional work includes country-level reports on brick making industry in Pakistan, India, Nepal, and Bangladesh and will provide: numbers of operational brick kilns, estimated quantity of coal / fuel consumed, estimated total production, and future trends. This information will be used to prepare regional and global estimates of total pollution from brick kilns.
- The products from measurements and country level reports will be used to
  - Produce regional and global inventories of black carbon from brick kilns, which will substantially aid climate-focused mitigation efforts.
  - Develop financial and political strategies for brick kiln replacement; we expect CO_2 emissions reductions and *recognition of BC emissions reduction climate benefits* will be important to driving technology change.

Appendix – Brick Kiln Technologies

CLEANAIR TASK FORCE

Brick kiln technology: intermittent

- **Intermittent** = bricks fired in batches
  - Clamp
  - Scove
  - Scotch
- Highly inefficient & labor-intensive.
- Use coal + scavenged fuels
- Most common, most primitive, most polluting



A typical scove kiln, Afghanistan.

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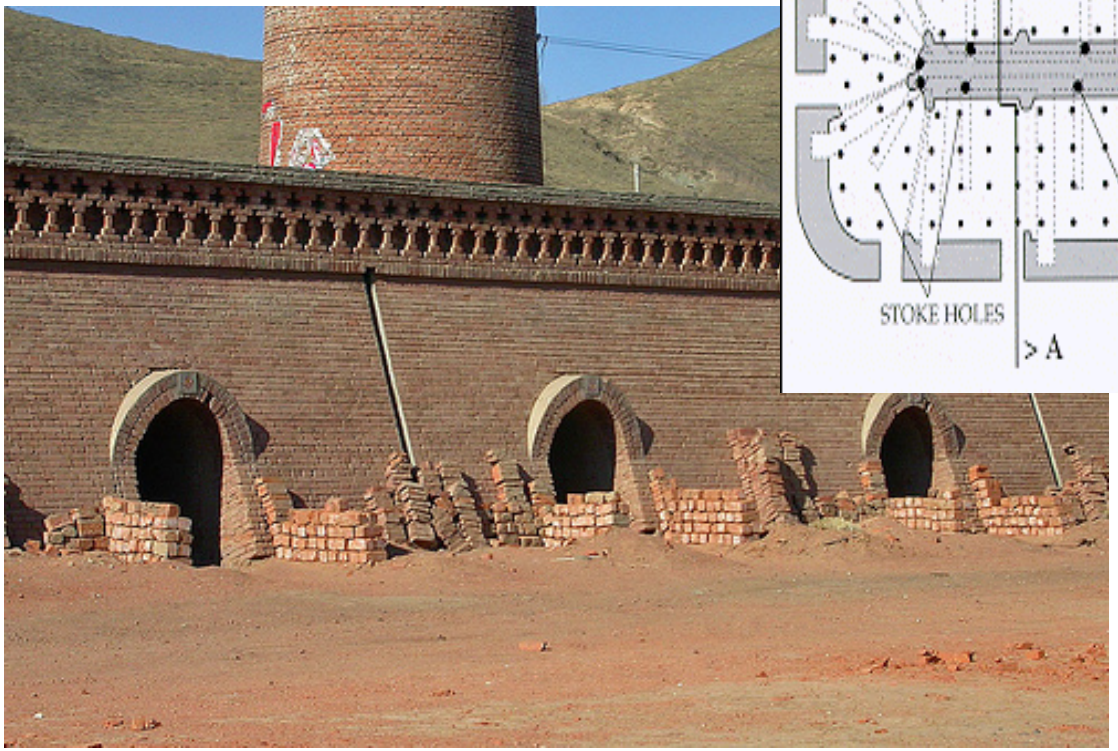
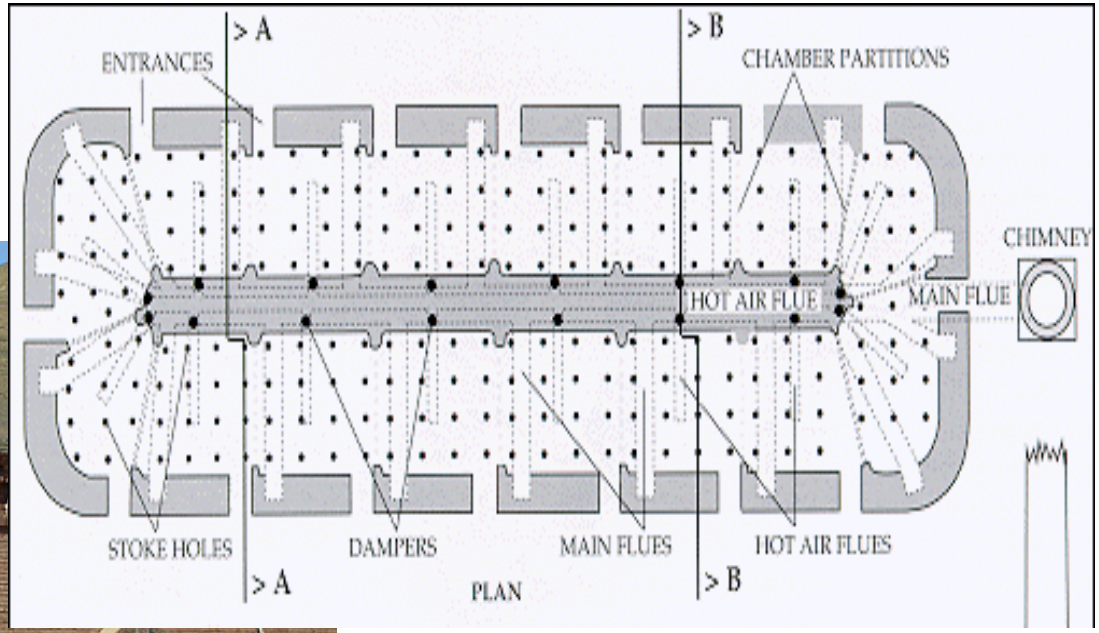
Brick kiln technology: continuous

- **Continuous** = fires burning all the time.
- Bricks move through kiln OR fire is moved through bricks within kiln.
- Different types
  - **Hoffmann** (“annular”) – original, modern, hybrid
  - **Bull's Trench Kiln** (BTK) – movable or fixed chimney
  - **Habla Zig Zag**
  - **Vertical Shaft Brick Kiln** (VSBK)
- Widely varying efficiency, emissions, productivity:

Hoffmann Kiln – Modern & Hybrid

- Widely used in China = 90% of bricks
- Can use coal or natural gas

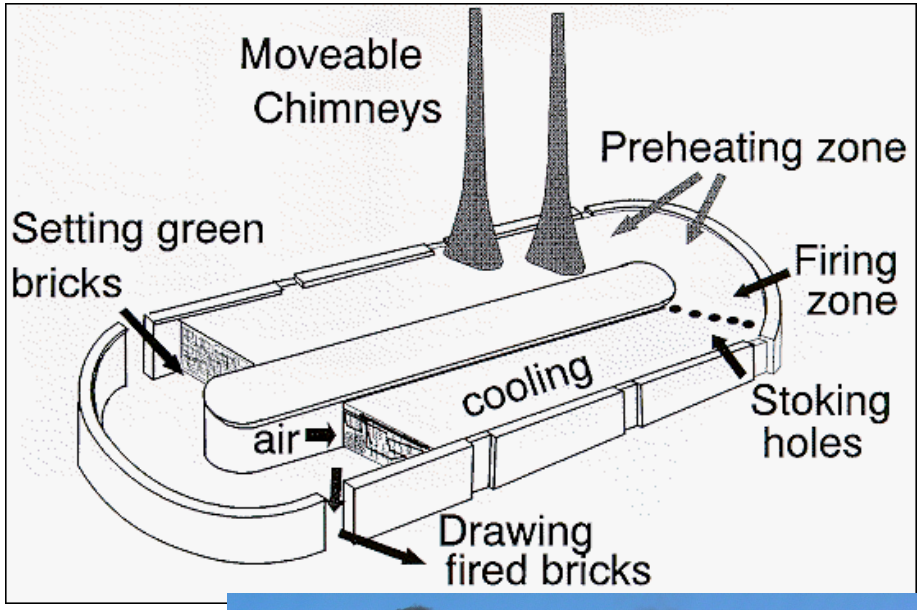




Schematic of a Modern Hoffmann kiln & a Hoffmann kiln in Reshui, China

Bull's Trench kiln (BTK)

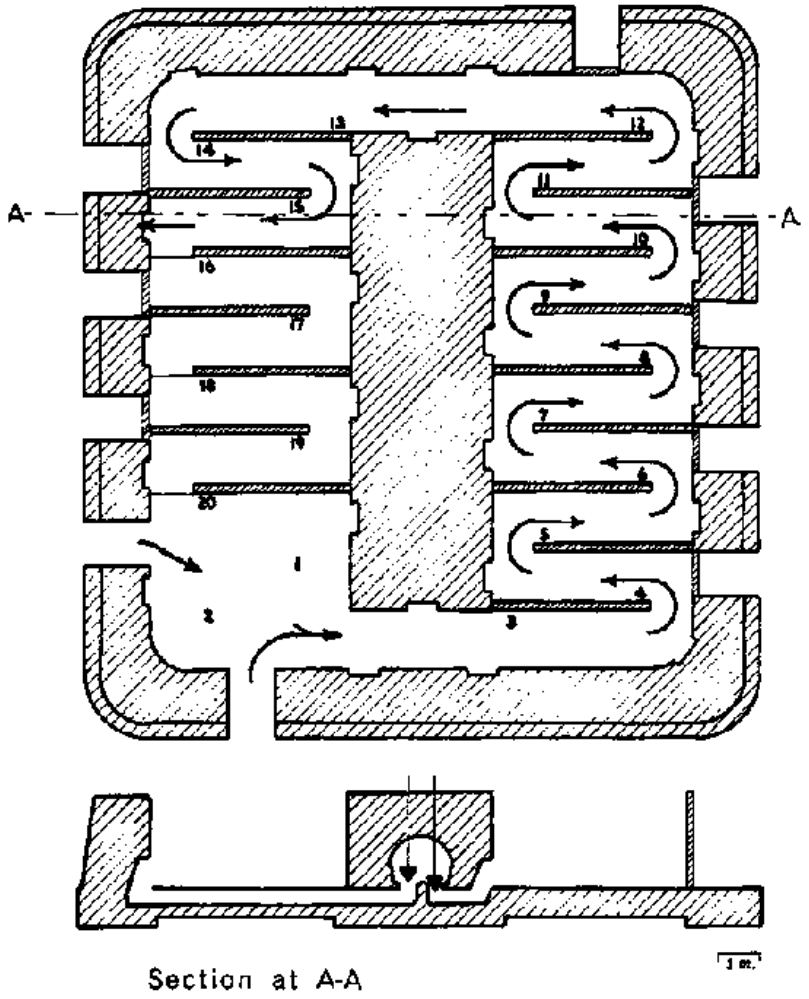
- Used in India, Pakistan, Nepal, Bangladesh
- Uses coal and scavenged fuels
- “Movable chimney” (MC) and “Fixed” Fixed (FC)
- MCBTK banned (but still used) in India, parts of Nepal & Pakistan due to **very high emissions**



Schematic of a MCBTK and plumes of smoke from a MCBTK in Kathmandu Valley

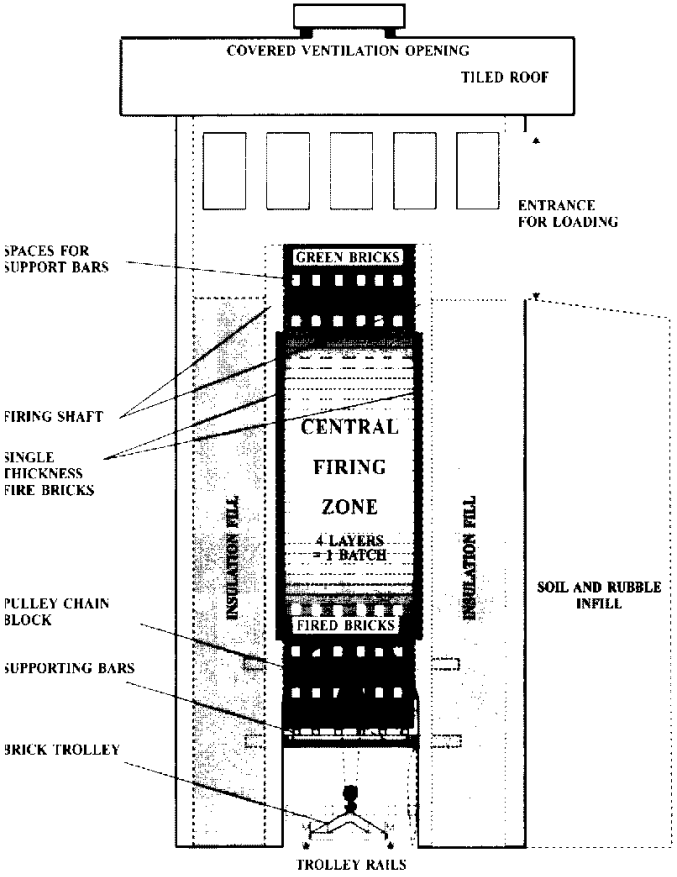
Habla ZigZag Kiln

- Effective tunnel length of Hoffmann increased with “zigzags” made of green bricks
- Larger capacity and more efficient than other kilns
- Needs fan to draw air through = needs source of electricity



Schematic of a Habla ZigZag kiln

Vertical Shaft Brick Kiln (VSBK)



Schematic of single shaft VSBK & a four-shaft VSBK in Kathmandu

- Loaded at top, bricks removed from bottom
- High efficiency, low emissions
- Kiln of choice for aid agencies
  - India, Nepal, Pakistan, Vietnam