INCINERATION IN CANTONMENTS IN INDIA.

By Captain P. S. LELEAN.
Royal Army Medical Corps.

Cantonment incineration presents many inherent difficulties which do not hamper the practice of this conservancy method in the field, and, in view of these special difficulties, the whole problem calls for re-consideration as we face afresh the familiar questions :—

(*A*) Is incineration practicable in cantonments?
(*B*) Will it increase the cost of conservancy?
(*C*) Will its adoption increase military efficiency?

A. Practicability.

Unfortunately this is not merely a matter of physics—rather is it a question dominated by the obstructive æsthetic, the myopic economist and the unspeakable *mehtar*. We want to know that we can incinerate excreta without causing undue offence, with the material at hand and without running up the conservancy bill, and without overtaxing the intelligence and reliability of the sweeper.

The hygienic desiderata are that potentially infective dejecta should be rapidly destroyed, while being protected meanwhile from all disseminating agencies, especially from flies which incidentally should be reduced to minimal numbers.

(1) *Disposal of Urine.*

The matter would be reduced to comparative simplicity if some means could be devised for safely disposing otherwise of the great bulk of the 300 odd gallons of urine passed daily by 1,000 men. Various methods have been adopted or suggested :—

(*a*) *Distant Trenching.*—If solids are to be burnt and urine trenched, it is clear that maintenance of this dual organization must militate against economy. Moreover, cartage of urine alone will lead to dumping of considerable quantities on cantonment outskirts, which could not occur if the carts contained mixed filth.

(*b*) *Surface Irrigation after Heat-Sterilization.*—No suggested device has provided automatic security against the chance of possibly infective urine being run, unsterilized, on to the surface soil of cantonments. Hitherto strong exception has been taken to this method, and especially so in stations deriving their water-supply from shallow wells in or near the lines.

(*c*) *Disposal in Buried Soakage-pits.*—It is suggested that urine from the urinal trough be piped direct through a buried iron lid into an underground pit filled with cinders. This certainly prevents dissemination of urinary organisms by flies and wind, but other aspects require very careful consideration.

On the one hand we know that *B. typhosus* cannot be recovered after the third day from soil contaminated by bacilluric urine; nor, after the fourth day, even from urine containing originally 60,000,000 *B. typhosus* per cubic centimetre.

On the other hand there are these factors: (i) The rains raise the subsoil water into direct communication with all urine pits and all wells in the station; (ii) Percolation can carry the *B. typhosus* through a 15 ft. belt of sand; (iii) *B. typhosus* and its allies are far more motile than *B. coli*, which frequently finds its way into filtered water supplies. Direct flow, percolation and motility may all combine to carry infective organisms from the pits towards the wells. In stations obtaining drinking water from a distant source cutting of the pipes at any time, by accident or by the enemy, would force large bodies of troops to drink water drawn from wells in subsoil levels saturated with percolating urine. He would be a bold man who would recommend this measure for general use while realizing that our knowledge of the transition and involution forms of specific organisms in their saprophytic phase still consists of a few scattered negations.

(*d*) *Evaporation.*—Three chemical firms having declined to make an offer for residual urinary solids obtained by evaporation, it is doubtful if this by-product can be worth anything approaching the sum stated; as, however, it is evident that its inorganic salts alone must possess a very definite manurial value, experiments have been persevered with. This question being the crux of the whole incineration problem, the time spent in briefly summarizing the results of those experiments will not be wasted.

Experiment 1.—The urine of a company (200 pints *per diem*) was all passed into a receptacle containing 90 lb. of sawdust, and having a surface exposed to permit evaporation. During the first four days, the season being the monsoon, the whole of it was evaporated. On the fifth day some effluent appeared, but this was inodorous. In order to delay the appearance of the effluent until the eighth day, and maintain it sterile indefinitely, the sawdust had to be increased to 270 lb. The sawdust at the end of the week contained some 13 per cent of its weight of urinary solids. The salinity of the urine in the upper layers was not, as was hoped would be the case, so great as to arrest fermentation, and great complaints of smell were made. It is clear that flies, offence and cost of material make the adoption of this method impossible.

Experiment 2.—Charcoal was tried next, an improved V-shaped trough being made of layers of charcoal upheld and enclosed by wire netting. The dry season results were: 225 lbs. of charcoal were needed per company; 1 per cent of effluent appeared on the sixth day, being sterile, odourless and so saline as to be anti-bacterial; flies abounded and the ammoniacal smell from the upper layers was much complained of.

Experiment 3.—The apparatus used is diagrammatically shown in fig. 1. A 3 ft. cube frame was enclosed with wire gauze. Urine

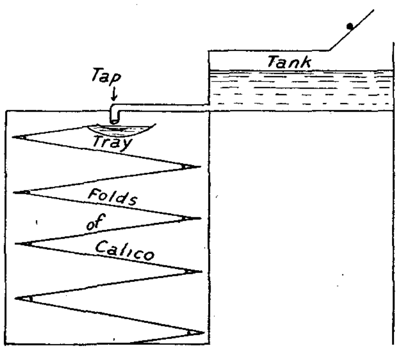


FIG. 1.—Urine Evaporator.

was conveyed by means of a tap into a shallow gutter in the roof, in which one end of a piece of calico, 60 ft. long by 3 ft. wide was fixed. The urine was sucked up by capillarity and flowed down the length of the calico, which zigzagged down the chamber, turning over horizontal wires at each side alternately. The flow of urine was adjusted by a tap so as to keep the whole of the calico moist. The total evaporating area (on both sides of the calico) was 360 sq. ft., and free access of sun and wind was secured, the folds being edge-on to the prevailing wind.

Theoretically the evaporation should be 15 gallons per hour at 85° F.; experimentally it was found to be 10 gallons, owing to lowering of the temperature by evaporation. This would appear to be most satisfactory, but strong complaints were made of ammoniacal smell, and it was found practically that the material sagged, so that urine dripped straight through the centre and the periphery dried up, while the loose stuff threw off a fine spray as it flapped in the wind. The gauze kept flies away, but the spray was carried to a considerable distance, and this was an obvious danger. The little effluent that came through was sterile owing to excessive salinity caused by concentration.

Experiment 4.—Dishes containing 100 grm. of water, with 3 sq. in. of surface, were exposed for an hour in the hot-air sterilizer at a temperature of 80° C. The evaporation amounted to 22·6 grm., which could be increased 25 per cent by adding sawdust, and 37 per cent by adding charcoal to the water. The sawdust sank when saturated. The evaporation of water without the addition of charcoal or sawdust is equivalent to roughly 0·23 gallons per square foot per hour.

Having thus proved that 1 sq. ft. of water gives off $5\frac{1}{2}$ gallons in the twenty-four hours at a temperature of 80° C., it was thought that the temperature of an incinerator furnace should reach 60° C., and at that heat it should induce an evaporation of 3 gallons per square foot of fluid surface per twenty-four hours. This raised hopes that evaporation of urine from trays in incinerator furnaces might be adopted in place of open-air evaporation, which had not been found practicable.

Experiment 5.—Details properly belonging to a subsequent section may here be anticipated in order to follow consecutively the development of this line of investigation. The evaporating tray adopted is shown in fig. 2. It forms a shallow receptacle fitted to form a false roof to the furnace—where the full heat is utilized by convection—and it is then extended to form the floor of the 3 ft. wide flue, where its water surface is exposed freely to the hot air which it was hoped thus to saturate with water-vapour. The furnace is connected with the flue by means of a funnel in the tray. The tray is fed with urine from a tank on the roof by a tap, which is automatically controlled by a ball-valve, so that the tray may neither overflow nor dry up and burn through. Provision is made for the tray to slide out for removal of the urinary solids deposited by evaporation. The following results were obtained :—

(i) With a tray of 9 sq. ft., evaporation never exceeded 2·5 gallons per square foot in the twenty-four hours.

(ii) On increasing the area to $17\frac{1}{2}$ sq. ft. the total amount of fluid evaporated only increased by 3 gallons (from 23 to 26 gallons) in the twenty-four hours, while the rate per square foot per twenty-four hours fell to 1·44 gallons.

Disposal of only 26 gallons certainly did not justify continuance of a device which added considerably to the cost of incineration and, although mechanically successful, was open to legitimate objection as being complicated and liable to get out of order.

(iii) It was further found that the evaporation was reduced to but 2 gallons per twenty-four hours if the fires were damped down by moistening the fuel and thus reducing the combustion rate, i.e., so much of the caloric value of the fuel was absorbed in evaporating the fluid from the saturated litter fuel in the furnace, that little remained when the air reached the urine in the tray; hot air left

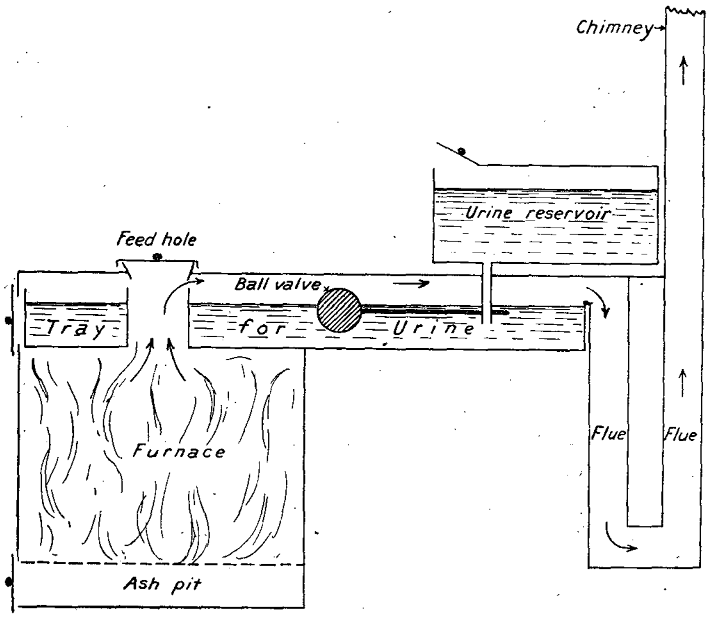


FIG. 2.—Incinerator with urine evaporating tray.

the furnace nearly saturated with water-vapour. This aspect will be more fully dealt with when we come to consider the physics of incinerators. It is sufficient here to point out that these experiments wholly contra-indicate the use of accessory evaporating devices in incinerator furnaces.

The conclusions drawn from this series of experiments may be thus summarized:—

(i) In the present state of our knowledge it is unjustifiable to dispose of urine by running it unsterilized into the subsoil of cantonments.

(ii) Maintenance of an organization for *separate* trenching of urine beyond cantonment limits is costly and difficult to safeguard.

(iii) Evaporation of urine in the open air cannot be conducted with economy and safety.

(iv) Evaporating trays in incinerator furnaces are complicated and unnecessary, considering that litter is capable of evaporating more than its own weight of liquid, if it be fully saturated before being used as fuel.

(2) *Offence.*

It needs but the whisper of "incineration" to convert the "delightfully familiar odour of burning peat—so reminiscent of the cotter's Saturday night at home," into the "intolerable stench and noxious effluvium from the burning of indescribably objectionable matter." It is some satisfaction to relate that one lady, anxious to launch her protest at the earliest opportunity, was unfortunate enough to apply the latter description with eager haste when a new incinerator was being tried with wood only, as a preliminary to commencing work proper! It is, however, immaterial to consider whether there is any essential difference between the smells of various burning organic matters or whether there is hygienic as well as æsthetic objection to the products of their combustion; unless the objection can be met, public opinion will crush the progress of incineration.

Two main types of incinerators have been designed, the open type and the closed type.

(*a*) *Open Types.*—It is impossible to review this subject without a tribute to the important part played in the evolution of this method by the initiative and energy of the inventor of the "Raitt pattern," to whom we owe a debt for his able demonstration of its general applicability. The value of that pioneer work is in no sense diminished by the fact that open types of incinerator must now be admitted to be unsuited for cantonment use. The best type of open incinerator is probably that adopted at Mhow, and it is sufficient to quote the opinion of the Principal Medical Officer 5th Division on that station, where this type was worked under the personal supervision of the inventor: "The pungent odour from the night-soil incinerators was an intolerable nuisance."

(*b*) *Closed Types.*—These marked a distinct advance, in that combustion was more complete and offensive products were more fully oxidized, becoming simple and innocuous bodies. Such patterns as Haines's, Young's, Hawes's and Cameron's still proved to be objectionable, as is shown by the fact that the chimneys had to be heightened until they discharged some 20 ft. above ground level. Such a type is in use in my own station—a Sialkote with a 20 ft. high chimney—and I have to record that, since writing my first article, I have become aware of a steadily increasing and more influential volume of complaint against this type. The station extends for about two miles in the direction of the prevailing wind, and the leeward end is constantly under a heavy pall of smoke and never free from an acrid smell, which becomes acute on windless days and especially towards nightfall. This will have to be remedied or our incinerators will be closed down. It is fortunate that we have a device which has been proved to deal most effectually with this difficulty and which is as simple as it is effective. If the top of the chimney be splayed out into a chamber, which is plugged with a bundle of dried litter, the retarded current of air deposits the greater part of its smoke and some condensed steam upon this litter filter. In addition, there is a heavy deposit of tarry material, to which carbon particles adhere. The resulting extensive surface of water and carbon absorbs a large proportion of the foul gases evolved during combustion, as well as entangling the soot. The more the chimney is splayed out, and the greater the resultant retardation of the current through it, the more completely will the deposition and absorption be effected.

One such incinerator has been in action for two years within 30 yards of a barrack-room, without any complaint being made by, or elicited from, the men. One officer, admittedly opposed to cantonment incineration, was taken directly up the wind towards this installation and failed to detect its presence until within 50 yards or so, although it was then working at its usual pressure and the chimney was but 12 ft. high.

It is probable, however, that the offence complained of is caused less by the escape from the chimney than by that which results from the constant opening—and leaving open—of the lid by the sweeper when stoking and feeding the furnace. It is obviously preferable to empty each *gumlah* as soon as used rather than to adopt the objectionable alternative of storage in *balties;* the tendency of the sweeper to leave the lid open must be checked. This has been done by fitting the lid with a water-sealed rim and hinging it with a counter-balancing weight and a flange, so that it is opened by the foot of the sweeper to only a certain angle and slowly closes of its own weight as soon as his foot is removed from the lever. Dusting of *gumlahs* with lime is found to be most effective as a means of keeping flies away, and the covering of dejecta with a layer of ash prevents offence while the *gumlah* is being carried from the latrine to the incinerator.

(3) *Fuel.*

This most important consideration controls not only the cost but the practicability of this method of conservancy. It will be best approached by the tabulation of certain essential data.

(*a*) *Amounts of Excreta, &c., to be Consumed.*—

Oz. Per Head in Twenty-four Hours.

	British troops	Native troops	Bazaar population
Fæcal solids ..	1	$1\frac{1}{2}$	$1\frac{1}{2}$
Fluid in fæces ..	3	$6\frac{1}{2}$	$6\frac{1}{2}$
Urine passed with fæces ..	5	5	5
Antiseptic fluid in *gumlahs* ..	10	—	—
Washing water ..	—	10	10
Urine collected separately ..	45	30	10
Ounces total fluid ..	63	$51\frac{1}{2}$	$31\frac{1}{2}$

Gals. per 1,000 Strength in Twenty-four Hours.

	British troops	Native troops	Bazaar population
Gumlah contents, without antiseptic ..	50	72	72
,, ,, with antiseptic* ..	112	—	—
Total, without *gumlah* antiseptic ..	331	322	199
,, with ,, ,, ..	394	—	—

Notes.

(i) Europeans pass daily fæces 4 oz., of which 75 per cent is water (3 oz.). Natives ass daily fæces 8 oz., of which 80 per cent is water ($6\frac{1}{2}$ oz.).

(ii) It is difficult to get natives to use urinals. The 30 oz. given above represents probably considerably more than the average per head collected daily from native units. The amount collected from bazaars was twice measured, it was respectively 7 per cent and 16 per cent of the total calculated to have been passed. This will cause no surprise to those conversant with native habits.

(iii) It is probable that lime is as effective as liq. cresyl. in keeping flies away from latrines; this is very important, as present regulations result in the addition of a considerable bulk of fluid to that which has to be disposed of.

(*b*) *Amounts of Fuel Available.*—(*i*) A cavalry regiment receives 2,400 lb. of bedding grass *per diem*, of which it is estimated that one half is eaten or stolen, thus leaving 1,200 lb. available. To this must be added the droppings, at 12 lb. per animal *per diem*, i.e., 4,800 lb., or a total of 6,000 lb. a day. Actual measurements for a month showed that 415 cubic ft. were collected on an average a day, which, at 15 lb. per cubic ft., gives 6,225 lb. a day.

(*ii*) I have no idea of the amount of sweepings available from

* Not used in native latrines.

dismounted units. Such rubbish is valued at one anna per cart, which, at 10 lb. per cubic ft. and 40 cubic ft. per cart, amounts to 400 lb., or say 300 lb.

(*iii*) A practically unlimited supply of grass is available; at grass-farm rates this costs 5 annas per 100 lb.

(*c*) *Amounts of Fuel Required.*—As fæcal solids provide for their own combustion, the matter is much simplified by the preceding table, which reduces the whole problem to the evaporation of so much fluid for each class.

All available data have been carefully collected. It is regretted that they are incomplete in most instances, but striking of averages for all comparable conditions has enabled many gaps to be filled. From the mass of results thus digested, there has been worked out the one essential datum, which is that showing how many pounds of fluid have been evaporated per pound of fuel expended.

Station	Type	Lb. fluid per 1 lb. fuel. During monsoon	Lb. fluid per 1 lb. fuel. Dry season
	(i) Open Patterns.		
Average of six	Raitt	Impracticable	0·80
Average of five	Hunt	0·25	0·95
	(ii) Closed Patterns.		
Dehra	Young	—	0·75
Wellington	Wellington	—	0·72
Ambala	Ambala "B"	—	0·80
Landour	Landour (model)	—	1·00
Meerut	Lancer	1·23	1·34

Notes.—(i) The Lancer pattern referred to above is one in which there is a urine evaporating tray in the furnace. These observations are now two years old. They were most carefully made daily from June 8 to November 20, and included exact weighings of fuel and measurements of fluid disposed of, through the monsoon and on into the dry season. The results obtained are so much better than those resulting from the use of other types that the following experiment was conducted to serve both as a control and to afford a comparison between the maximum evaporation from tray and furnace combined and that from the furnace only. Of the 1·23 lb. of fluid per 1 lb. fuel, 0·3 was evaporated from the tray and 0·93 from the furnace.

Experiment.—A foot-cube model was made of iron, of the type which will be described as our latest modification. It is evident that this small model could not be expected to give as good results as the incinerator itself, but the fuel and fluid were most carefully measured, and it was proved by five trials that the model would easily deal with 1 lb. of liquid per 1 lb. of fuel consumed. Although there was no cause to doubt the accuracy of the Lancer pattern results—taken by three men over so long a period—it was satisfactory to have the added assurance of experiments conducted in the laboratory, and it was also satisfactory to find that the furnace alone was capable, even in this small model, of dealing with 82 per cent as much liquid as from tray and furnace combined.

(ii) Careful scrutiny of the figures will detect disparity between the ratio given and the claims advanced on behalf of the open types. This is explained by the recorded measurements of the amount of urine actually collected in bazaars, where these installations have mostly been used. Measurements have not been given, but it has been broadly stated that incinerators of certain dimensions have disposed of the total solid and fluid excreta of so many persons. The report has been quite true, but the urine collected and thus disposed of has, as shown, amounted to but a fraction of that passed, e.g., it is stated that a 7 ft. diameter Raitt will deal with the total excreta of 750 persons—i.e., 250 gallons, or 7 gallons per square foot. Experimentally it was found, however, that the maximum charge of fluid per square foot of surface, which did not drip right through within a couple of minutes, was 0·5 gallon, so that it would be necessary to have urine sprinkled on it at least fifteen times in the twenty-four hours, which could not be done, as the sweepers work only twelve hours a day.

We are now in a position, with the foregoing data, to state the actual fuel requirements as follows :—

Lb. of Litter or Grass Fuel Required per 1,000 Strength per Day.

	British troops	Native troops	Bazaar population
Gumlah contents, without antiseptic	400	574	574
,, ,, with ,,	896	—	—
Total, without *gumlah* antiseptic	2,648	2,560	1,592
,, with ,, ,,	3,152	—	—

For natives this provides for a considerable margin over the amount of fluid actually collected.

The factor used in this calculation is 1·23, viz., the amount of fluid evaporated by 1 lb. of fuel at Meerut during the monsoon. That this figure does not represent the possible maximum is shown by the fact that on July 18 the fluid evaporated per 1 lb. of fuel was 1·6, while on August 10 it rose to 1·7, but it should be noted that on those dates facilities were afforded for rough-drying the litter beneath an open shed.

It will further be noted that there is much less difference than would have been expected between the results obtained during the dry and wet seasons; this is probably accounted for by the fact that the relatively high temperatures at which this experimental incineration was conducted made the humidity of the external atmosphere of comparatively little consequence.

Conclusions.—(i) The total fluid and solid excreta can be disposed of by incineration with $2\frac{1}{2}$ lb. of fuel per head per day.

(ii) Using this quantity of fuel, the litter of one cavalry regiment will dispose of the total excreta of 2,000 men.

(4) *Flies.*

With regard to flies, we wish to prevent their gaining access to human dejecta, and, as an extra precaution, to reduce their numbers.

All modern latrines now have an enclosed space for the receptacle, which is supposed to be fly-proof. Actually it seldom is so, and hence the following routine has been adopted: *Gumlahs* have a thick layer of ash placed in them, on which is dusted some lime; immediately after use it is the duty of the sweeper to cover the dejecta with ash and empty it forthwith into the furnace. The ash is sufficient to absorb all the dejecta, and the whole contents fall out in one mass, leaving the *gumlah* quite clean and dry so that it has no attraction for flies. Practically it is found that, although some flies may gather about the incinerator, attracted by its moisture, there are very few in latrines in which this routine is properly carried out.

The prevention of fly-breeding in litter is more difficult, but is surmountable with a little care, although the difficulties are enhanced in the rains when the litter must undergo some preliminary drying. All litter should be carried daily to the drying-shed beside the incinerator. This shed consists of a metal roof with fly-proof gauze sides and iron bars about a foot above the concrete floor. It has a feed-hole at the top of one end and a rake-hole at the floor level of the other end; both holes are protected by fly-proof doors closing by gravity. The litter is thus passed through the chamber, which should not be of a capacity of more than two days' supply. Some provision must be made for removal of the drainage which drips through the bars on to the floor; this is necessary not only on account of flies, but also to prevent it affording breeding grounds for mosquito larvæ. This is secured by raising the floor somewhat and giving it a slope, so that shallow runnels lead the water to a pipe opening into a properly lidded receptacle which should be emptied daily.

(5) *Types.*

We now come to the most interesting part of this complex problem—the consideration of various types of incinerator. It is hoped that none of the many details hitherto dealt with has been irrelevant, and their consideration has, incidentally, disposed of many preliminaries to a review of the numerous types which have been described.

(*a*) *Open Types.*—It has already been shown that these types are not suitable for cantonment use owing to the offence to which they give rise. It has also been shown that they will not deal with the amount of fluid which it is essential to dispose of. It may be here pointed out also that they will not work in the rains unless covered, while they are sources of very considerable danger of dissemination of infective material by wind unless they are also enclosed by wind-screens. If they must be roofed and enclosed it is clear that they approximate to the closed type; but they cost more than the latter, while their combustion is less under control. In short, for use in British lines they are obsolete and discredited.

(*b*) *Closed Types.*—(i) Primitive patterns. These—of which Hawes's was the pioneer and the Sialkote is the modern representative—consist merely of a furnace in which the mixed fuel and excreta are burnt together and the fumes are led off by a chimney. The creation of a nuisance has not been obviated by the heightening of the chimney, although that now discharges 20 ft. above the ground level (*vide supra*). Various attempts have been made to destroy these fumes, and the suggested devices may be divided into two groups, according as the dejecta are burnt with, or in a separate chamber from, the fuel.

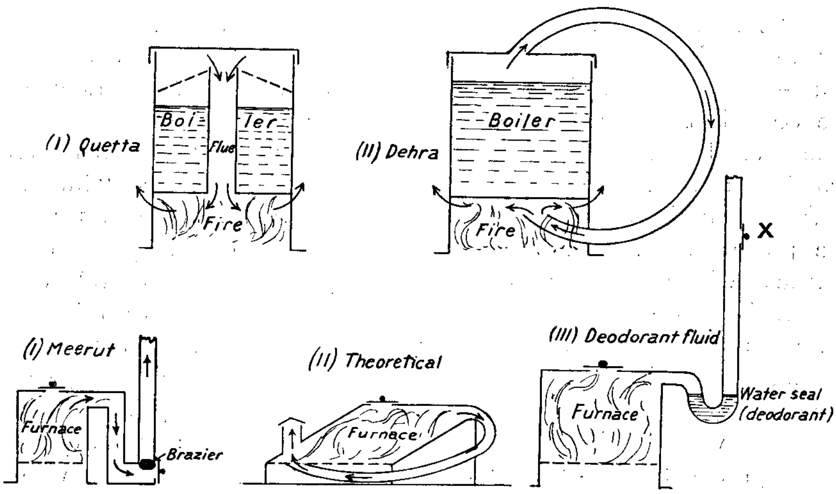
(1) *Dejecta in a Separate Boiler.—Thompson's* (*Quetta*): This is shown in fig. 3 (a) (i). The fumes pass from the boiler down a central pipe and so escape through the fire, which is supposed to oxidize them. At first it was found that the contents frothed over and put the fire out. This was prevented by the addition of a perforated diaphragm (shown dotted), which broke up the froth and allowed the fluid to run down its upper surface into the boiler again. It was found that it took over twenty-four hours to burn out and was costly in fuel.

Dehra Dun, shown in fig. 3 (a) (ii): This is somewhat similar, and it "took sixteen hours to incinerate, with excessive fuel consumption." It is evident that the combustion of excreta and fuel in separate chambers must involve enormous waste of the latter, and this idea was therefore not pursued further.

(2) *Dejecta and Fuel Mixed.*—Attempts were made to pass the fumes through a secondary fire, through a part of the main fire, through a deodorant fluid, and through litter used as a filter.

Meerut.—The flue was taken down to ground level, where it was splayed out to permit of deposit of heavy soot particles. The flue then narrowed to the chimney foot, where a small brazier of

(*a*) With a separate boiler for fluids.



(*b*) Fuel and dejecta mixed in the furnace.

FIG. 3.

charcoal was inserted. It was hoped that the amount of carbon monoxide present would prevent rapid combustion of the charcoal and maintain it economically at a dull red heat, which would destroy the fumes passing through. Also, by thus heating the air in the chimney, it was hoped to secure extra forced draught through the furnace. Practically this device served its purpose, but it burnt out in a few minutes and proved too costly for use. It is shown in fig. 3 (b) (i).

Theoretical.—Shown in fig. 3 (b) (ii). It was proposed to set the furnace at an angle, so that the red-hot layer would slide down into one corner. The fumes were to be brought by a pipe which discharged beneath that corner, so that they passed up through it, to escape by a small chimney immediately above. This escape chimney being below the main body of the fire, it was thought that no fumes would escape directly by that route. Unfortunately there were no means of preventing chokage of the end of the pipe by ashes falling directly into its mouth; moreover, there would obviously be great difficulty in establishing and maintaining a through draught, therefore the idea was abandoned as impracticable. At this time it was realized that, if any such simple device were feasible, it would long since have been taken advantage of for commercial purposes, and not left to would-be devisers of incinerators to evolve.

Deodorant Fluid.—The next suggestion was that the escaping products of combustion should be bubbled through a deodorant fluid—an excellent idea if it could be carried out. It could be done if the excreta were consumed in a boiler separate from the fuel, but this procedure has already been shown to be too costly in fuel. From experience of the ordinary "hubble-bubble," it is apparent that, to be effective, the gases must be passed through a considerable depth of liquid. The difficulties will be apparent from a glance at fig. 3 (b) (iii). First, it is obvious that it will require some force to take the fumes through the deodorant fluid in the U-shaped bend, and it is further equally obvious that, if the furnace were got going, and the U-shaped bend then filled, the expanding air in the furnace would take the route of less resistance and blow back through the firebars rather than ascend the chimney. It would therefore be necessary to secure a suction effect by a secondary fire near the top of the chimney—as indicated at "X"—which would involve all the expense indicated under that proposal initially. Further, some device would have to be adopted by which the supply of fluid in the bend would be renewed automatically; and there is the great objection that the sweeper would have to be responsible that the fluid was renewed when the deodorant was exhausted; while, finally, as an additional complication, the supply of deodorant would have to be maintained.

Litter Filter.—This has already been discussed. The design is shown in fig. 4. It has the advantages of being so simple as to be within the scope of even the sweeper's intelligence, of requiring only material always at hand, of costing nothing, and being renewable in a few seconds, of being itself combustible, owing to the condensation of the products of partial combustion in its interstices, and, finally, of being of proved efficiency. It can be inserted at any point in the ascending flue, the only essentials being that the sides of the chimney beyond it should be air-tight, and that the door through which it is inserted should fit so closely as to prevent short-circuiting of the forced draught produced by ascent of heated air through the chimney. Its efficiency becomes greater as the tarry deposit increases, it is advisable that two such filters should be used in the circuit, to be renewed alternately on alternate days, or as may be found necessary.

Patterns Fitted with Devices for Aiding Evaporation.

In the simplest of these designs a receptacle from which urine was evaporated was placed in the furnace. The smell of urine increased the offence considerably without an adequate return, for it is clear that a tank affords so little surface in proportion to bulk as to make the amount of urine thus disposed of inconsiderable. In other patterns the urine, after it had been supposed to be boiled, was drawn off by a tap, and thrown on the surface soil. The decision as to whether the urine were sterile or not was left to the discretion of the sweeper!

Next came the era of trays, of which the Wellington and Meerut were the pioneers. That at Meerut has been described—it has the advantage that urine is evaporated completely, while the exposure of the large area of 17½ sq. ft. for 6 in. of depth enabled 26 gallons to be disposed of in the twenty-four hours. Difficulty arose, however, from the need of some automatic device to prevent the tray being overfilled, thus flooding the fire. For the first time this installation enabled the whole excreta, fluid and solid, of a unit to be disposed of with a moderate consumption of fuel.

This was followed by a most ingenious invention at Ambala. There the urine was placed in cylinders in the furnace. The cylinders had a number of small perforations in the base, which were covered with a layer of 1½ in. of wood ash. When the urine boiled, the ebullition allowed the urine to drip through the ash on to secondary evaporation trays placed beneath. There are, however, two very strong criticisms to be offered to this installation: (*a*) It is clear that, if the urine is to be boiled in these cylinders, there must be fierce combustion in the furnace, and a large proportion of the caloric value of the fuel must be wasted as the heat passes the cylinders to the chimney. This is evidenced by the fact that the fuel required in this pattern is 60 per cent greater than that of the Lancer pattern. It would appear that this ingenious idea might be turned to better advantage if it were applied to a shallow tray of large area, so as to secure a uniform distribution of urine upon the mass of litter in the body of the furnace. It is a mistake to suppose that leading the fumes from the cylinders into the chimney has disposed of the offence which is inseparable from the evaporation of urine. A certain amount will doubtless be absorbed by the soot in the chimney, but that will be but a small fraction of the whole. Without some means of dealing with the nuisance, this installation is just as offensive as the Sialkote type, and it has been shown that strenuous objections are being made to the latter.

Suggested pattern for Landour. It is advisable to pause here and, in the light of the practical experience gained, consider the physics of the means whereby we hope to attain our triple aim, of (a) maximum evaporation, (β) minimum offence, and (γ) minimum fuel expense.

The caloric value of the fuel consumed in incineration is expended on:—

(1) Evaporation of fluid.

(2) Maintenance of the draught necessary for continued combustion.

(3) Loss through the chimney of heat in excess of that needed for draught.

(4) Loss of heat by radiation, &c., from the exterior.

Now (4) is probably a constant, whatever our rate of combustion, and not worth the cost of prevention by building a fuel chamber around the furnace. (3) should be capable of reduction to small dimensions by practical application of sound principles. (2) is a matter of friction and is intimately concerned with the removal of nuisance caused by the smoke and fumes. If this can be assured, the extra expense of fuel incurred thereby is well spent. (1) is the most important hygienic consideration, as upon it depends our ability to dispose safely of urine.

To return to our aims—

(a) *Maximum evaporation.*—The ideal method is that which secures an intimate admixture of excreta with a "matrix" fuel, which provides the fluid with an enormous evaporating surface in proportion to its bulk, forms a spongy mass, through the interstices of which hot air percolates until saturated with water vapour, and automatically ensures that the fuel cannot burn until its charge of moisture has been evaporated. If the liquid be separated from the fuel by enclosure in a boiler, the furnace heat only transmits a part of its value to the boiler contents, while the remainder roars to waste up the chimney. The importance of this point is evidenced by the fact that, as shown, the matrix-fuel method requires but 62 per cent of the fuel needed by the alternative boiler method.

It was hoped to ascertain, by the model referred to, whether slow or rapid combustion gave the better result—the rate of combustion being controlled by differential temperature readings from thermometers in the furnace interior and in the external air. The records have unfortunately been lost, but it is highly probable that slow combustion is the better, and, if so, this affords an additional argument in favour of the matrix-fuel method, which works continuously throughout the twenty-four hours.

(β) *Minimum of Offence.*—This raises some interesting points for consideration. The only practicable and effective means evolved so far is that of the litter filter, the efficiency of which depends upon its extent of surface, the moisture of that surface, the retardation of the current through it, and the filter being left long enough to be coated with a carbonaceous tarry deposit. Extra fuel must be used to overcome the additional friction thus thrown into the circuit, though this may be lessened by heightening the chimney.

It is found experimentally that, if the caloric value of the fuel be utilized to within 5 per cent of saturation point by water vapour, the remaining energy is sufficient to afford the necessary balance for meeting friction and loss. At that point water is progressively deposited in the litter filter if that be placed in an external chimney. It is obvious that the litter filter must be placed in the ascending chimney so that the ascent of the hot air on the distal side of the filter secures aspiration and forced draught sufficient to maintain combustion. The objection to this is that a certain amount of water condenses continuously and either has to be evaporated afresh or else causes nuisance by soaking through the chimney and running on to the ground. Also the cooling of the hot air in the interior of the chimney throws extra work on the furnace, and might just be sufficient to determine the equilibrium point at which the fire would be put out if it were too much damped down at night.

It is proposed to meet both these difficulties by taking the flue through the heart of the furnace, before it turns to ascend through a fuel drying chamber on the furnace roof. The litter filter would then be inserted in a box on the portion of the flue inside the furnace, the box having an iron door in the furnace wall. By this means water would condense at once on the filter, but, once deposited, would be maintained at that amount by the balancing forces of condensation and evaporation—with the cooling action of radiation from the door just turning the balance. Moreover, the temperature inside the flue would adjust itself to that of the furnace and energy would thus be economized, with a consequent lessening of any tendency for the fire to go out. It is probable that this is not actually necessary, for the Lancer pattern described worked night and day for twelve months, during which time it only went out accidentally twice.

(γ) *Minimum Fuel Expense.*—This has been sufficiently discussed under the two preceding headings.

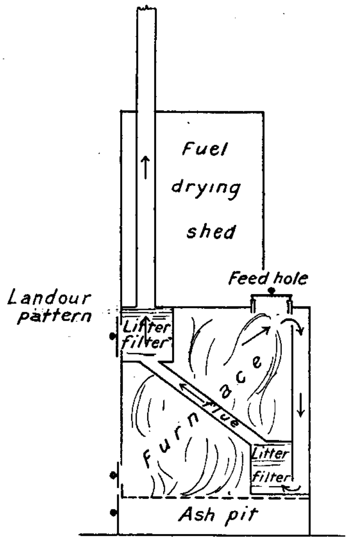


FIG. 4.

Conclusions.—(i) That the admixture of excreta with matrix fuel and combustion in a furnace affords the maximum evaporation of which the caloric value of the fuel is capable.

(ii) That this simple method obviates the necessity for any accessory means to evaporate fluids.

(iii) That offence can be obviated to a large extent by the use of litter filters at a small increase to fuel expense.

(iv) That such litter filters are best situated in a portion of the flue taken through the furnace for that purpose and for the more certain maintenance of combustion.

It only remains to remark that the drawing of this type, now in course of erection, appears in fig. 4 and that its soundness of principle has been thoroughly demonstrated by experiment with a 1 ft. cube iron model, which has disposed of 1·25 lb. of water for each 1 lb. of fuel consumed, and when once heated, burns quite steadily without extra forced draught.

(*B*) Cost of Conservancy if Incineration is Adopted.

This section, fortunately, can be dismissed in a few words. It has to be considered from two standpoints, according as the value of the litter to the grass-farm authorities is, or is not, taken into account.

(1) *Not considering the value of litter to the grass-farm.*—It has been estimated that, at Meerut, the cost of conservancy to one British cavalry regiment has been Rs. 373 per 1,000 strength per annum less since incineration was adopted.

At Dehra Dun it has been calculated that the cost per annum per 1,000 strength of native infantry has been reduced by Rs. 216 per annum.

At Ambala it is stated that the comparative costs are "about the same" for the conservancy of British troops by the two methods.

At Meerut it is estimated that the establishment of forty-seven incinerators in cantonments has resulted in an economy of Rs. 4,000 per annum, the population being approximately 12,000, this amounts to a saving of Rs. 350 per 1,000 strength per annum.

These illustrations suffice to show that incineration enables a definite economy to be effected.

(2) *If the value of the litter to the grass-farm be considered.*—It has been seen that the litter from one British cavalry regiment amounts to 6,000 lb. per diem. The grass-farm authorities claim that this litter enables them to surface-trench six acres per annum, with an increase in the grass crop from 100 to 600 maunds per annum for eight years. Before this estimate can be accepted, information is required showing how much of this increased crop is due to turning over the soil, and how much to the manurial value of the litter. Until that information is forthcoming it is impossible to say what the net cost of incineration really is.

(*C*) Effect of Adoption of Incineration upon Military Efficiency.

With so many improvements in the hygienic conditions of the troops in India, and marked advances in the art of preventive medicine, it is impossible to allot to any one measure its share of credit for the remarkable diminution of sickness amongst the troops in India which has characterized the last few years. It is, however, significant to note the unanimity with which those most directly in touch with the advances and shortcomings of Indian sanitation—the divisional sanitary officers—attribute, in their annual reports, a large share in the diminution of sickness in their respective divisions to the more general adoption of incineration as a means of disposing of dejecta. It may well be that only on general principles are we entitled to that belief, but none the less is that belief in its turn entitled to credence if based on the application to conservancy methods of definite knowledge of specific disease acquired by the accumulated experience of many years of patient research. This much at least is certain—the sanitation of native units more especially has left, and still leaves, much to be desired, and the attention that has been drawn to sanitary conditions (or perhaps one should rather say to *insanitary* conditions) by the introduction of incineration has already had a most beneficial effect in its educational influence upon the attitude towards sanitary matters adopted by both officers and men.