SANITATION IN CHINA

PRACTICES OF EXCRETA TREATMENT AND REUSE

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SANITATION AND THE HEALTH CARE SYSTEM

In China, the technologies and approaches used for environmental sanitation and in particular excreta collection and reuse are integral parts of the overall health care system. This system provides continuing institutional support, information and even motivation for the successful use of certain technologies and approaches in the rural areas. In contrast to the vast majority of other countries, health care and environmental sanitation are carried out by the villagers themselves and not by government agencies, although the latter act in a supportive capacity. Health care and environmental sanitation are intimately integrated into the political and administrative system.

Administratively, China is divided into some 70,000 communes which serve as the basic unit, each comprising about 10-15,000 people. These are subdivided into 'production brigades' which are again divided into 'production teams'. The Ministry of Health operates largely in an administrative role at national and provincial levels. At the county level, the County Health Bureau maintains Epidemic Prevention Stations which are responsible for mass health campaigns, training of personnel, mobile health teams and support for the health and medical care programs. Health Centres are located within the communes to provide health and family planning services and to train barefoot doctors and health aides. Environmental sanitation activities are centred at the production brigade level and, along with other duties, are the responsibility of the barefoot doctors, who receive four months' basic training and a month-long refresher and upgrading course each year. The barefoot doctor is supported by a sanitary worker at brigade and a health aide at team levels in his sanitation work.
Sanitation programs are promoted through mass campaigns originating from the Epidemic Prevention Stations. The best-known national mass campaign was against the Four Pests (mosquitoes, flies, rats and bed-bugs). The Epidemic Prevention Stations are also responsible for prevention of infectious diseases, including the parasites, occupational diseases and promotion of continuing efforts towards environmental health through the county hospitals, commune health centres and brigade health stations. The sanitation programs depend heavily on the peoples' financial support and participation. Each activity or program is repeatedly described and discussed with the people and promoted through a variety of media including the radio, manuals, wall posters, group meetings, home and meeting-place visits and personal contacts. The Ministry of Health does not enjoy any extraordinary enforcement powers.

Although this paper focusses on technologies used for excreta reuse, it should be recognized that the environmental health programs in China do cover other activities such as wastewater disposal, pollution control, water supply, food and industrial hygiene, and solid wastes management. It is emphasized that success of the following technologies in practice has depended heavily upon active participation of the people and the administrative and promotional support described above.

As rural water supplies are fast becoming a focus of international health programs elsewhere, comment should be made at this point with regard to China's activities in water supply delivery. Compared to other activities in environmental sanitation, the provision of clean water has not been given high priority in China. There are no 'national targets' for improving water supplies. The protected village open well remains the
most important source of water which is sometimes provided with a cover
slab and simple handpump. Where deep groundwater tables are encountered,
wells are drilled and motor-driven pumps used to supply piped water to
village stand-pipes or house connections. (1)

THE CHINESE BIOGAS PLANT

It is reported that 80,000 biogas plants are operating in China,
most of them located in Szechuan Province and operated at the brigade or
production team level. (2) Lesser but important efforts to introduce
biogas plants have been undertaken in India and Korea. The Chinese bio-
gas plant design differs from the Indian and Korean in that it does not
use a floating gas holder as a storage chamber for the gas which, in the
Indian and Korean designs, rises and falls as the gas is produced and
drawn off for use in the household. Instead, a simpler, cheaper and
more maintenance-free design is used which incorporates a fixed-tap gas
holder. (3) The plant comprises six parts, as follows:

(1) the inlet chamber which daily receives human excreta (10%),
animal faeces (30%), crop stalks (10%), and water (50%);

(2) the rectangular or circular fermentation tank used to store
the wastes during fermentation;

(3) the fixed-top gas storage tank, providing space for gas
accumulation;

(4) the outlet chamber, receiving digested wastes from the
fermentation tank at its mid-depth;
(5) the slurry displacement tank located on top of the fixed gas storage tank, which is used to store excess slurry as the gas accumulates; and

(6) the gas vent pipe and ancillary equipment.

As biogas is produced by digestion of the wastes, it accumulates under the inverted gas holder, forcing the liquid level in the fermentation tank downwards. The equivalent volume of slurry is displaced, moving through the outlet chamber and on top of the fixed gas storage tank where it is stored. As gas is used in the household, the displaced slurry returns to the outlet chamber.

There are several disease-causing organisms which are transmitted through excreta and may pass unharmed through the biogas plant to reach the soil, crops, and eventually be ingested by man. Although some investigations have indicated that the biogas plant is capable of removing or destroying many parasites, it is by no means certain that the effluent from the plant is free from disease-causing organisms.

Research on transfer potential of biogas plants was carried out by the Research Institute for Parasitic Disease Prevention and the Revolution Committee of the Mien Chu County Communicable Disease Prevention Office, both of the Province of Szechuan. (3 and 4) The several plants under study were reported to be fed a mixture of swine (30%) and human (10%) excreta, with waste vegetable stalks (10%) and water (50%). The biogas plants normally had a capacity of about 10 m³. Samples were drawn from the influent, the fermentation tank bottom and the bottom and top of the
outlet chamber. Total parasite eggs (including Schistosoma, Ascaris and hookworm) were counted; it was determined that there was a 94% egg retention in the plant. It is emphasized, however, that the effluent still contained over 1,500 parasite eggs per 100 millitres; this was due to the fact that there were over 23,000 eggs/100 ml in the influent. The hookworm die-off was both rapid and effective. It is likely that the hookworm eggs settled to the bottom of the tank to digest with the sludge. Unfortunately, little could be said about the schistosomes, in that too few a number were observed. Later experiments did, however, indicate that even with improvements to the biogas plant's physical configuration, schistosome miracidia were found in the effluent liquid in four out of six examinations. Further, schistosomes were later observed to live up to 37 days in a simulated biogas plant experiment.

The hardiest egg of all is the Ascarid or roundworm ovum. The percentage of viable eggs in the influent was 68%, whereas in the effluent it was 60%; the total number of viable eggs in the effluent was 710/100 ml. Thus, the biogas plant had relatively little impact on the roundworms' viability. The reduction in levels of disease-causing organisms is due both to the physical separation of the organisms by their settling to the bottom of the tank and to their natural die-off in the tank under adverse growth conditions. Certainly, the major contributing factor to their reduction in the case of the hardier parasite eggs is that of physical separation. In one experiment, an improvement of the plant's effluent storage chamber and point of effluent removal from the tank clearly indicated an improvement in total parasite egg reduction from 80% to 98%.
Although research has increased our knowledge of the relationship between man, parasites and their intermediate hosts, little information is available on the transfer of such organisms through excreta or manure reuse systems. This is also true of the bacterial and particularly the viral diseases. As described above, indications are that a healthy removal of some of the hardier and/or more prevalent organisms does take place in the biogas plant; but a significant level remain in the effluent, which is applied to land or aquaculture ponds.

THE THREE-TANK SYSTEM

Much has been said but little published on the Chinese three-tank toilet system (also known as the three-vault septic tank and the two-partition, three-tank type toilet). The Epidemic Prevention Stations of Chiang and Chinkiang Counties of Kiangsu Province have provided us with full design, construction and operational details. (5) The unit is made up of three tanks connected in series and constructed either separately or with common adjoining walls. Human excreta, as collected in buckets or flushed from a nearby toilet with a minimum use of water, are deposited directly through a vertical, aqua-privy type water-seal chute and let to settle in the first underground chamber. The liquid and some of the sludge pass through a horizontal connection in the lower portion of the tank to the second tank, where anaerobic decomposition of the wastes proceeds. The second tank discharges by means of an outlet at its surface which leads to the bottom of the third tank. This is used as a storage chamber from which digested liquid is removed by dipper bucket on a handle or rope for use in the fields or in aquaculture. The purposes
of this design are basically twofold. Firstly, the digesting liquid moves very slowly through the system, being displaced only by incoming excreta and small amounts of flush water. Treatment is effected by anaerobic digestion and settlement of the heavier solids (including parasite ova) on the bottom of all three tanks. Secondly, the overflow of liquid from second to third tanks allows for removal of excreta for use as a fertilizer only after the liquid has had the full retention period in the first and second tanks. Provided that the three-tank system is properly used, it effectively raises a barrier against using fresh excreta on crops. Based on a per capita output of 2 l/c-day, the first two tanks are designed to provide ten days' retention each and the third one up to a maximum of thirty days.

Ascarid ova destruction and nitrogen transformations are reported. (4) Samples were taken from the upper, middle, and lower levels of a typical system in Shih Chiao. The influent excreta contained over 2,300 ova per gram. Ova concentrated in the bottom sludge and surface scum of the tanks. No viable eggs were found in the upper and middle layers of the third tank, from which effluent was drawn for fertilizer. The bottom of the third tank, however, contained 2,263 eggs/gm, of which only 2% were viable. Some 20 - 30% of total nitrogen is lost in the bottom sludges and given off as gas; however, the ammonia-nitrogen which is considered available for plant utilization increases from 0.08% to some 0.20 - 0.35%, thereby improving the fertilizer quality of the excreta over what it would have been had it been applied directly to the soil without three tanks' treatment.
CHINESE COMPOSTING METHODS

Composting as a method of nightsoil treatment and reuse has been practised for centuries in China. Human and animal excreta, river and pond bottom muds, and even feathers, were used to fertilize the soil at least as long ago as the Yuan dynasty. (6) Along with other methods of nightsoil reuse, improvements in excreta composting have been made since the early 1950's to reduce dangers to human health, while at the same time recovering as much of the wasted nutrients as possible.

Two methods of nightsoil composting are described (7) which represent significant improvements over practices being used elsewhere in Asia. They are:

1. the surface aerobic continuous method; and
2. the large-pit, aerobic composting method.

The interesting features of these methods are that they both (a) use a mud-cake covering to reduce heat losses and fly/maggot infestation, and (b) use air ducts formed by bamboo rods originally placed in the compost during pile formation and later withdrawn. The surface method is best for climates which do not reach freezing temperatures in winter. Human excreta, livestock manures, refuse and soil are usually mixed in equal portions by weight (although these vary considerably depending on location and availability of raw materials) and are first placed on the ground in a 9 x 9 x ½ ft. layer. Four three-inch bamboos are placed horizontally at three-foot intervals; four vertical poles are placed and supported where the horizontal poles cross. The rest of the compost material is added to reach a total depth of three feet. The pile is covered with a two-inch pack mud, horse dung and straw mix, and let to compost.
Aerobic, or at least micro-aerobic composting takes place over the following month, during which the temperature in the pile rises to 50-60°C over a period of 5-7 days. The average compost temperature was reported to be just above 40°C during tests in Hopei Province. Ascarid egg viability was reduced from 68.5% to 2% in the final humus. Loss of total nitrogen was not reported, although ammonia-nitrogen rose from approximately 0.07% to 0.11%.

The pit method uses a five-foot deep pit or trench of 4 ft. width and 3" x 3" air channels dug in its bottom which are covered with crop stalks. Vertical bamboos are placed and supported at channel intersections and later removed after the pit is filled with raw compost material and covered with a layer of mud. Although the pit technique requires more labour, it does permit composting in northern regions which reach sub-zero temperatures in the winter.

THE VIETNAMESE DOUBLE-VAULT LATRINE

I have not been able to find reports of the use of the double-vault latrine within China; however, it is worthwhile mentioning here as another method of excreta treatment and recovery of nutrients. The double-vault latrine (otherwise known as the double septic tank) is the backbone of the 'Stop the Faecal Peril' Movement of the Vietnamese Health Care Program. (8) The Vietnamese double-vault latrine comprises two chambers in which faeces and ashes are deposited for micro-aerobic mouldering (composting). The toilet itself is located above and faeces and ashes drop through the hole into the mouldering chamber. Kitchen ashes and compostable wastes (about one part ashes to two of wastes) are sprinkled
on the faeces after defecation. The ashes are said to absorb odours. After filling one chamber (approximately 1.1 x 1.6 x 0.7 metres high), the contents are levelled and ashes used to fill it to the brim. The chamber is then sealed off and let to ferment, while the alternate chamber is used for defecation. The temperature in the compost rises to some 5°C higher than ambient conditions, although it is reported to reach 50°C during the summer. Micro-aerobic conditions probably persist within the chamber. After some two months or upon filling the alternate chamber, the first chamber is emptied of humus and returned to service as a storage chamber. One aspect of the Vietnamese toilet should be noted: urine is separately drained off to the soil and not allowed to enter the chamber. This reduces the moisture content of the mouldering material and thereby avoids anaerobic liquefaction of the faecal material.

The Vietnamese Ministry of Health has prepared a manual on the subject (9) which provides design, construction and operation details. It also gives results of tests on the humus and concludes that 85% of viable ova are destroyed by the process. It is reported that 98% of organic nitrogen in the waste material is transformed to inorganic forms. (9)

EXCRETA COLLECTION AND REUSE PRACTICES IN CHINA

The wooden bucket collection system is widely used in urban China. The buckets of about 10 litres in size are manually collected and tipped into sealed carts for delivery to holding tanks for later sale and use as a fertilizer on the communes. Reduction (not total removal) of pathogens may be effected by tank storage, depending on the season and
how urgently the excreta is needed. Public latrines are being favoured over individual ones. These use either a simple vault for storage or more preferably the three-tank system, which provides a further barrier to disease transmission. In the denser city centres, sewerage is being used as the only means of removing wastewater from high-rise areas. Conventional sewage treatment methods are employed and the sludge and treated effluent recovered for reuse on the communes wherever possible.

The bucket latrine is also employed in rural areas where concentrated excreta is reported as being valued higher than inorganic fertilizers. The shallow container latrines, which require frequent emptying and are open to insects and rhodents, are being replaced by communal three-tank systems. In the cases of bucket and shallow-container latrines, the excreta is removed to a tank or sump from which it is distributed for use as a fertilizer. These tanks or sumps should be covered and the contents allowed to ferment anaerobically for 2 - 4 weeks, thereby destroying schistosome and hookworm ova.

In 1949, intestinal diseases were rampant throughout China, as were poverty, malnutrition and illiteracy. The government was faced with having to make do with a very poor resource base; thus, recovery of all reclaimable materials was mandatory. Having a history of unhygienic practices of human excreta recycling as being the primary cause of the spread of intestinal disease in the population, efforts were made not to eradicate the practice (as would have been the first reaction of Western governments) but to improve upon methods of collection and reuse to include treatment in as practical and inexpensive a way as possible.
Chao has estimated the quantities of natural fertilizers used in China between 1952 and 1966 (10); an adapted Table of these estimates is given in the following Table. (11)

<table>
<thead>
<tr>
<th>Application of Natural Fertilizers in China (after Kang Chao (10))</th>
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</thead>
<tbody>
<tr>
<td>Night-soil (gross weight)*</td>
</tr>
<tr>
<td>Night-soil nutrients, %**</td>
</tr>
<tr>
<td>Pig Manure</td>
</tr>
<tr>
<td>Pig manure nutrients</td>
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<tr>
<td>Large animal manure</td>
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<tr>
<td>Large animal manure nutrients</td>
</tr>
<tr>
<td>Compost plant residues</td>
</tr>
<tr>
<td>Compost plant nutrients</td>
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<tr>
<td>Oilseed cakes</td>
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<tr>
<td>Oilseed cakes nutrients</td>
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<tr>
<td>Green manure</td>
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<tr>
<td>Green manure nutrients</td>
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<tr>
<td>Muds</td>
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<td>Muds nutrients</td>
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<tr>
<td>Total nutrients, million tons</td>
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</tbody>
</table>

* gross wet weight in millions of metric tons  
** % total nutrients applied as fertilizer available to plant

Over this period about one-third of the nutrients applied for plant growth was provided through human nightsoil. Chao estimates that during 1952, 70% of human excreta was collected and used as fertilizer; this was pushed up to 90% (297,800,000 tons) in 1966, a truly remarkable undertaking of gigantic proportion.
By 1953, the task of redistributing land was complete and the first five-year plan launched. Economies of scale were sought through collectivization and consolidation of land holdings. Land was reclaimed, and multi-cropping schedules were introduced to many areas. During 1954-1955, there was a rapid acceleration of centralization and ambitious goals were set. Eager to raise agricultural productivity, an 'Accumulate Fertilizer' campaign was initiated and spread throughout China during the winter of 1955-1956. Chao reports that 70 million rural youths participated in gathering 400 million tons of natural fertilizers.

The key to the successful reclamation of human waste in China has not been merely the innovation of appropriate technologies but their being developed and promoted through active participation of the people, backed by an effective information system and supported by motivated cadres at the village level. The technologies employed could be transferred to other countries in the region but care must be taken to ensure that they are not simply 'demonstrated and enforced' without the necessary administrative support and extension services.

Many questions can be thrown up as to the advisability of using excreta in the process of food production. In our ignorance of the mechanisms of pathogen die-off and transfer, it is tempting to take the path of least resistance and enforce unrealistic regulations which may prohibit such practices. It should be emphasized, however, that we are trying to improve an existing situation rather than force it to meet unrealistic standards. It is highly possible that the existing malpractices of excreta and manure disposal in other countries are far worse in terms of transmitting disease.
than what may result from the Chinese and Vietnamese approaches as described above.

ACKNOWLEDGEMENTS

The foregoing has been written on the basis of a literature search and not on first-hand observation in China. Personal discussion with Somnuek Unakul, who visited China for purposes of reviewing sanitation programs there during 1973 and again in 1974, assisted greatly in verifying the data, as did an IDRC-supported review of Chinese sanitation by W.L. Kilama, J.H. Lindsay, P.A. Oluwande, A.G. Onibokun and U. Winblad in 1975. Of greatest help was the Compilation of Data and Experience on Sanitary Management of Excreta and Urine in the Village, published by the Peoples Hygiene Publisher and brought from China by Somnuek Unakul and later translated for IDRC by Thim Loy Lee. The translation is currently being prepared for publication under the IDRC Technical Series of publications.
REFERENCES


3. Revolution Committee, District of Mien Chu, Province of Szechuan "Excreta Removal from the Middle of a Fully Enclosed Type Biogas Plant", in Compilation of Data on Experience and Sanitary Management of Excreta and Urine in the Village, Publ. Peoples Hygiene Publisher, China, 1974, pp. 55-65.


