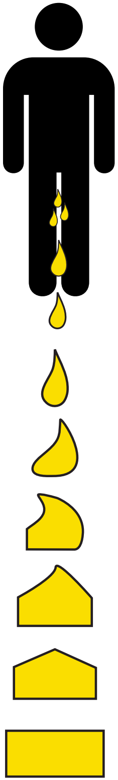
towards the use of human urine in mud brick construction



To pause at the level of scientific results is to ignore to essential social, environmental and practical issues.

Armed with the principle that human urine *can* be used in mud brick construction, whislt also drawing together and analysing research gathered from different fields, what can we propose to conserve water and change existing methods of building?

We must look at how we might collect, store and make urine safe for people to use across the world, whilst constantly recognising the need for local changes in infrastructure, and perhaps most vitally, re-education to instigate any shift in current practices in arid areas and areas of crisis.

Research into using urine in mud brick construction has been scarce, and is frequently anacedotal or at best unsubstantiated. A unified strategy is the only way to make real steps towards implementing such a scheme, with education as the driving force for all methods involved.

A summary of the key issues, both speculative and factual, that have been highighted by our research and experiments are as folllows:

Education

Any change in local production methods in developing countries, requires a period of teaching and learning.

All aspects of this project require the setting up of a system of education, vital when the proposal involves continued exposure to urine, are potentially hazardous waste product if not handled correctly, in a densely populated area where disease is commonplace and travels rapidly.

Introduction of any such system is a slow and complex process with constant awareness of risks a vital component. If the programme introduces a new technique that alters existing routines, then then this need to be taught, as quickly and efficently in order to prevent further aggrevating the crisis situation, but without reducing safety of the people involved. For example, mud bricks are easily worked with more fluid but if the proposal is the conservation of fluid then a balance must be taught between speed of production and water conservation.

Local Acceptance

The people within a community may not be prepared to take risks with unproven / unknown innovation. It has taken members within the group some time to accept working with human urine. For a much larger number of people within a refugee community to accept making mud bricks, building and living within shelter made from human urine wll require time.

Religion and Gender

Attitudes to human excreta vary between cultures all over the world. Within cultures, different social groups have differing social policy for facilities for excreting, be it separation through age, marital status, sex, class, etc. For example, Islamic custom demands that Muslims minimise contact with human excreta. One must realise the context in which a programme is set in order to create successful production system using human urine as a construction material. There may also be specific cultural or religious issues with women working, or being in contact with human excrement.

Health and Safety

Is there a threat to human health? Human excreta are seen as waste products, unhealthy, unhygienic and detrimental to humans. So, what are the hazards with working with urine?

The subsequent sections include detailed suggestions on handling methods required to make using urine as risk free as possible. Higher risks from use of urine may be acceptable in areas where there is simply a shortage of water and a greater need for shelter. In areas of high displacement, where any sense of home is a luxury, the benefits of being able to provide more buildings in times of extreme drought will outweigh minimal health risks in order to provide more permanent shelters for individuals. The awareness and reduction of risk is reinforced through education.

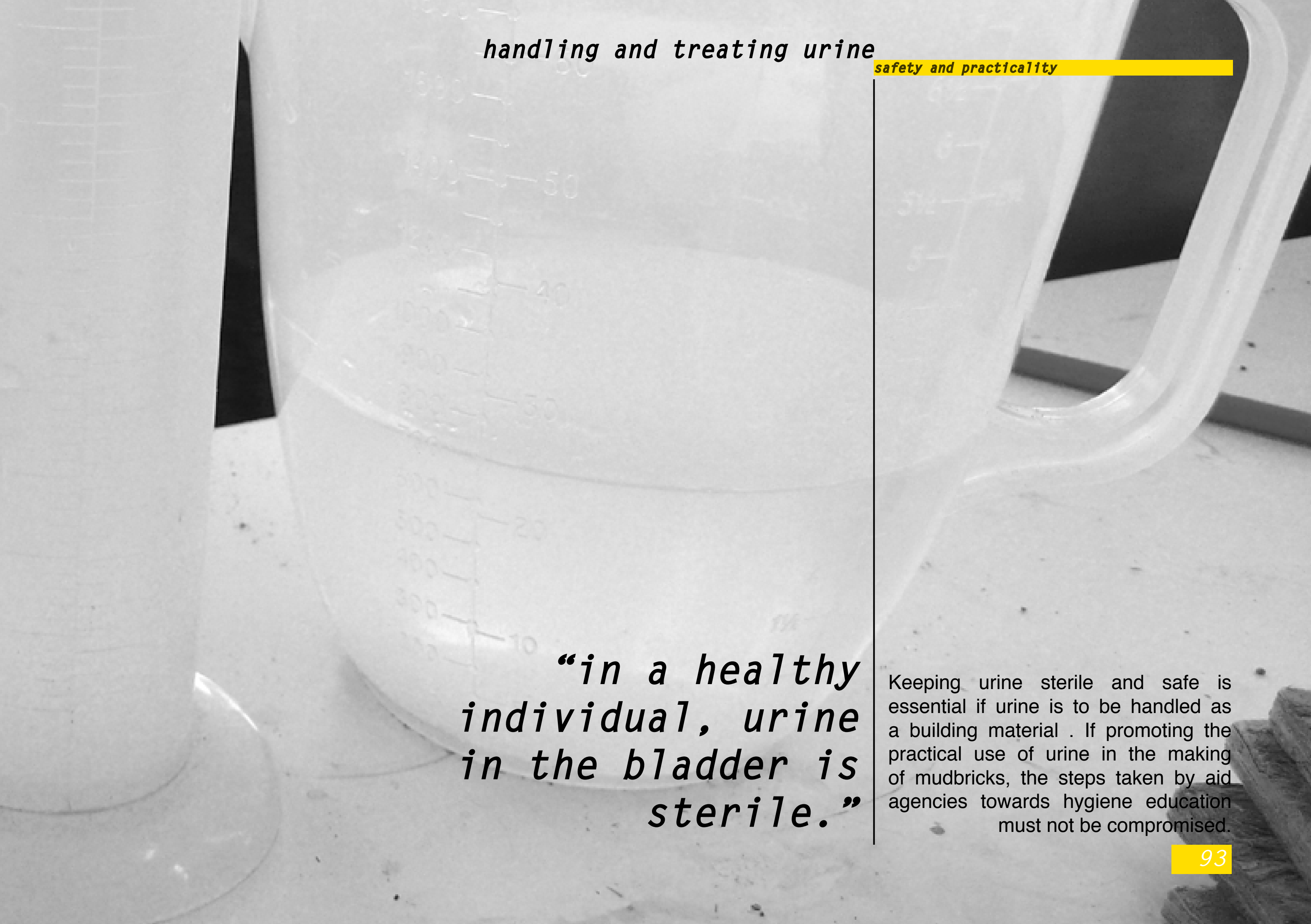
Infrastructure and Timescale

The health and safety of handling any form of human waste requires increased local infrastructure and spending. The system of collection, strorage and organisation increases the current timescale of mud brick manufacture.

Management and Social Sustainability

Social and management factors influence the sustainability of any sanitary system. To implement the use of urine in the making of mud bricks for shelter requires the whole community to be involved, and all members to adhere to the programme. Labour is plentiful in refugee camps but the programme must be well managed. It is the collective involvement of community members that will determine the success of the suggested programmes.


alue
emon
calorie drink
1litre e
Each 50ml serving contains
Sugar
trace
<1%
Fat
trace
<1%
Saturates
trace
<1%
Salt
0.2g
3%
of your guideline daily amount
Caution
Ingredients
Nutrition
Storage
WELSH NATURAL



> *"in a healthy individual, urine in the bladder is sterile."*

Keeping urine sterile and safe is essential if urine is to be handled as a building material . If promoting the practical use of urine in the making of mudbricks, the steps taken by aid agencies towards hygiene education must not be compromised.

Health concerns related to urine

In a healthy individual, urine in the bladder is sterile. However, different types of bacteria are picked up in the urinary tract. Freshly excreted urine normally contains less than 10 000 bacteria per ml [72] which is is low enough to not be dangerous.

Sexually transmitted pathogens may occasionally be excreted in urine, but there is no evidence that their potential survival outside the body would be of public health importance.[73] Human urine does not generally contain pathogens that can be transmitted through the environment.[74]

It can be concluded that pathogens that may be transmitted through urine are rarely sufficiently common to constitute a significant public health problem and are not considered to constitute a health risk in the reuse of human urine in temperate climates.[75] (refer Table 3.3 in appendices)

Cross-contamination with faeces

The main health risks in the use of excreta are related to the faecal and not the urinary fraction. It is the presence of faeces in urine that gives rise to the most significant health risks for handling, transporting and using urine.

Faeces contain pathogens to a much higher degree than urine. In source-separated urine, the faecal cross-contamination was estimated to be within a range of 1.6 to 18.5 mg of faeces per litre of urine, with a mean of 9.1 ± 5.6 mg/l, less than those for wastewater diluted one hundred fold. [76]

Reducing faecal cross-contamination of the urine fraction is therefore, an important control measure. Contamination of urine with faeces considerably increases the need for urine sanitization.[77]

72. World Health Organization, Guidelines for the Safe Use of Wastewater, Excreta and Greywater, 'Volume 4: Excreta and Greywater Use in Agriculture', chp 3, p. 36, http://www.who.int/water_sanitation_health/wastewater/gsuww/en/, 2006

73. International Sanitation Commity, 'Urine-diversion composting latrines', http://www.irc.nl/page/22831, 2007

74. Hoglund, 'Evaluation of microbial health risks associated with the reuse of source-separated human urine', Doctoral Theses, Stockholm, KTH, Biotechnology, http://www.diva-portal.org/kth/theses/abstract.xsql?dbid=3090, 2001

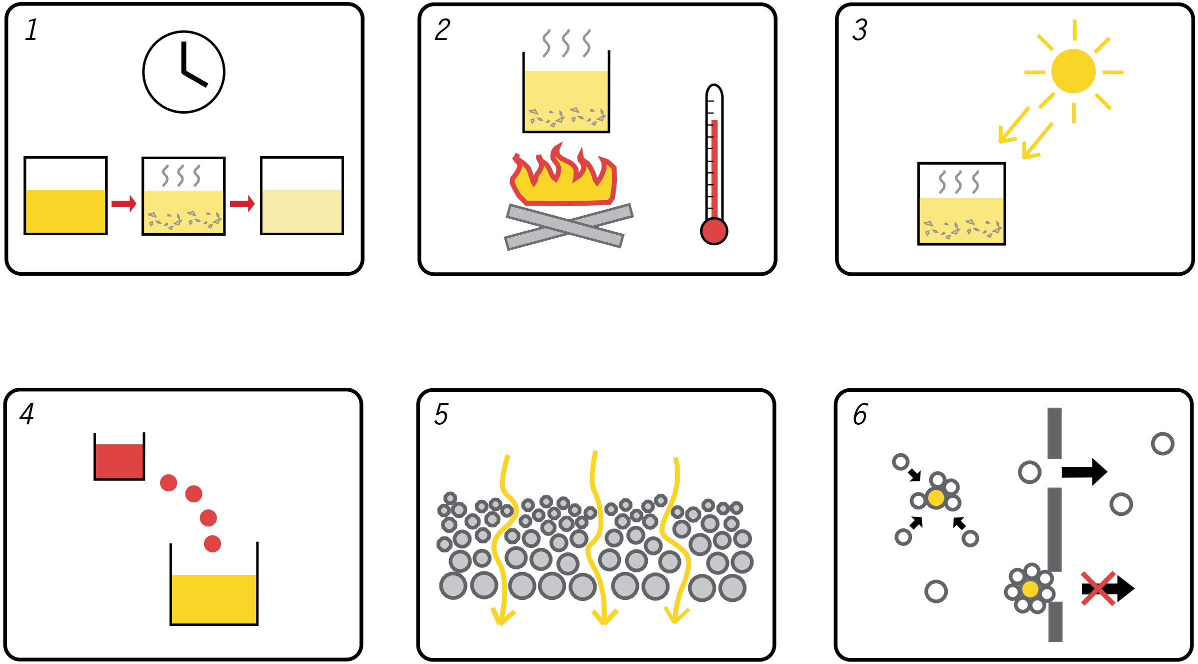
75. Op. cit. WHO, 2006

76. ibid. p.49

77. ibid. p.49

Image: http://en.wikipedia.org/wiki/Image:SalmonellaNIAID.jpg

options for treating urine



1. Storage

During storage, urea is rapidly converted to ammonia, which increases the pH. The ammonia content together with the increase in pH has a sanitizing effect. Bacteria concentrations diminish quite quickly during storage, but prolonged storage is necessary in order to adequately reduce the number of viruses and protozoa.[77]

The urine should preferably be stored undiluted. Concentrated urine provides a harsher environment for microorganisms, increasing the die-off rate of pathogens and prevents breeding of mosquitoes.[78] The urine should be contained in a sealed tank or container. This prevents humans and animals from coming in contact with the urine and hinders evaporation of ammonia, decreasing the risk of odour and loss of nitrogen.[79]

In order to reduce the number of pathogens to “probably none” it is recommended that urne is stored for 6 months at 20^{o}c (refer to Table 4.6 in appendices).[80] Temperature above 20^{o}c would probably increase the inactivation of microorganisms.[81] In addition to temperature, an appropriate storage time will depend on the size and health of the source group. A period of 6 months could be excessive, as some research suggests that urine stored for over one month may be found to be appropriate whilst remaining accetable for use. [82]

2. Boiling

Extreme temperatures kill pathogens. The higher the temperature, the harder it is for pathogens to survive. Boiling is an effective way to make urine safe.[83]

3. UV + heat

Sunlight has two synergetic mechanisms: radiation in the spectrum of UV-A and increased liquid temperature. UV irradiation damages DNA and inactivates pathogens. Subjecting urine and subsequently bricks to UV and heat will speed up the rate at which pathogens die-off.[84]

4. Chemical additives

A chemical additive such as iodine (0.1 solution mix) will kill pathogens. This is expensive and could have potential affects on brick stability.[85]

5. Filters

There are two types of filter: natural and artificial. A natural filter (e.g. sand), reduces pathogen levels by providing competition from other micro-organisms. This is however, time consuming and success is unpredictable. An artificial filter (e.g. micro-mesh) works by reverse osmosis. This is more efficient , but is very expensive.[86]

6. Flocculation

Flocculating agents attached themselves to patrhogens allowing them to be filtered and collected.[87]

77. ibid. p. 87

78. ibid. p. 70

79. ibid. p. 71

80. EcoSanRes, ‘Fact Sheet 5: Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems’, Stockholm Environment Institute http://www.ecosanres.org/pdf_files/Fact_sheets/ESR5lowres.pdf, 2005

81. Schonning, ‘Urine Diversion: Hygienic risks and microbial guidelines for reuse’, Stockholm Environment Institute, Sweden, World Health Organization http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html, 2001

82. Consultation with Dr M Wainwright, Microbiologist, University of Sheffield, 07.11.07

83. Ibid.

84. Ibid.

85. Ibid.

86. Ibid.

87. Ibid.

87. ibid.

88. WHO, op.cit chp 3, p. 36

89. Wainwright, op.cit

90. WHO, op.cit. chp 7, p. 112

91. Austin. van Vuuren, 'Case Study: Urine Diversion Technology, Integrated Development for Water Supply and Sanitation', 25th WEDC Conference, Addis Ababa, Ethiopia http://wedc.lboro.ac.uk/conferences/pdfs/25/018.pdf, 1999

92. Wainwright, op.cit

93. Consultation with Dr N Milestone, Senior Lecturer, Department of Engineering Materials, 30.10.07

Photos:

far left: http://www2.gtz.de/dokumente/oe44/ecosan/cb/en-general-overview-ecosan-2005.ppt

centre left: http://satyamag.com/apr06/hungry.html

centre right: danielandthelions.wordpress.com

far right: www.china.org.cn/english/health/224977.htm

1. Inspect urine

Urine should be inspected only used when it is 'gin' clear. Clear urine indicates that the urine is free of bacteria (99% sterile). Cloudy / stringy urine is a sign of poor health and should be discarded.[87]

2. Use correct holes in urine diversion toilet

Using correct holes will reduce faecal cross-contamination of the urine fraction and reduce requirement for sanitization (see 'cross-contamination' section above).[88]

3. Undertake collection within families or small groups

If the urine is handled by members of one family, or smaller groups using their own urine, then the risks will be reduced; the risks will increase if urine from outside of a group is used, as this will bring in new pathogens.[89]

4. Wear gloves and boots when handling urine

Encouraging workers to use protective gear (e.g. rubber boots and gloves) when exposed to the urine will reduce exposure to infectious agents.[90]

5. Wash hands with soap after handling urine

Poor domestic and personal hygiene diminish the positive impact of improved waste management on community health.[91]

Smell

When using fresh urine, the initial smell is due to the release of nitrogen compounds; purins, toxic substances and a little ammonia.

After a few days the release of nitrogen ceases and the smell is wholly due to ammonia release.

If stored for a prolonged period in a sealed container, a concentrated ammonium solution is created, with a strong ammonia smell. When this urine is ready to be used, it is recommended to open the container and leave it open for a few days prior to application. This will provide sufficient time for it to de-gas and the volatile ammonia to be released.

Although a longer storage time is beneficial in terms of 'treating' the urine, the longer the solution is left, the more caustic it will become. If the solution becomes caustic, gloves are required, not recommended, during handling.[92]
The pungency of urine will be reduced once mixed in with clay, in particular expanding clays such as montmorillonite. The structure of these clays is such that substances are absorbed, reactions prevented, and therefore smells reduced.[93]

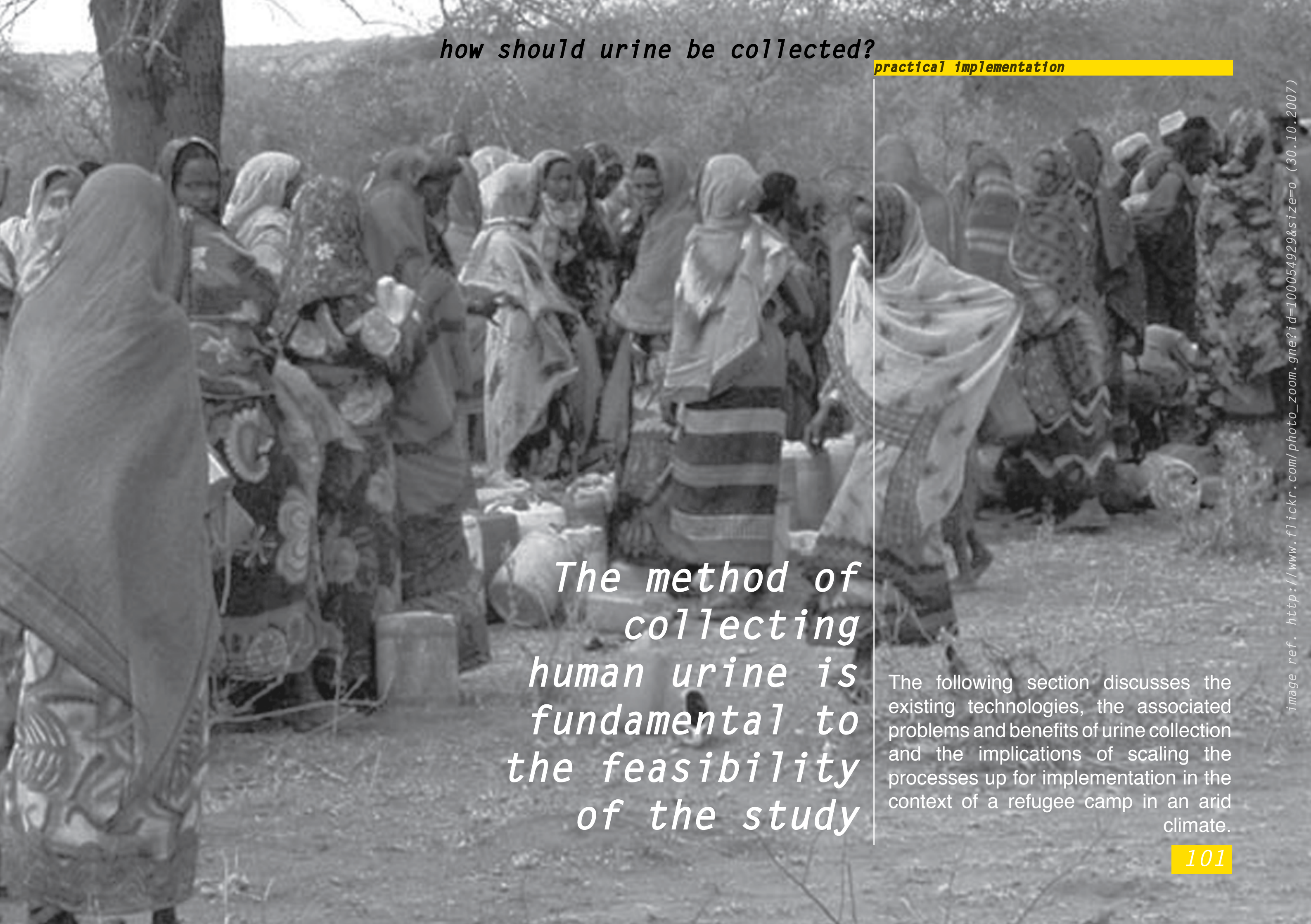


image ref. http://www.flickr.com/photo_zoom.gne?id=1000549298&size=o (30.10.2007)

The method of collecting human urine is fundamental to the feasibility of the study

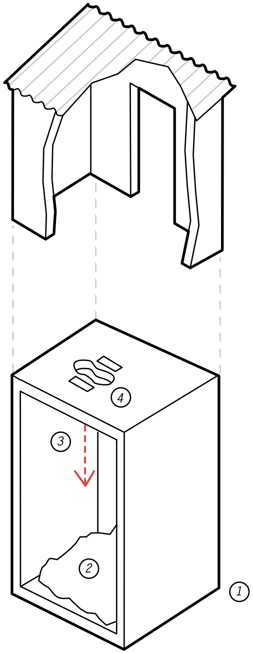
The following section discusses the existing technologies, the associated problems and benefits of urine collection and the implications of scaling the processes up for implementation in the context of a refugee camp in an arid climate.

urine collection typologies

based on existing case studies

A.

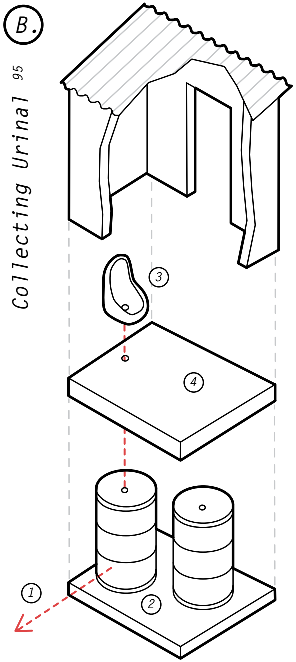
Standard Pit Latrine 94



1. Bottom of the pit latrine must be at least 1.5 metres above the water table.
2. Urine and faeces slurry.
3. Deep subterranean pit.
4. Standard squatting plate.

B.

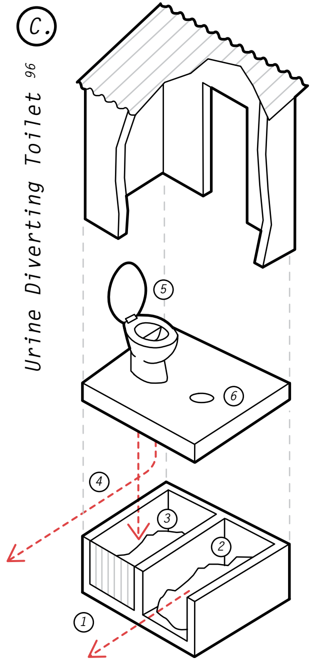
Collecting Urinal 95



1. Urine collected in drums or piped to central container.
2. Moveable storage tanks.
3. Dry urinal.
4. Elevated base for ease of urine collection and removal.

C.

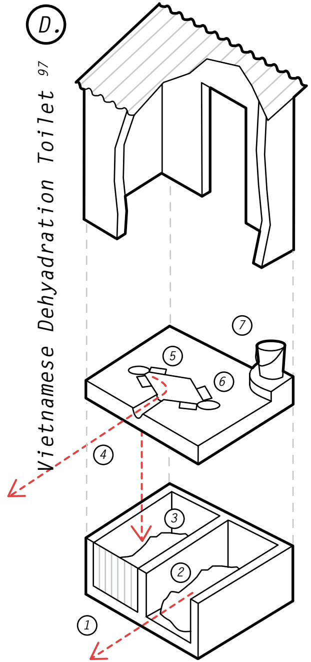
Urine Diverting Toilet 96



1. Composted faeces collected, to be used for agriculture.
2. Faeces stored for approx 6 months before use.
3. Active chamber.
4. Diverted urine channeled and collected.
5. Urine diverting pedestal toilet
6. Plugged inactive faeces shaft.

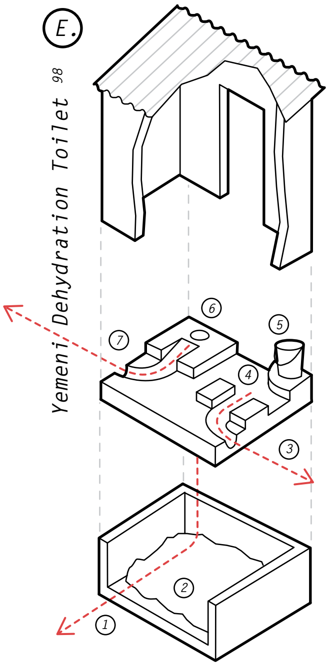
D.

Vietnamese Dehyadration Toilet 97



1. Composted faeces collected, to be used for agriculture.
2. Faeces stored for approx 6 months.
3. Active chamber.
4. Diverted urine channeled and collected.
5. Dual chamber squatting plate.
6. Plugged inactive faeces shaft.
7. Anal cleansing water.

how should the urine be collected?



Indicative Shelter

User Interface

Collection System

Method of use

1. *Dried faeces collected, dehydrated on rooftops, then used as fuel.*
2. *Faeces chamber.*
3. *Anal cleansing drain.*
4. *Anal cleansing squatting stones.*
5. *Anal cleansing water.*
6. *Urine diverting squat plate and faeces shaft.*
7. *Urine drains and discharges on the external wall of the house where evaporation occurs.*

Image ref: Heavens, Andrew. (http://www.flickr.com/photo_zoom.gne?id=100054929&size=o), 2007

94. SPHERE, 'The Sphere Project Handbook. Humanitarian Charter and Minimum Standards in Disaster Response', Chapt. 2 Minimium Standards in Water supply, Sanitation and Hygiene Promotion. Oxford, Oxfam Publishing http://www.sphereproject.org/, 2004, p. 74

95. Gesellschaft für Technische Zusammenarbeit (GTZ), 'Data sheets for Ecosan Technologies', Urine Diversion - Urinals http://www2.gtz.de/ecosan/english/publications-GTZ-technicaldatasheets.htm, 2005

96. Urine Diversion - Toilets ibid.

97. Dehydration Toilets- Double ibid.

98. Dehydration Toilets - Traditional dehydration toilets in Yemen. ibid.

99. Urine Diverting Composting Latrines, IRC www.irc.nl, 2007

There are many examples worldwide of human urine being collected and used as a natural fertiliser.

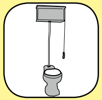
The most widespread technology used for collection is the 'Urine Diversion Toilet'. Diverting toilets separate urine and faeces at source using a dividing interface. Low, medium, and high cost alternatives of this technology have been developed and are produced in both squat and pedestal forms. The toilets can be made from local materials but are also commercially manufactured and available on all continents; prices start from 8 Euros for a basic squat plate unit.[99]

Unlike standard latrines user diligence is required to ensure proper function. Potential problems through mis-use include:
1. Urine infiltrating the dry faeces chamber.
2. Anal cleansing water or diarrhoea contaminating the collected urine.

Effective maintenance, supervision and cultural education would help to prevent this and enable the beneficial implementation of a strategy in which waste that was previously harmful could be harnessed as a useful resource.

advantages and disadvantages of collection typologies

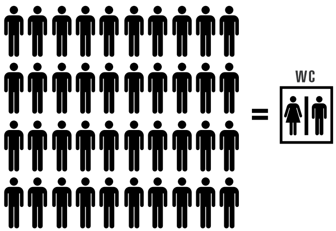
for arid regions and refugee camp contexts



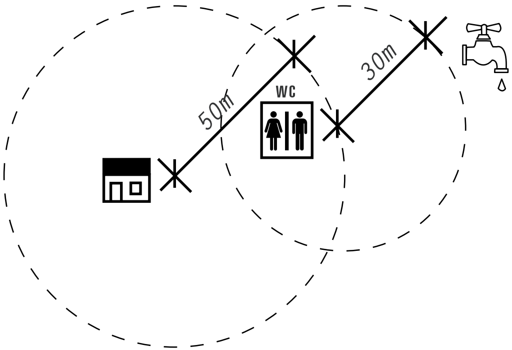
	advantages	**disadvantages**
Pit Latrine	- *Existing technology.* - *Inexpensive.*	- *No urine collection.* - *Possible ground water contamination.* - *Bad smell and flies.*
Collecting Urinals	- *Simple technology.* - *Inexpensive.* - *No contamination of urine.*	- *Only male urine.*
Urine Diverting Toilets	- *Maximium volume of urine collected.* - *Dry waste and elevated construction prevents pollution leaching into the water table.* - *Composting process destroys pathogens in dry faeces.* - *Reduced smell and flies.* - *Reduced waste volume.* - *Addition agricultural uses for composted waste.*	- *System fails if users urinate into faeces chamber.* - *Unfamiliar technology requires user education and supervision.* - *Increased complexity of construction would increase cost.* - *Collected urine can become contaminated by anal cleansing water.* - *Separate disposal of toilet paper and sanitary waste is required if faeces is to be collected.*
Urine and Anal Cleansing Water Diverting Toilet	- *As above.* - *No contamination risk.*	- *As above.* - *Additional complexity would increase costs and educational requirements.*

scaling the strategy for a refugee context:

Sphere - Minimum Sanitary Requirements[100]



Provision - 20 people per toilet



Access - 50m maximum distance to nearest toilet from dwelling

Location - Latrines should be a minimum of 30m from ground water supplies

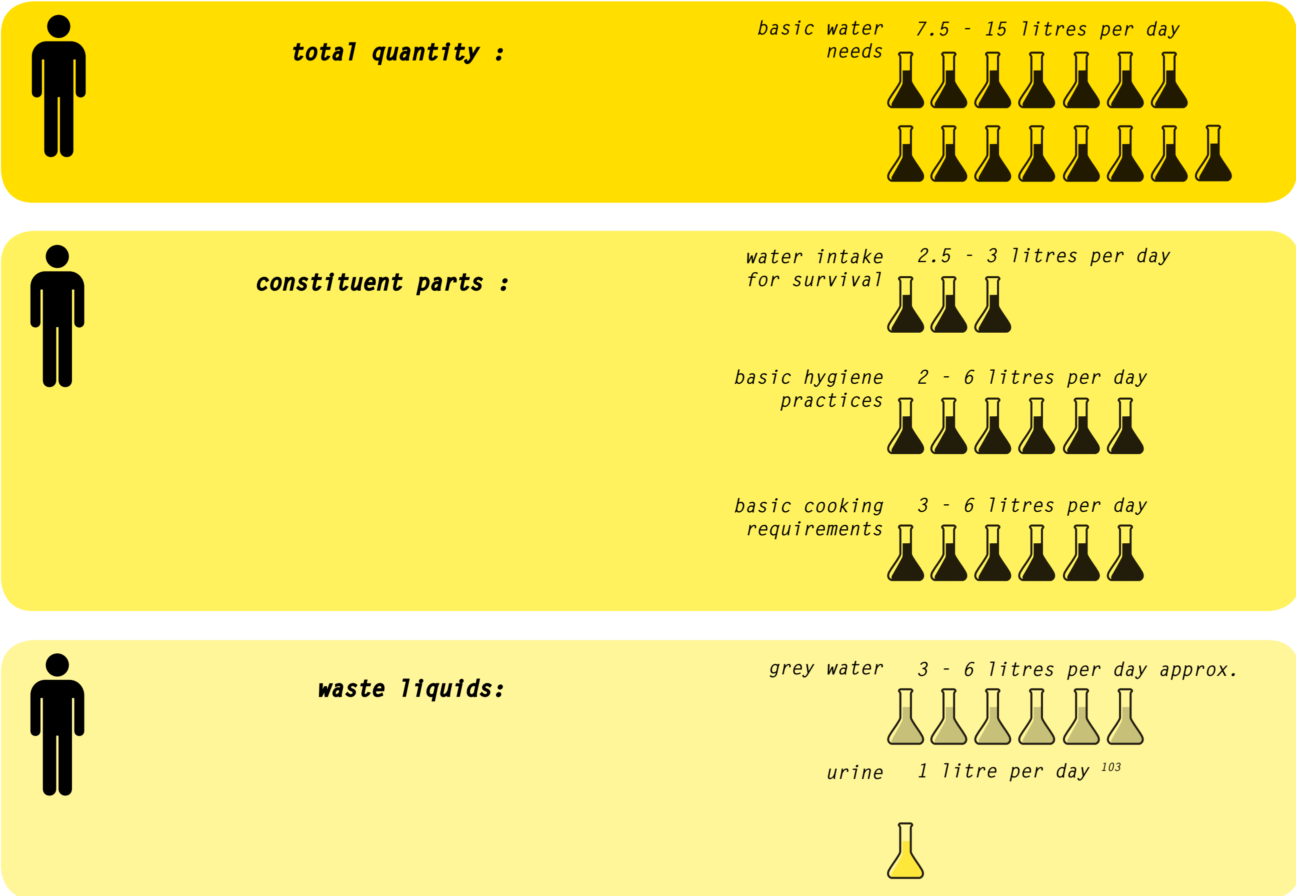
100. SPHERE, op.cit. p. 74

The suitability of any urine collection strategy is dependant on a myriad of variables including: the scale of the operation, the religious context, gender issues, the age of the users, and the changeable nature of site conditions.

The most important recommendation for an implementation process is to conduct a detailed survey of the specific context to ensure that the potential end users participate in the decisions to determine the most viable collection option(s). The SPHERE standards emphasise the importance of ownership in successful hygienic sanitation projects.

minimum survival water needs per person per day [102]

SPHERE standards



what are the alternative liquid resources?

Alongside the primary research into the potential for harnessing urine or 'black water' in mud brick construction it is worth considering alternative sources of liquid; in particular 'grey water'.

"The term 'grey water' refers to untreated household wastewater, which has not been contaminated by toilet waste. It includes the water from bathtubs, showers, hand basins, laundry tubs, floor wastes and washing machines.[101]"

The SPHERE minimum standards in water supply, sanitation and hygiene promotion specifies a basic provision of between five and twelve litres of water for basic hygiene and cooking purposes. Based on these figures grey water from refugee camps could potentially contribute a significant quantity of useful liquid for mud brick construction. It would also be less problematic in terms of pathogen contamination and social perception.

The considerations associated with using grey water as a liquid resource for mud brick construction include:

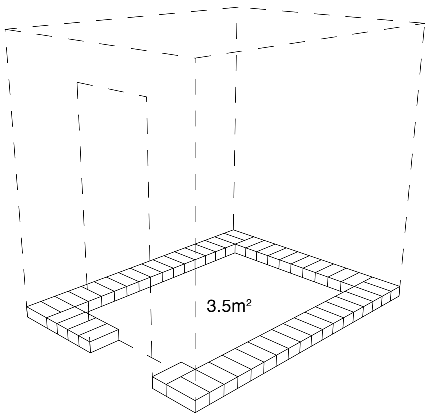
- The complexity of collection.
- The health risks.
- The treatment process.
- The effects of detergents, starches and fats on the material.

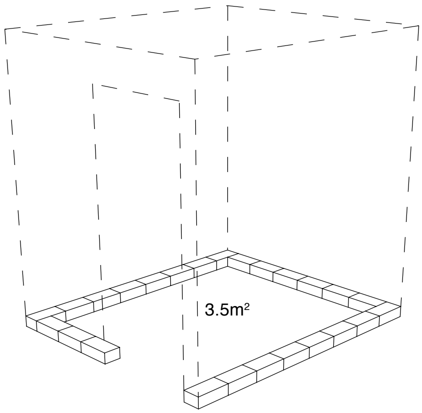
101. World Health Organisation, 'Overview of Greywater Management Health Considerations', World Health Organization Regional Office for the Eastern Mediterranean Centre For Environmental Health Activities, Amman, Jordan http://www.emro.who.int/ceha/pdf/Greywter%20English%202006.pdf, 2006

102. SPHERE, op.cit. p. 64

103. Netherlands Water Partnership NWP, 'Smart Sanitation Solutions', Examples of innovative low cost technologies for toilets, collection, transportation, treatment and use of sanitation products. NWP, WASTE, PRACTICA, IRC and SIMAVI p.14 http://www.irc.nl/page/28448, 2006

proposals for creation of shelter using urine mud bricks





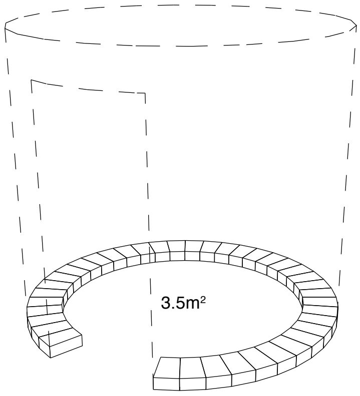


Fig 17.

Rectangular Plan (header only)

Per Individual:
51 Bricks per course
25 courses-1293(1300) bricks
Volume of mud-5.85m³
Litres needed-1950l
Based on 1 litre of urine a day-5.3 years

Fig 18.

Rectangular Plan (stretcher only)

Per Individual:
25 Bricks per course
25 courses-634(650) bricks
Volume of mud-2.9m³
Litres needed-966l
Based on 1 litre of urine a day-2.6 years

Fig 19.

Circular Plan

Per Individual:
39 Bricks per course
25 courses-993(1000) bricks
Volume of mud-5m³
Litres needed-1667l
Based on 1 litre of urine a day-4.5 years

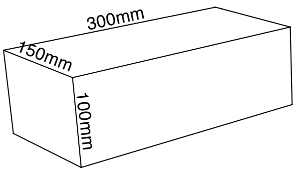


Fig 21.

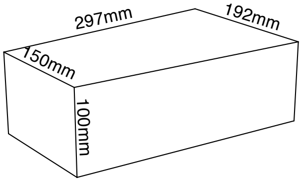


Fig 22.

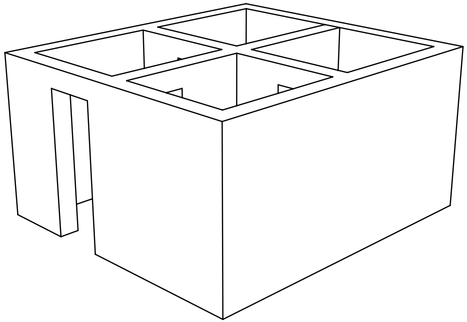


Fig 20.

Rectangular Plan

4 Person House:
3900 Bricks
Volume of mud-17.6m^3
Litres needed-5850l
Based on 1 litre of urine a day(x4)-4 years

Rectangular Plan (stretcher only)

4 Person House:
1950 Bricks
Volume of mud-8.8m^3
Litres needed-2933l
Based on 1 litre of urine a day(x4)-2 years

104.The SPHERE Handbook, 2004, Shelter and settlement standard 3: covered living space pp. 219-221

Fig 20. UN Standard mud brick dimensions: Volume-0.0045m^3

Fig 21. Modified mud brick dimensions: Volume-0.005m^3

SPHERE Standards:
"People have sufficient covered space to provide dignified accommodation. Essential household activities can be satisfactorily undertaken, and livelihood support activities can be pursued as required.

Key indicators:

The initial covered floor area per person is at least 3.5m2.

The covered area enables safe separation and privacy between the sexes, between different age groups and between separate families within a given household as required.

Essential household activities can be carried out within the shelter.

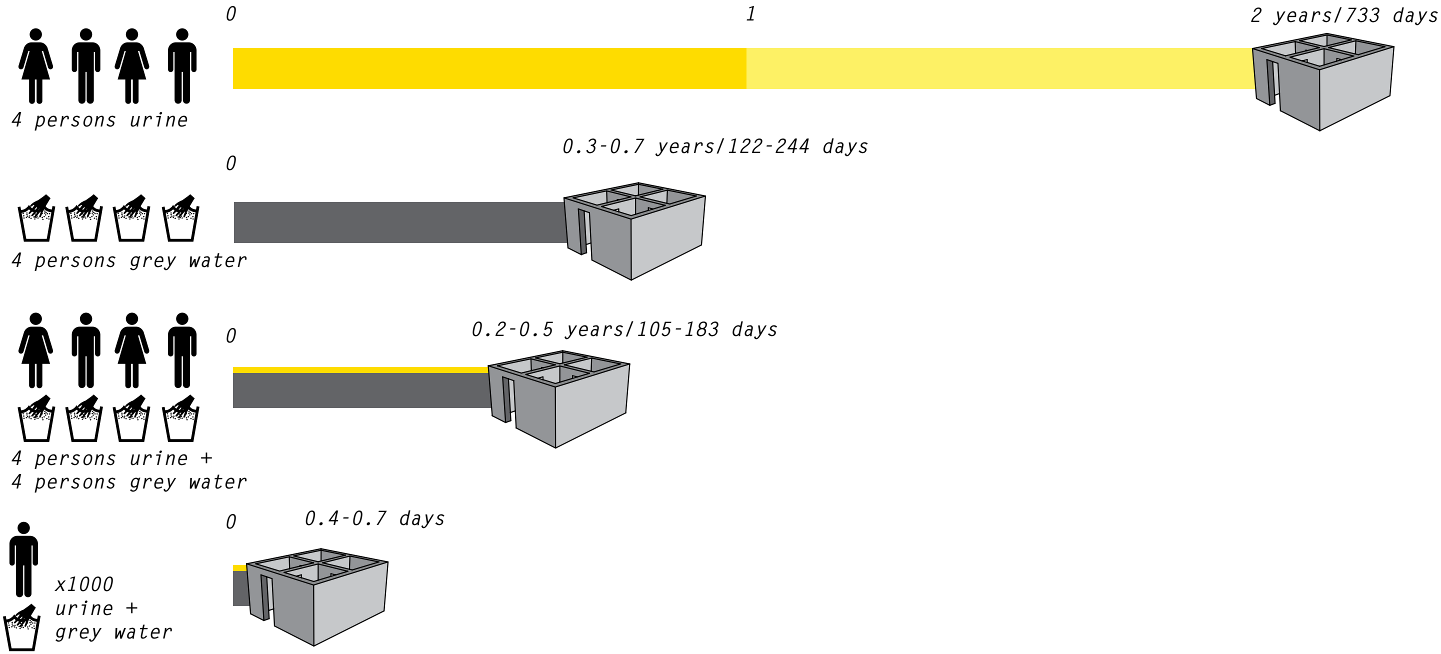
In hot and humid climates, space to allow for air circulation is required to maintain a healthy environment. The floor to ceiling height is also a key factor, with greater height being preferable in hot and humid climates to aid air circulation".

SPHERE standards

Based upon the SPHERE standards a simple exercise was carried out to give an indication of how much material would be necessary to produce a single person, semi-permanent mud brick shelter.

Using the UN standard dimensions (300 x 150 x 100mm), mud bricks were laid in both header and stretcher courses around rectangular and circular plans (area 3.5m^2)[104] up to a height of 2.5m. This gives the minimum number of bricks required for each shelter (minus a standard entrance of 900 x 2200mm and roof covering). The exercise was then continued to see how this may relate to a four person house. In the practical experiment, a ratio of three parts dry soil to one part liquid was used, so for a UN standard 1.5 litres of liquid is required.

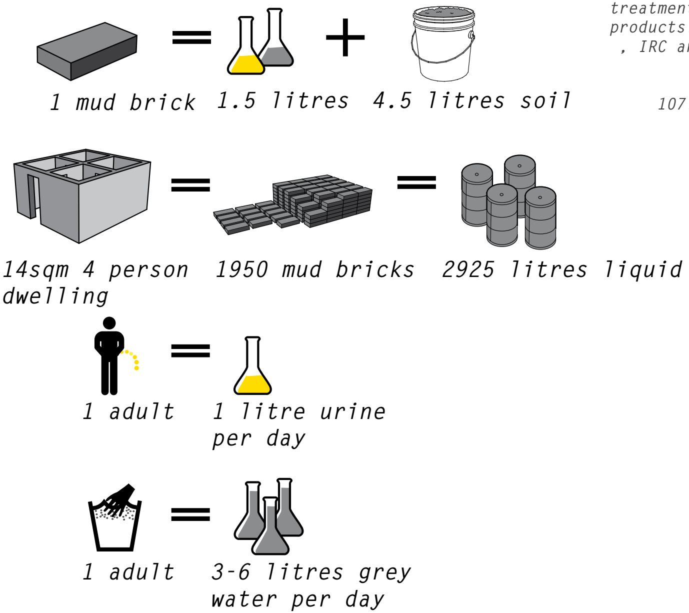
This exercise has implications when relating it back to a daily average amount of urine produced showing that: in ideal circumstances and using a stretcher only bond, it would take a family of 4 at least 2 years to produce enough urine to build their own shelter. A number of considerations were omitted that would affect the findings, such as: roof covering, amounts of urine and wasted bricks.The local vernacular for housing type, living arrangements and building methods are also influencing factors.


0
1
2 years/733 days
4 persons urine
0.3-0.7 years/122-244 days
0
4 persons grey water
0
0.2-0.5 years/105-183 days
4 persons urine +
4 persons grey water
0
0.4-0.7 days
x1000
urine +
grey water

105. SPHERE Handbook, p.219

106. 'Smart Sanitation Solutions' - Examples of innovative low cost technologies for toilets, collection, transportation, treatment and use of sanitation products. NWP, WASTE, PRACTICA , IRC and SIMAVI, p.14 http://www.irc.nl/page/28448

107. SPHERE Handbook, p.63



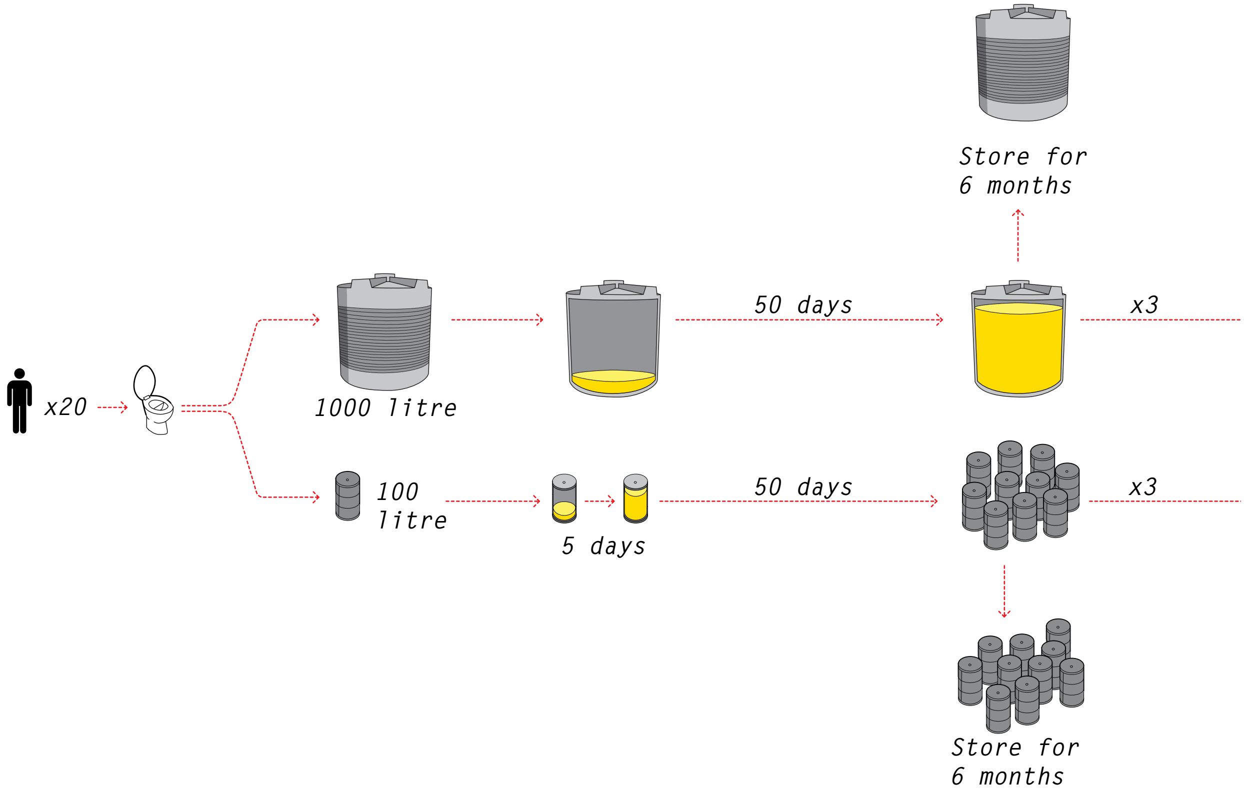
A simple house type for 4 persons providing the SPHERE minimum standard of 3.5 m² per person wih 4 separate rooms to allow for privacy, separating room functions, etc.[105] requires 1950 mud bricks laid flat as stretchers only.

Based on WHO figures for persons in a tropical climate, urine production per person is 1 litre per day.[106] The graph shown assumes 1 litre collected per person, per day.

The first graph indicates the length of collection time for enough urine to build a 4 person sheleter.

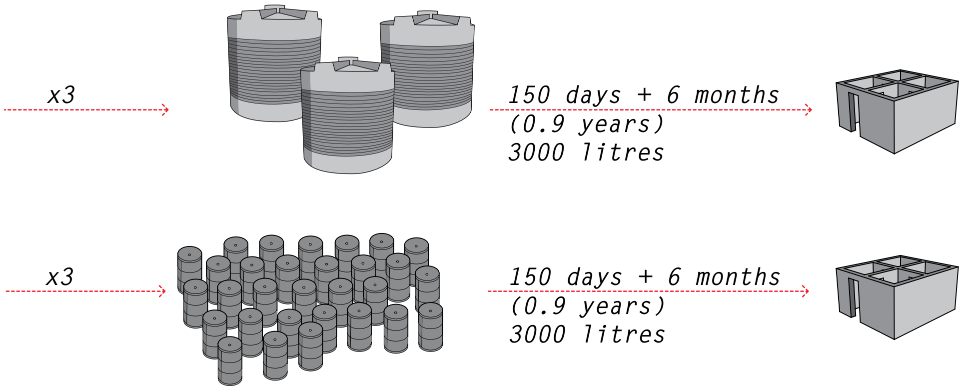
SPHERE requires additional water for cooking , washing, etc[107]. This is a potential source of additional grey water to use in mud brick construction.

The second & third graphs indicate the use of grey water, and mixed grey water and urine. This could greatly increase production rate, but further investigation would be required to determine if any chemical constituents present in grey water would affect mud bricks.



x20
1000 litre
50 days
x3
Store for
6 months
100
litre
5 days
50 days
x3
Store for
6 months

timeline to implementation



Almost 3000 litres is the estimated requirement to build a 4 person shelter. This is a large volume of liquid to collect and store.

To reduce possible disease spread urine should be collected from small groups, ideally families. This also conforms to SPHERE standards of 1 toilet per 20 persons.[104] Research suggests that urine is stored for 6 months in sealed containers for the pathogen content to reach near zero, thus reducing risk of disease.[105]

Two possible staged collection and storage strategies are illustrated left.

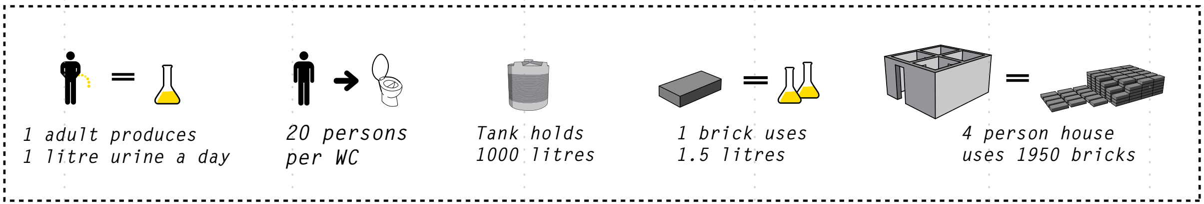
Filling large tanks of 1000 litres (1m^3) collects a large volume of urine, whilst allowing for separation for storage every 50 days. Once aged the tank can be drained and re-connected. The toilet will then be connected to an empty tank. This requires permanent toilets and tanks and a diversion system.

Collecting in 100 litre (0.1m^3) barrels requires simpler equipment, and a fills mobile storage units. However there will more organisation for numerous barrels and regular barrel changing required.

104. SPHERE Handbook, p.71

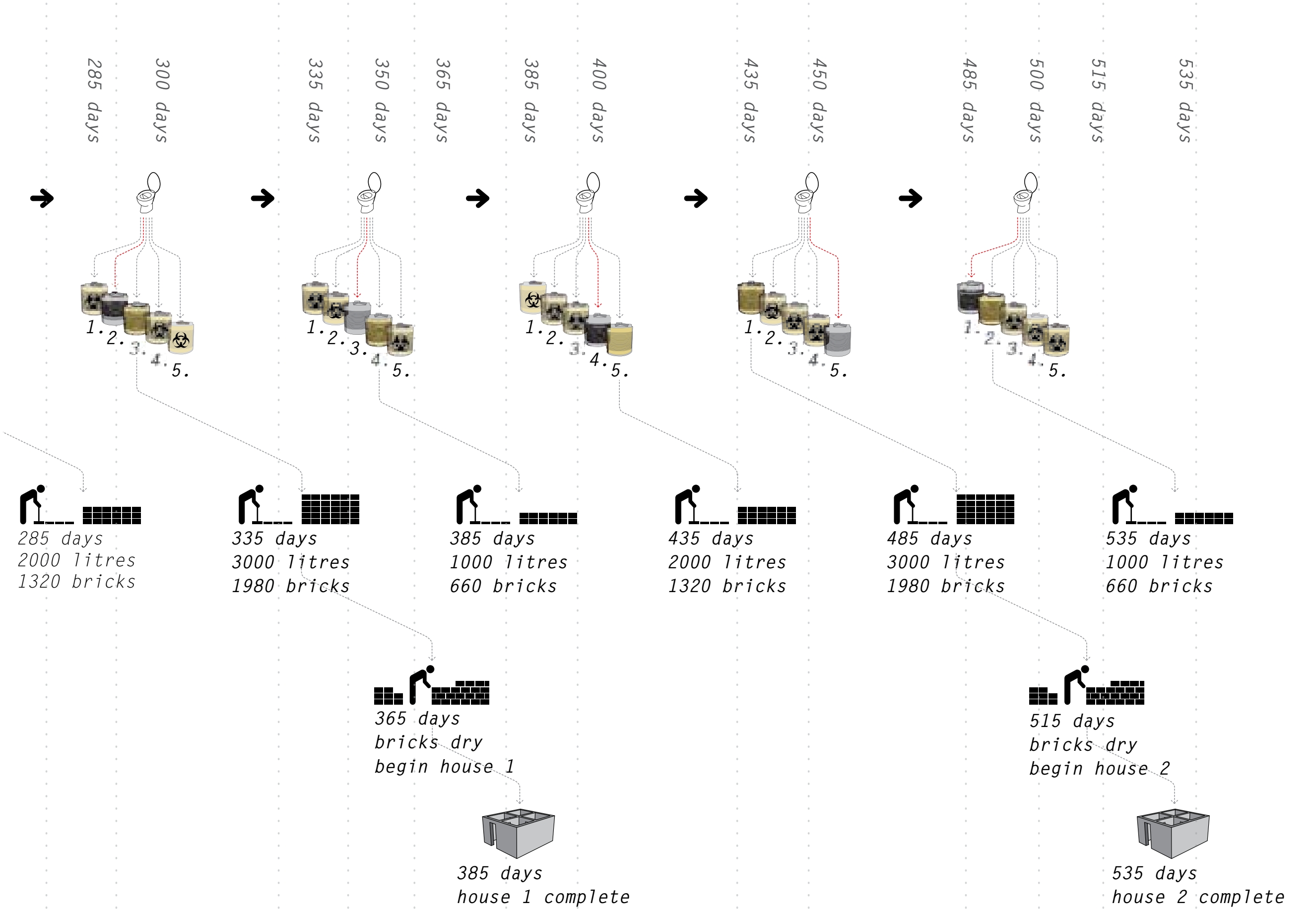
105. Fact Sheet 5: Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systmes, www.ecosanres.org (14.10.2007)

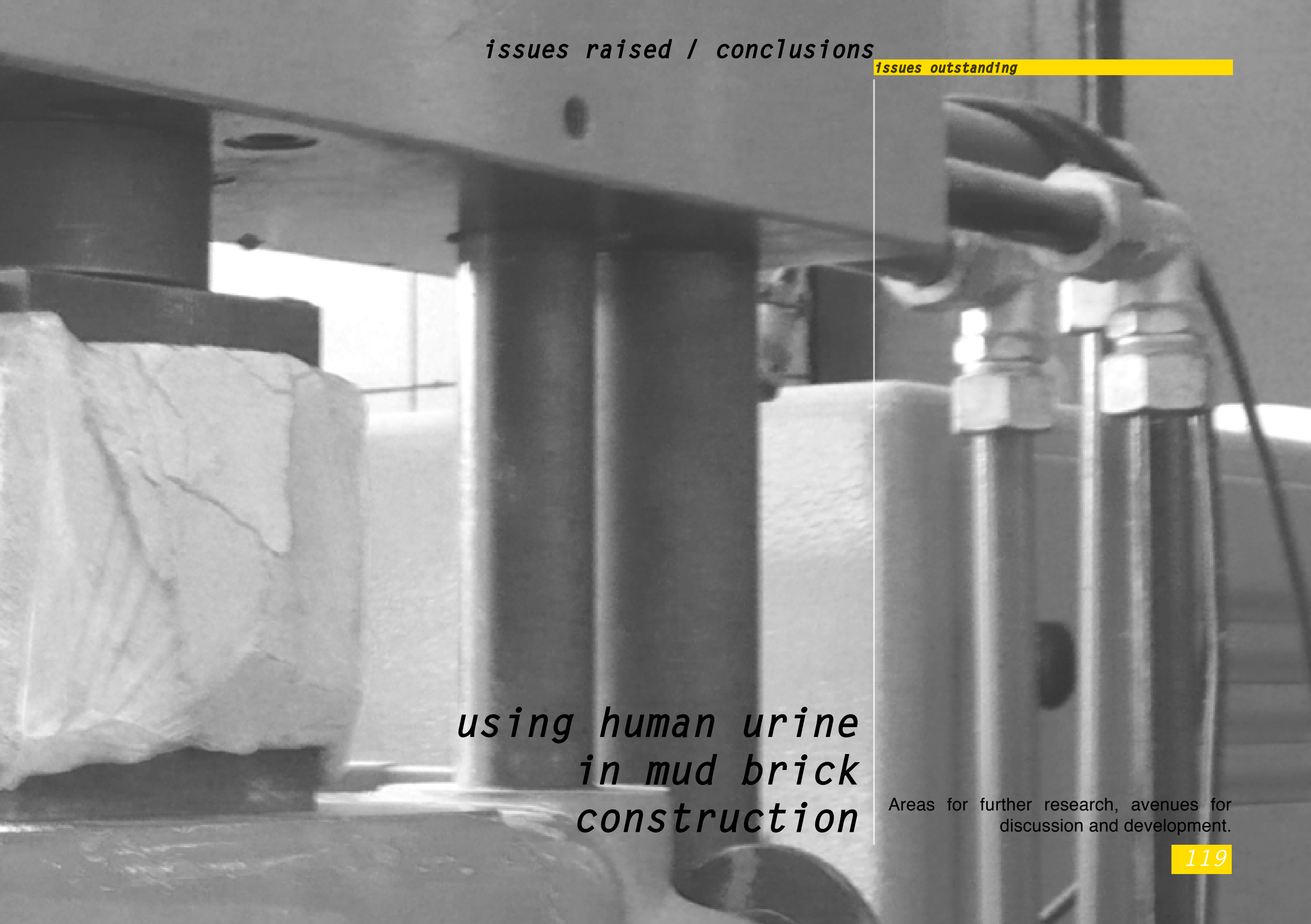

0 days
50 days
100 days
150 days
200 days
235 days
250 days
1. 2. 3. 4. 5.
1000l urine tank sealed and stored for 6 months
to reduced pathogen content to safe levels
235 days
1000 litres
660 bricks


1 adult produces
1 litre urine a day
20 persons
per WC
Tank holds
1000 litres
1 brick uses
1.5 litres
4 person house
uses 1950 bricks

timeline to implementation

from collection to construction





using human urine in mud brick construction

Areas for further research, avenues for discussion and development.

Having made a start in understanding the use of urine in mud-brick manufacture, there is an obvious need for further research into issues that have become apparent during our work.

1. Our suspicion is that, despite the lack of statistical significance of our results, there is a strengthening action of urine in mud-bricks made using montmorillonite clays and that this needs to be confirmed using a larger sample size and a slower, more controlled drying process than we were able to use.

2. Our observation that kaolinite blocks containing urine offered more resistance to water damage than those without urine needs following up. Although kaolinite is not suitable for mud-brick manufacture, it is never found in isolation and, therefore, mud-bricks in real-world situations where kaolinites are present may have a benefit in being resistant to water damage. Our observation of this effect is not quantified which it needs to be to make the results useable.

3. More tests need to be made on montmorillonite blocks to see it the effect of water resistance seen in the kaolinite blocks can be replicated. The soak tests conducted on the montorillonite blocks were not exhaustive and may not have run for long enough for any observable change to happen.

4. Our tests were made on blocks that were new. Although we found that there was no significant effect using urine in place of water we cannot say that this is going to remain the same over time as the urine components may degrade and may in turn cause a mud-brick to lose some structural strength.

5. Our tests "favour water" in that the "optimum" mix was based on the ideal liquid/solid ratio for water, not urine. In practice, using the same volume of urine in an identical mix produced a drier mix, but our tests did not compensate for this. Therefore, quite possibly, rather than comparing urine and water "optimum" results to each other (Montmorillonite: Urine, optimum = 0.603 MPa; Water, optimum = 0.532 MPa), we should, for example, be comparing urine's "wet" mix with water's "dry" (eg Monmorillonite: Urine, wet = 0.661 MPa; Water, dry = 0.460 MPa). These give very different results – the former implying that the urine bricks are 13% stronger than the water, the latter that they are 43% stronger. In future, tests that wanted to avoid this bias could:

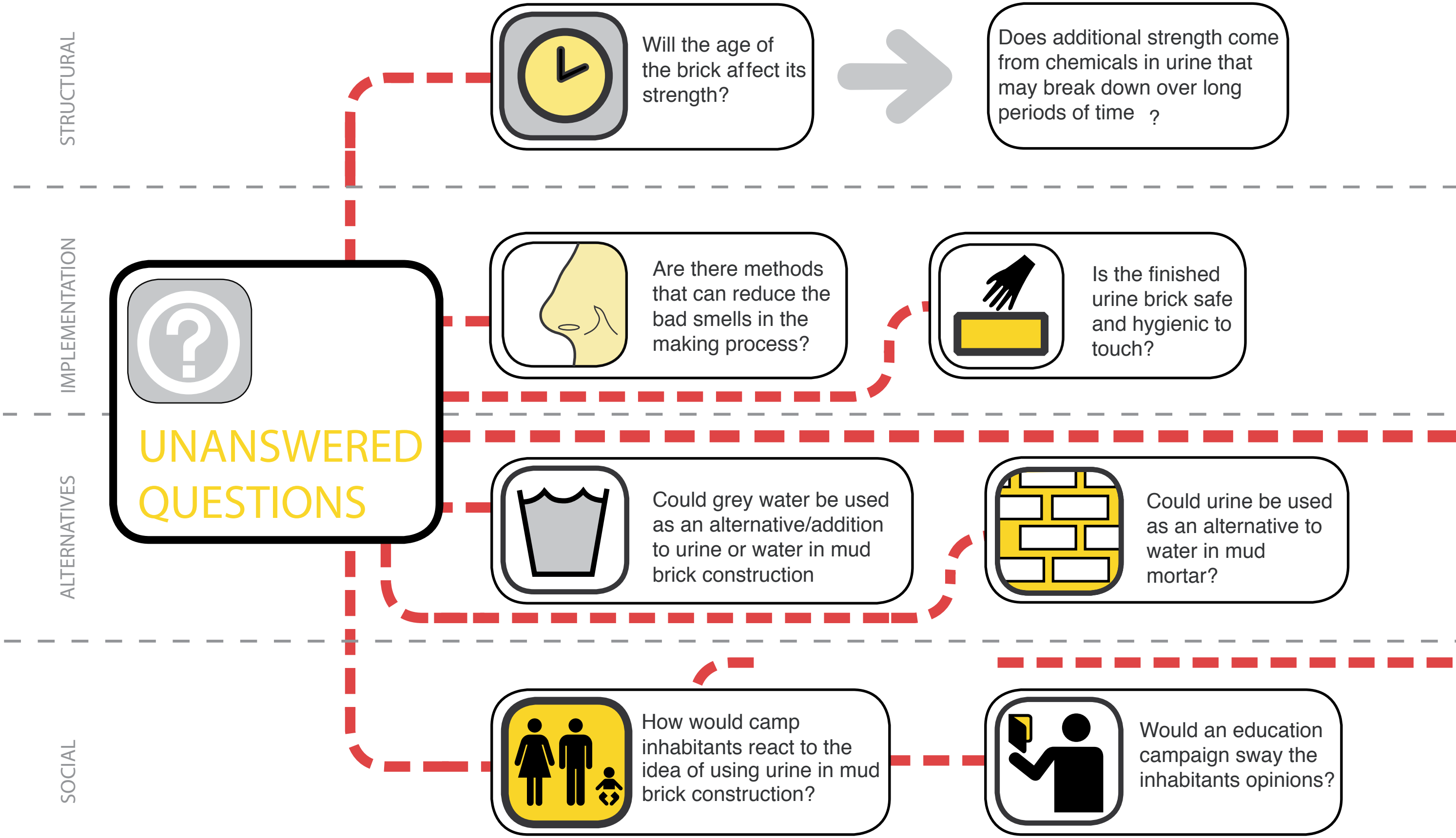
a) Do a drop test, or even a more accurate but simple 'cone penetration' test for each mix combination, as an indication of workability.

b) Carry out a moisture content test for a few key mix combinations (need not take the standard 24 hours of a British Standard soils moisture test, but can get very accurate results in 5 minutes using a microwave oven).

6. We still don't know exactly how urine strengthens (if indeed it does.) We speculate in our report that the intercollating nature of montmorillonite clay may be why urine could affect the binding properties, but this has not been proved (indeed, if this is so, Kaolinite should show NO signs of being affected by urine, which it does). Is the intercollating theory a red herring?

7. Because we don't know why urine may improve binding, we don't know how the properties of old urine (ie, urine stored for 6 months in a sealed container) might affect the mix and eventual properties of a brick. Some of our research and literature suggests that putrefied urine may have longer chains of chemicals that would therefore form stronger intercollating bonds between clay platelets.

Although this list is not exhaustive it provides what we see as some of the more pertinent issues that could be taken further in the practical application of our work.



STRUCTURAL
IMPLEMENTATION
ALTERNATIVES
SOCIAL
UNANSWERED QUESTIONS
Will the age of the brick affect its strength?
Does additional strength come from chemicals in urine that may break down over long periods of time ?
Are there methods that can reduce the bad smells in the making process?
Is the finished urine brick safe and hygienic to touch?
Could grey water be used as an alternative/addition to urine or water in mud brick construction
Could urine be used as an alternative to water in mud mortar?
How would camp inhabitants react to the idea of using urine in mud brick construction?
Would an education campaign sway the inhabitants opinions?

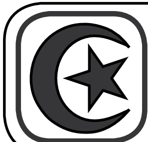
The Live Project Team has endeavoured to cover as many issues as possible. However within the course of the live project a number of issues arose which the team considered to be important but have not had the means to cover.

Will the age of the urine brick affect its structural strength? we could speculate that additional strength of urine bricks may come from chemicals in urine that may break down over long periods of time, which can only be answered by extended research in this area.

How would the camp inhabitants react to the concept of using urine in mud brick construction? Would an education campaign sway the inhabitants' opinions? Are there religion and gender issues that need to be addressed? Is the finished urine brick safe and hygienic to touch or would the urine brick structures need to be rendered? What render would work well? Our research thus far suggests that it is relatively safe, but if the bricks were subject to an extended wet season, where they were continuously damp, the likelyhood of the porous bricks harbouring harmful pathogens greatly increases, making the walls of peoples homes unsafe to touch for risk of transmitting disease. Wherever these questions arise, they must always be considered against the possible benefits in further research.

Does the brick structure need to be rendered? What render would work well?

Could the plastic or woven bags in which cereals are delivered be used as an alternative to straw in mud brick construction



What are the religious issues that need to be addressed?

What are the gender issues that need to be addressed?

Why us? The role of the architect

The live project team of 12 architecture students had little to no previous experience in mud construction, the chemical makeup of urine, compositions of soil, structural engineering, molecular biology, geotechnics or biomedical engineering. So why did Architects for Aid approach us when they decided to explore the idea of using human urine in mud brick construction? The answer to this question became increasingly clear throughout our explorations and is defined by the role of the architect as the mediator of expertise.

The research network that has been created throughout the University of Sheffield and far beyond has been the triumph of 'Human Urine in Mud Brick Construction' and the information in this book is heavily reliant on the enthusiasm and knowledge of a great number of individuals to whom the team is tremendously grateful.

This pioneering research represents a potential new building technique that could make very real and hugely important changes to the standard of living of an immense number of refugees and IDP's worldwide. The role of the live project team has been to create a basis of research that draws upon a very wide number of issues and future developers can feel confident in the use of our findings.

Urine mud brick strength

This project is not solely about the strength of urine mud bricks, but rather about whether the use of urine in mud brick construction is a viable solution in parts of the world with severe water shortages and the need for semi-permanent shelter. For this reason the physical strength of the urine mud brick is merely one of many issues to consider in whether this is an employable solution.

The tests show very encouraging results. In general, the urine mud bricks either equal or outperform the water mud bricks, in both compressive strength and their durability against water – these being the two most important structural issues. The first thing that we take from our results is that urine does not have a detrimental effect on the strength of a mud-brick. Secondly, though the statistical results show no significant difference between test conditions our results indicative that there may be a strengthening or reinforcing effect.

The early aim to prove whether a urine mud brick can physically replace a water mud brick, in terms of structural strength, was a resounding success. Armed with a confidence in the strength of urine mud bricks, the team had the assurance to progress towards assessing how the use of urine mud bricks could be practically applied within the field.

Infrastructure

The most prevalent factor in determining the potential success of substituting water for urine in mud brick construction entails an evaluation of the infrastructure required to implement essential process tasks such as: the collection of urine; the process of making urine and mud bricks, and instruction for camp inhabitants. Considering the size and nature of refugee and IDP camps in areas such as Darfur or the Sudan/Chad border, the project is heavily reliant on the success of implementation in the field.

The collection and storage of urine is fundamental to the potential achievement of the project. Disease can quickly become widespread within refugee and IDP camps and for this reason NGO's have tirelessly promoted stringency in sanitation use. The possible collection options certainly complicate the use of toilets within the camps. And while storage tanks and urine diversion toilets go a long way toward ensuring human urine is safe to use, user education and safe use promotion requires a high level of commitment to future implementation research. A sustainable infrastructure could be timely and costly but would certainly dictate whether the idea could be realised.

The making of urine mud bricks is another area which demands attention. Although the team are confident that the urine mud bricks do not smell once entirely dry, it is undeniable that the process of making urine mud bricks can be unpleasant. It is also clear that traditional techniques of pouring water directly into the ground would need to be readdressed. Some simple equipment including containers, boots and gloves could solve theses problems, but again require an investment into the future of refugee camps.

The future of urine mud bricks

Using human urine in mud brick construction initially seems like a drastic measure. The concept of using our own excrement as a building material is not a novel technique, but in the 21st century it sparks strong reactions. Is it unethical to expect people to use there own urine in the construction of their homes? Or do desperate needs call for desperate measures?

While the team has continuously considered these questions throughout the course of this project, it seems impossible to give one clear answer. There are highly complex sociological issues that surround these questions. Alarmingly high proportions of refugees and IDP's have experienced trauma and acute depression and are in the process of grieving loved ones. These factors highlight the urgency in the need for semi-permanent shelter rather than makeshift transitional shelter. However, does the use of excrement signify a higher level of extremity and desperation for people who have already been subjected to unforgiveable injustices?

As far as possible, the team have endeavoured to present a nonaligned and non-political approach to a series of questions. 'Human Urine in Mud Brick Construction' is pioneering research into a previously undocumented possibility for the future of refugees and IDP's in dry, arid locations. While there are questions left unanswered, the team feel confident this study can form the basis of future progressions into this exciting new possibility for humanitarian architecture.

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