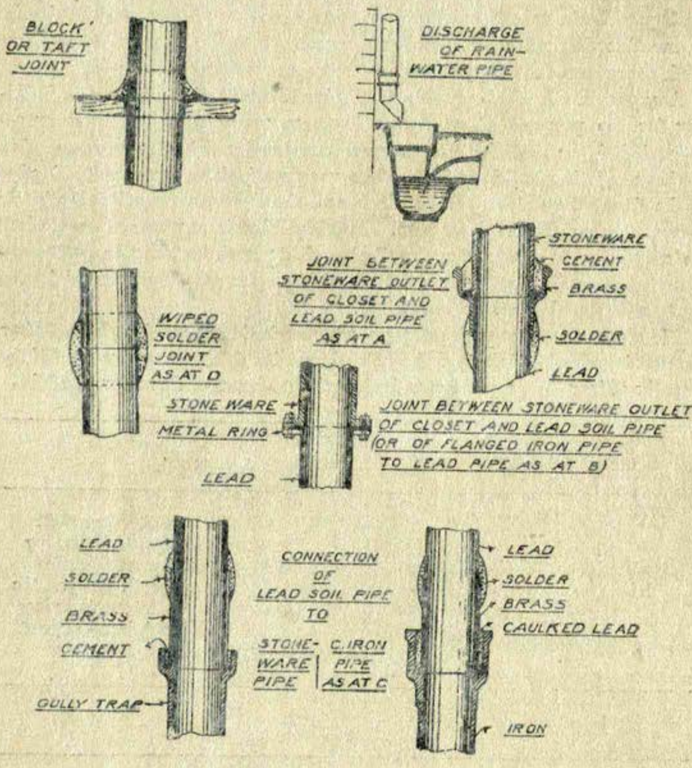
space for the lead in the case of $3\frac{1}{2}$ inch and 4 inch pipes to be not less than $\frac{3}{4}$ inch in width, and in the case of 5 inch and 6 inch pipes to be not less than $\frac{5}{8}$ inch in width. If he shall construct such soil pipe with flange joints, he shall cause such joints to be securely bolted together with some suitable insertion.

He shall construct such soil pipe whether inside or outside the building, so that it shall not be connected with any rain-water pipe or with the waste of any bath, or of any sink other than that which is provided for the reception of urine or other excremental filth, and he shall construct such



soil pipe so that there shall not be any trap in such soil pipe or between the soil pipe and any drain with which it is connected.

He shall cause such soil pipe, whether inside or outside the building, to be circular and to have an internal diameter of not less than $3\frac{1}{2}$ inches and to be continued upwards without diminution of its diameter, and (except where unavoidable) without any bend or angle being formed in such soil pipe to such a height and in such a position as to afford, by means of the open end of such soil pipe, a safe outlet for foul air

Any person who shall connect a lead soil pipe, waste pipe, ventilating pipe or drain communicating with the sewer shall insert between such lead soil pipe, waste pipe, ventilating pipe or trap, and such iron pipe or drain, a flanged thimble of copper, brass, or other suitable alloy, and shall connect such lead soil pipe, waste pipe, ventilating pipe, or trap with such thimble by means of a wiped or overcast metallic joint, and shall connect such thimble with such iron pipe or drain by means of a joint made with molten lead properly caulked; provided always that it shall be sufficient if he shall connect the lead soil pipe, waste pipe or ventilating pipe, or trap with the iron pipe or drain in an equally suitable and efficient manner.

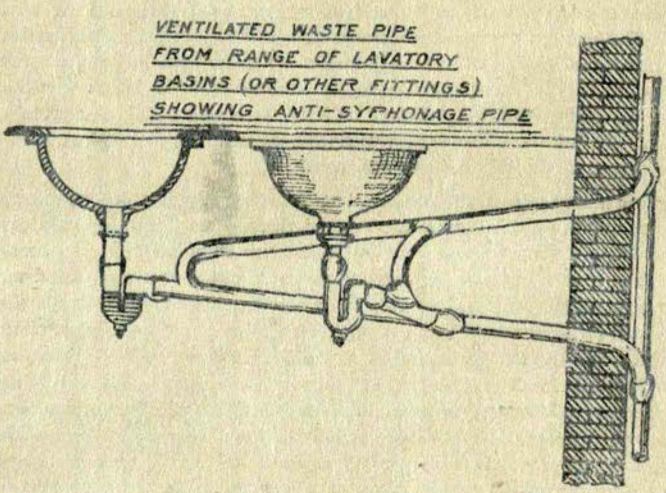
Any person who shall connect a stoneware or semi-vitrified ware trap or pipe with a lead soil pipe, waste pipe or trap communicating with a sewer, shall insert between such stoneware or semi-vitrified ware trap or pipe and such lead soil pipe, waste pipe or trap, a socket of copper, brass, or other suitable alloy, and shall insert such stoneware or semi-vitrified ware trap or pipe into such socket, making the joint with Portland cement, and shall connect such socket with the lead soil pipe, waste pipe, or trap by means of a wiped or overcast metallic joint; provided always that it shall be sufficient if he shall connect the stoneware or semi-vitrified ware trap or pipe with the lead soil pipe, waste pipe, or trap, in an equally suitable and efficient manner.

Any person who shall connect a lead soil pipe, waste pipe, ventilating pipe, or trap with a stoneware or semi-vitrified ware pipe or drain communicating with a sewer shall insert between such lead soil pipe, waste pipe or ventilating pipe, or trap and such stoneware or semi-vitrified ware pipe or drain, a flanged thimble of copper, brass, or other suitable alloy and shall connect such lead soil pipe, waste pipe, ventilating pipe, or trap with such thimble by means of a wiped or overcast metallic joint, and shall insert the flanged end of such thimble into a socket of such stoneware or semi-vitrified ware pipe or drain making the joint with Portland cement; provided always that it shall be sufficient if he shall connect the lead soil pipe, waste pipe, ventilating pipe, or trap with the stoneware or semi-vitrified ware pipe or drain in an equally suitable and efficient manner.

Any person who shall connect an iron soil pipe, ventilating pipe or trap with a stone ware or semi-vitrified ware pipe or drain communicating with a sewer shall insert the beaded spigot end of such iron soil pipe, waste pipe, ventilating pipe, or trap into a socket of such stoneware or semi-vitrified ware pipe or drain making the joint with Portland cement; provided always that it shall be sufficient if he shall connect the iron soil pipe, waste pipe, ventilating pipe, or trap with the stoneware or semi-vitrified ware pipe or drain in an equally suitable and efficient manner.

Any person who shall connect a stoneware or semi-vitrified ware trap or pipe, with an iron soil pipe, waste pipe, trap or drain communicating with a sewer shall insert such stoneware or semi-vitrified ware trap or pipe into a socket of such iron soil pipe, waste pipe, trap or drain making the joint with Portland cement; provided always that it shall be sufficient if he shall connect the stoneware or semi-vitrified ware trap or pipe with the iron soil pipe, waste pipe or drain in an equally suitable and efficient manner.

Any person who shall construct any water-closet, the soil pipe of which shall communicate with any sewer and shall be in connection with any other water-closet, shall cause the trap of every such water-closet to be ventilated into the open air at a point as high as the top of the soil pipe or into the soil pipe at a point above the highest water-closet connected with such soil pipe and so that the ventilating pipe shall have in all parts an internal diameter of not less than 2 inches and shall be connected with the arm of the soil pipe or trap at a point not less than 3 and not more than 12 inches from the highest part of the trap and on that side of the water seal which is nearest to the soil pipe. He shall cause



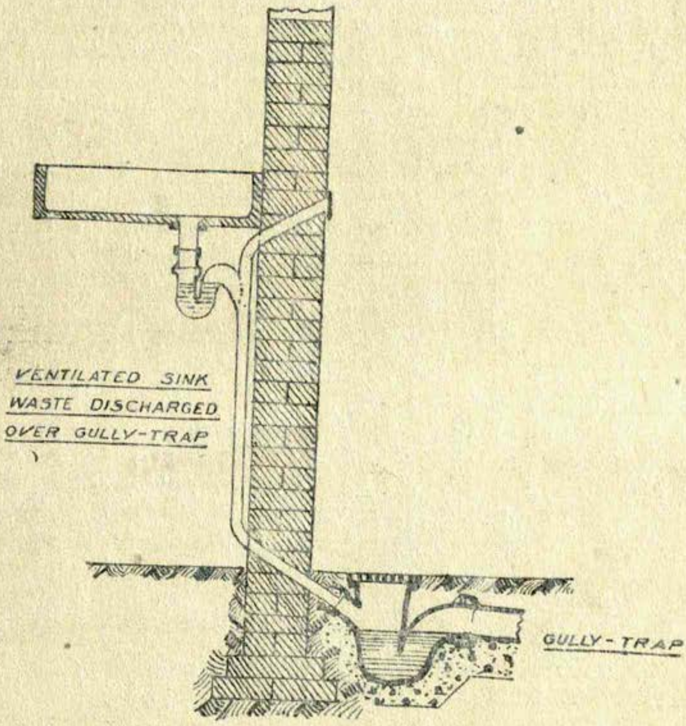
the joint between the ventilating pipe and the arm of the soil pipe or the trap to be made in the direction of the flow.

He shall construct such ventilating pipe in drawn lead or heavy cast iron. Provided that in any case where it shall be necessary to construct such ventilating pipe within a building he shall construct such ventilating pipe in drawn lead.

He shall construct such ventilating pipe, whether inside or outside a building so that if the pipe be of lead its weight shall not be less than 25 lbs. per 6 feet length.

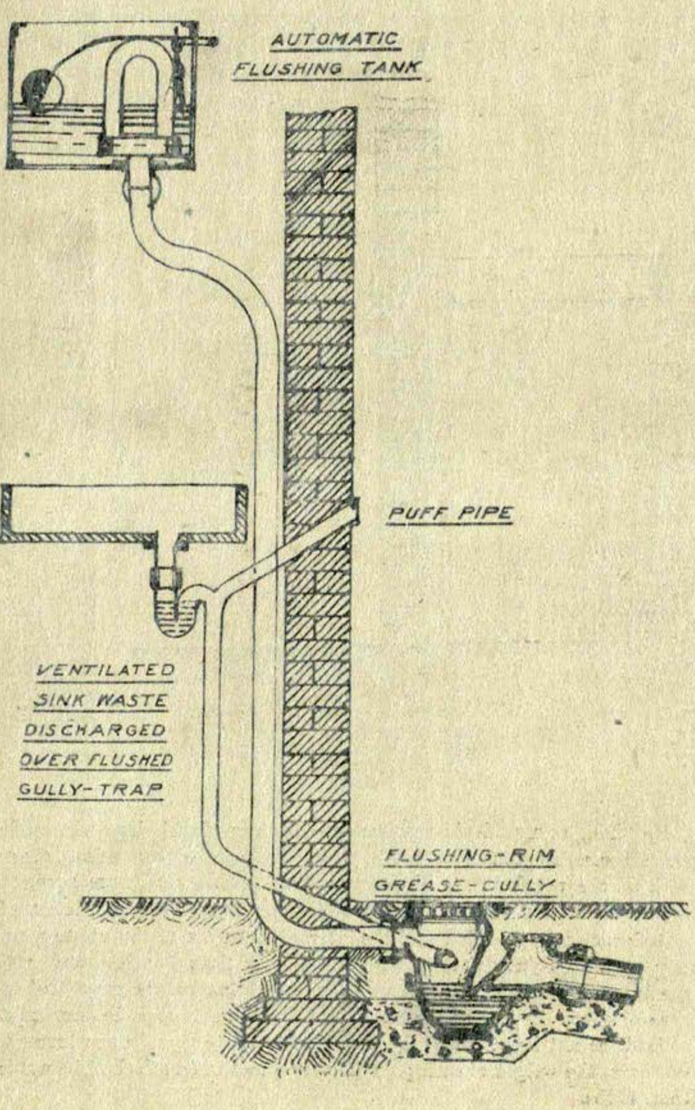
He shall in all cases cause the joints in and the connections to such ventilating pipe to be made in the same manner as if such ventilating pipe were a soil pipe.

A person who shall erect a new building and shall construct in connection with such building a slop-sink or urinal constructed or adapted to be used for receiving any solid or liquid excremental filth or conveyance to any sewer, shall construct or fix immediately beneath such slop-sink or urinal an efficient syphon trap, so constructed as to be capable of maintaining a water seal between such slop-sink or urinal and any drain, soil pipe or waste pipe in connection therewith. He shall not construct or fix in or in connection with such slop-sink or urinal any trap of the kind known as a bell-trap, a dip-trap or a D-trap.



He shall, as regards the ventilation of the trap of such slop-sink or urinal and the construction of the waste pipe of such slop-sink or urinal, comply with all the requirements of the preceding by-laws which are applicable to the ventilation of the trap of a water-closet and the construction of a soil pipe, always provided that the internal diameter of the waste pipe of any such slop-sink or urinal shall not be less than 3 inches, and where the internal diameter of such waste pipe is 3 inches, the weight of such pipe of every 10 feet of length shall, if such waste pipe be constructed of lead, be not less than 60 lbs. and if such waste pipe be constructed of cast iron, the weight of such pipe of every 6 feet of length shall be not less than 40 lbs.

The owner of any building shall, as respects such building, at all times maintain in a proper state of repairs all pipes, drains, and other means of communicating with sewers and the trap and apparatus connected therewith.



A person who shall newly fit or fix any apparatus in connection with any water-closet existing shall, as regards such apparatus and its connection with any soil pipe or drain, comply with such of the requirements of the foregoing by-laws as would be applicable to the apparatus so fitted or fixed if the water-closet were being newly constructed.

There are special by-laws also in reference to outside closets, basement closets, earth closets, privies and cesspools.

Every person who shall intend to construct any water-closet, earth closet, or privy, or to fit or fix in or in connection with any water-closet, earth closet or privy, any apparatus or any trap or soil pipe, shall, before executing any such works, give notice in writing to the clerk of the Sanitary Authority.

The occupier of any premises shall cause every water-closet belonging to such premises to be thoroughly cleansed from time to time as often as may be necessary for the purpose of keeping such water-closet in a cleanly condition.

Provided that where two or more lodgers in a lodging-house are entitled to the use in common of any water-closet, the landlord shall cause such water-closet to be cleansed as aforesaid: one closet to every twelve persons.

The owner of any premises shall maintain in proper condition of repair every water-closet and the proper accessories thereof belonging to such premises.

PENALTIES.

Every person who shall offend against any of the foregoing by-laws shall be liable for every such offence to a penalty of two pounds, and in the case of a continuing offence to a further penalty of forty shillings for each day after written notice of the offence.

BY-LAWS OF THE BOMBAY MUNICIPALITY.

Construction of Water-Closets and Privies.

[Clause (*a*), Section 461].

5. Every person who shall construct a water-closet for use in connection with a dwelling-house shall comply with the following regulations :—

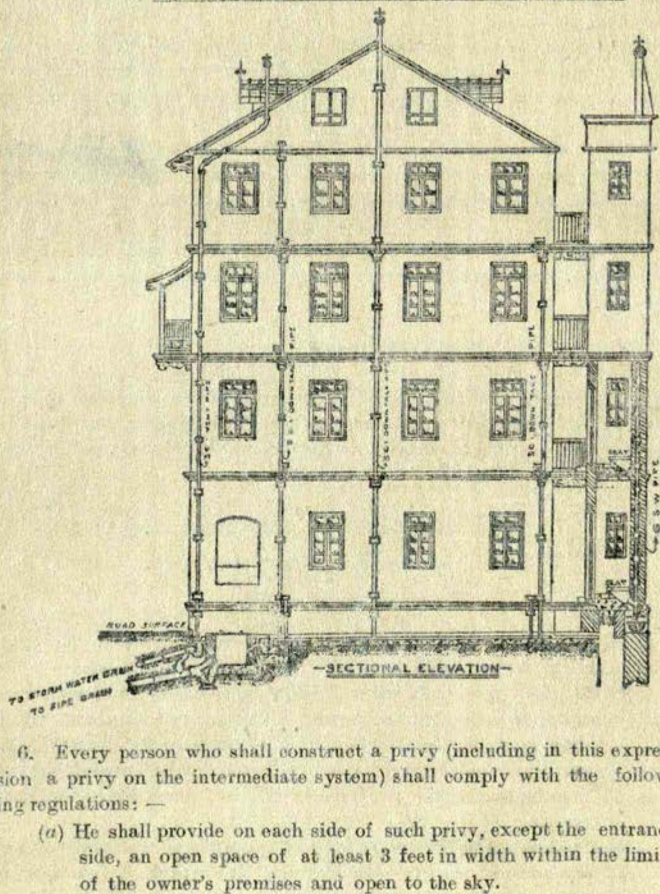
(*a*) He shall cause such water-closet to be separated from any rooms intended to be used for human habitation, by a *dead* wall which shall be lined *internally to a height of six feet* with a smooth, impervious, non-absorbent coating of neat Portland cement not less than half an inch in thickness, or of glass, glazed tiles or polished marble.

(*b*) He shall make, in one at least of the walls of such water-closet, a window of not less than 3 square feet superficial area opening upon an external open space.

(c) He shall cause the entrance to such water-closet to be through a lobby or *bath-room having at least one window*, or through a gallery which is entirely open to the outer air on one side.

(d) He shall not construct any portion of such water-closet so as to be within a distance of 3 feet from the boundary of the owner's premises, provided that this rule shall not operate to prevent a water-closet being constructed to abut on a street or service passage or open space intended to be permanently reserved as such.

—TYPE OF HOUSE-CONNECTIONS WITH AN OPEN DRAIN—



—SECTIONAL ELEVATION—

6. Every person who shall construct a privy (including in this expression a privy on the intermediate system) shall comply with the following regulations: —

(a) He shall provide on each side of such privy, except the entrance side, an open space of at least 3 feet in width within the limits of the owner's premises and open to the sky.

(b) He shall cause any entrance, gallery or communicating bridge to be at least 3 feet in width and open to the external air on both its sides and to be shut off from any portion of any dwelling-house by a closely fitting door.

(c) He shall make, in one at least of the walls of such privy, a window of not less than 3 square feet superficial area, opening upon an external open space.

(d) He shall cause the walls of such privy to be lined *internally* with a smooth, impervious, non-absorbent coating of neat Portland cement not less than half an inch in thickness or of glass, glazed tiles or polished marble to a height of not less than five feet of such privy.

RULES FOR HOUSE AND STABLE DRAINAGE.

OPEN DRAIN.

1. In no instance shall a drain interior to a building for the conveyance of the house-sullage to the street-sewer be an open drain.

2. Open drains shall be constructed according to the plans in the office of the Deputy Executive Engineer, Drainage Department. The Drainage Engineer shall have the option of allowing the open drain to be in the centre of a house-gully and without side walls. The bottom part or invert shall be lined with a 4″ half round stoneware channel, the remaining part of the drain being plastered with at least a 1″ coating of cement and sand (1 to 1) trowelled to a smooth surface or with any other impervious material.

3. At the end of the open drain a silt chamber 2′ long by 7″ wide, and 12″ deeper than the bed of the drain shall be constructed with a vertical cast iron grating 1′-6″ from the open drain the full size of the silt chamber. This shall discharge into a gully trap connected to an inspection chamber. (See sketch.)

4. The inspection chamber shall be not less than 3′ long by 18″ wide constructed of brick work laid on cement concrete and be internally plastered with a 1″ coat of cement and sand (1 to 1). In the chamber a stoneware channel with a half round S. W. invert shall be formed of the width and full depth of the pipe drain. The walls shall be brought up to the surface of the ground and covered with a cast iron air-tight cover and frame.

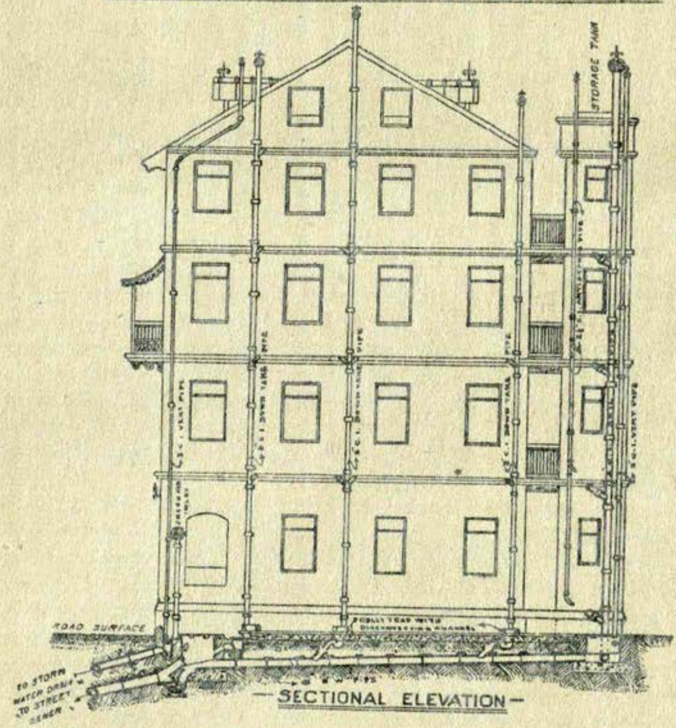
5. The cover of an inspection chamber shall be of cast iron air-tight and fitted with a lip into a grooved frame. The cover and frame of an inspection chamber subject to wheel traffic shall be of cast-iron of heavy pattern. At the connection between the 6″ pipe drain laid in the street by and at the expense of the Municipality and the drain constructed by the owner, an inspection chamber shall be provided fitted with a 6″ stoneware intercepting sewer trap of approved pattern having a water seal not less than 2″ and a 3″ ventilating shaft in accordance with Rule 11. In all other respects the inspection chamber shall be constructed in accordance with Rule 4.

6. All down-take pipes shall be of cast iron, 3″ in diameter and not less than ⅛″ thick.

7. The connection between every nahani and the down-take pipe shall be by means of a 3″ stoneware or 3″ cast iron pipe, discharging into a cistern head. Nahani traps may be used, but, if directly connected to the waste water pipes, the latter shall be extended above the roof in accordance with Rule 11.

8. In the case of nahanis abutting on a street or road, the waste water pipes shall discharge into a stoneware gully-trap by means of a stoneware

—TYPE OF HOUSE CONNECTIONS WITH A 6″ PIPE DRAIN



—SECTIONAL ELEVATION—

or cast iron bend. The gully-trap shall discharge into an inspection chamber fitted with a sewer trap as per Rule 5, or into a private pipe drain. The waste water pipes or nahani connections shall be constructed in accordance with Rule 23 for pipe drains.

9. In the event of the plinth of a house being much higher than the bed of the open drain, nahanis on the ground floor shall discharge into the

open drain by means of a 3″ discharge pipe brought down to such a level as to avoid a splash.

10. No water-closet or any arrangement by which night-soil is to be removed on the water carriage system shall, except with the written permission of the Municipal Commissioner, be allowed to be connected with an open drain.

11. Every vent pipe, anti-siphon pipe and waste water pipe shall, if not provided with cistern heads and discharging into an open drain, be protected at the top by a wire dome and shall be (*a*) carried at least 15′ higher than any sky-light or window situated within a distance of 40′ therefrom ; (*b*) carried at least 5′ higher than the eave of the roof if affixed to a wall supporting the eave ; (*c*) erected or affixed so as to create the least practicable nuisance or inconvenience to the inhabitants of the neighbourhood.

12. The surface of all house-gullies not occupied by, or beyond what is occupied by, an open drain shall be paved with fine dressed blue-stone or Indian patent stone or other stone approved by the Commissioner. At the lower end of the gully, whether the open drain for sullage or sewage be in the centre or at the side, a jump-weir shall be formed as per full size plan to be seen in the offices of the Drainage Department, so that, while any ordinary flow of sewage will discharge into the connection with the inspection chamber, a rush of storm-water will jump over the opening and pass into the storm-water drain. (See sketch.)

General Rule .—All gully traps, when directed by the Drainage Engineer, shall be covered with a hinged iron cover and frame of approved designs,

PIPE DRAIN.

13. In all cases where house-owners desire to drain their premises by a pipe drain instead of an open drain, the drain shall be a 6″ stoneware pipe drain jointed in cement and laid at a gradient of 1 in 50 where practicable. When necessary, a flatter gradient may be allowed by the Drainage Engineer.

14. In such houses as are without gullies, a heavy cast iron pipe drain (the joints to be run with molten lead and soundly caulked) may, in accordance with Section 240 of the Municipal Act, be laid under the building. Pipe drains may be of 4 inches diameter, only when allowed by the Drainage Engineer.

15. At the connection between the 6″ pipe drain laid in the street by and at the expense of the Municipality and the pipe laid by the owner, an inspection chamber shall be constructed and fitted with a 6″ stoneware intercepting sewer trap having a water seal of not less than 2″ and with fresh air inlet, the open end of the pipe being placed wherever practicable above the roof or in such position that, in the event of a reverse current of air it will not cause nuisance or annoyance to passers-by or persons residing within or near to the premises. (See sketch.)

16. The cover of all inspection chambers shall be of cast iron air-tight and fitted with a lip into a grooved frame. The cover and frame of an inspection chamber subject to wheel traffic shall be of cast iron of heavy pattern. In all other respects the inspection chamber shall be constructed in accordance with Rule 4.

17. Inspection chambers shall be so placed on any pipe drain that no portion thereof more than 75′ long shall be without an inspection chamber. An inspection chamber at the point of every change of direction in any drain shall be deemed indispensable.

18. Every 6″ gully-trap shall be connected with a 6″ pipe drain by means of a 4″ stoneware branch pipe.

19. The head of every pipe drain shall be provided with a 3″ cast iron or galvanized iron vent pipe.

20. A nahani trap, approved by the Commissioner, shall be provided in every nahani except those specially provided for in Rule 23. (See sketch.)

21. All down-take pipes shall be of cast iron 3″ in diameter and not less than $\frac{1}{8}$″ thick.

22. Every down-take pipe shall be carried up above the roof as a vent-pipe and be protected at the top by a wire dome as far as practicable in accordance with the distances specified in Rule 11 as amended.

23. Every nahani on the ground floor shall discharge into a stoneware gully trap by means of a 3″ stoneware pipe, and every down-take or waste water pipe shall be disconnected from the gully-trap by means of a disconnection channel discharging into the gully-trap. (See sketch.)

24. In the event of there being an open *chowk* in the house, the nahanis shall be constructed adjacent to the external wall of the *chowk* to allow of the down-take pipes being fixed to and carried up against external walls.

WATER-CLOSETS.

25. In the case of water-closets, native pattern soil pans of design approved by the Drainage Engineer may be provided and shall be properly laid and bedded in cement concrete at the required level and connected by means of porcelain traps and 4″ stoneware pipe and bends with an inspection chamber or soil pipe as the case may be. European pattern soil pans of design approved by the Drainage Engineer may be provided and shall be fixed in position with a teakwood moveable or hinged seat. (See sketch.)

26. The junction between a closet and a branch, if the latter is of lead, shall be effectively made by a brass ferrule soldered with a wiped joint to the lead pipe, and the joint between the porcelain trap and the brass ferrule made in cement, boiled oil and spun yarn or soldered to porcelain. (See sketch.)

27. All soil pipes shall be 4″ in diameter and of cast-iron not less than 3·16″ in thickness. The connection between the soil pipe and the water-closet trap shall be by means of a pipe fitted with a screw cap external to the wall for cleaning purposes. (See sketch.)

28. Every soil pipe shall discharge into the 6″ stoneware pipe drain by means of a 4″ stoneware bend into a chamber fitted with a cast-iron cover. (See sketch.)

29. In every case where there is a tier of water-closets one above another, a 2½″ anti-siphon pipe shall be taken from each water trap except that of the highest water-closet and carried up above the roof and to such height as is prescribed in Rule 11. (See sketch.)

30. A three-gallon automatic or pull off flushing cistern of a pattern approved by the Drainage Engineer shall be securely fixed to the wall at least 5 feet above the seat and shall be connected by means of a 1¼″ lead pipe with an India rubber cone to the connection with the closet. (See sketch.)"

31. All such flushing cisterns shall be supplied by means of an efficient water supply from a reservoir tank placed in a suitable position and height. The capacity of this reservoir tank shall not be less than 90 gallons for each seat.

RULES IN CONNECTION WITH THE CONSTRUCTION OF PRIVIES ON THE INTERMEDIATE WATER-CARRIAGE SYSTEM.

32. Every proposal for the construction of privies on the intermediate water-carriage system shall comply with clause 6 of the by-laws and also with the definition of the privy on the intermediate system at page 5 of the new Building By-laws.

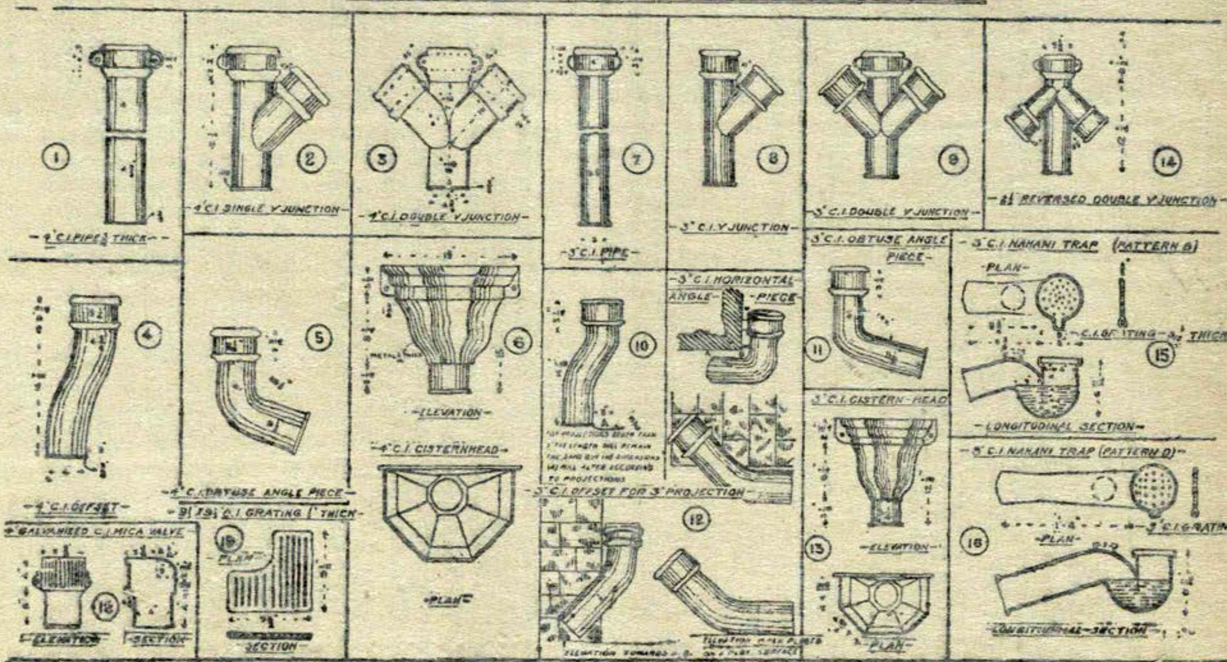
33. Each seat shall be provided with a porcelain or earthenware pan with a sharp slope, or with a midmost flat glass plate with a sharp slope embedded on either side with cement or porcelain tiles. (See sketch.)

34. In case of a privy with a range of seats, arrangements shall be made to leave inspection holes at a distance of at least 5 feet for cleaning purposes. These holes shall be covered with C. I. frames with a hinged lid of the same pattern as hydrant boxes over the water mains. The openings over the gully traps shall also have covers of the same kind and not grating. (See sketch.)

35. The capacity of the flushing tank shall be determined by the length of the drain behind the privy and the number of storeys at the premises in which the privies are situated. The distance from the centre of one privy to the centre of the next shall not be less than 3 feet and for every foot run of the drain, one gallon flush shall be provided and for every storey one gallon more irrespective of the number of privies on each storey. For example, if the length of the drain is 12 feet and there are three upper storeys, the capacity of the tank will be 15 gallons. If the length of the drain is 20 feet and there is only one upper storey with 6 privy seats, the capacity will be 21 gallons.

36. The length of the drain or 6″ S. W. pipe line shall not exceed 20′ feet, but if it exceeds this length it should be graded from either end of the privy so as to meet near the centre, and flush tanks of the capacity mentioned in Rule 35 should be provided at either end

DIMENSIONED SKETCHES OF THE PIPES FITTINGS &c.



37. All flush tanks should be regulated to flush twice in one hour.

38. The storage tank should have 20 (twenty) times the capacity of all the flushing tanks combined.

GENERAL RULES FOR THE LAYING OF DRAINS, ERECTION OF ALL CAST-IRON PIPES AND THEIR FITTINGS AND FOR TESTING THE SAME.

39. The pipes must be of well-burnt glazed stoneware, uniform in thickness.

40. No pipe drain shall be less than 6″ in internal diameter, unless otherwise allowed by the Drainage Engineer, and must be laid at a gradient of 1 in 50 wherever practicable, unless otherwise allowed by the Drainage Engineer. Branch drains may be 4″ in diameter.

41. The stoneware pipes shall be all laid and fitted dry previous to the jointing being commenced, such pipes being neatly cut as may need to be shortened in order to bring in the junctions in the exact position required. All the pipes shall be laid perfectly true both in line and gradient and they shall be laid on a 6″ concrete bed in the case of 'made ground,' or when in the opinion of the Drainage Engineer this course is necessary.

42. All the pipe joints shall be caulked with cemented or tarred gasket in one length for each joint and sufficiently long to entirely surround the spigot end of the pipe, the gasket to be driven as far as possible into the joint by means of a suitable instrument. After the pipes are thoroughly cleaned and moistened, neat Portland cement is to be forced into the joint until the whole space around the spigot, between it and the socket, is quite full, and a splayed fillet of neat cement is to be laid all round the joint.

43. Before filling in the trench, the joint of the pipe drains must be proved water-tight by filling the pipes with water to the level of 6″ above the top of the highest pipe in the stretch and heading the water up for the period of one hour or such further time as directed.

44. No stretch of pipe line shall under any circumstances be covered up until inspected and passed by the Head Plumber or the Drainage Inspector of the District as the case may be.

45. The inspection chambers on the pipe drains shall be constructed of brick work laid on cement concrete and be internally plastered with a 1″ coat of cement and sand (1 to 1). In the chamber a stoneware channel with a half round invert shall be formed of the width and full depth of the pipe drain. The walls shall be brought up to the surface of the ground and covered with a cast-iron air-tight cover and frame. The cover of an inspection chamber shall be of cast-iron air-tight and fitted with a lip into a grooved frame. The cover and frame of an inspection chamber subject to wheel traffic shall be of cast-iron of heavy pattern.

SOIL, WASTE AND VENT PIPES.

46. The socket joints between metal and metal when above ground shall be made completely air-tight with a mixture composed of Portland cement, boiled oil and chopped hemp and by a ring of hemp gasket.

47. The joints of pipes and shafts above ground after they are thoroughly set must be proved air-tight by smoke produced and applied as directed.

48. All the cast-iron appliances and fittings must be of approved pattern and coated by dipping in Dr. Angus Smith's solution before being used in the work.

49. In case of new buildings the drainage must be in accordance with the plan which has previously been approved by the Municipal Commissioner.

HORSE-STABLES—PUBLIC OR PRIVATE.

50. The foundation of each stall shall consist of at least 6″ of lime concrete well rammed and laid at a slope equal to 1 in 36.

51. Above the concrete shall be put down a layer of good and well selected *muram* properly rammed and finished off to the same slope as the concrete or such suitable paving as may be approved by the Drainage Engineer.

52. Meeting the *muram* or paving and at right angles to the stalls shall be constructed a half round channel 12″ wide of suitably dressed blue stone or other suitable material.

53. The channel shall have a longitudinal slope of at least 1 in 100 to one point, or more as may be selected, and at each of such points a 6″ by 6″ stoneware gully trap fitted with horizontal and vertical cast-iron gratings shall be fixed. (See sketch.)

54. All the gully traps shall be connected by a 6″ stoneware pipe drain or drains with an inspection chamber constructed on a line of 6″ stoneware pipe drain connected with the street sewer. (See sketch.)

55. The construction of an inspection chamber, the laying of the pipe drain and connecting with the street sewer shall be in accordance with the rules laid down for pipe drains.

56. It shall be incumbent on every owner of a stable to renew the *muram* in the stalls at least twice a year or as often as may be required by a responsible officer of the Municipality.

CATTLE STABLES.

57. The floor of every cattle stable shall be paved over the whole area with suitably dressed bluestone or other suitable material laid on a 6″ bed of good lime concrete. The paving shall be sloped at an inclination of at least 1 in 60 towards the channel hereinafter described.

58. Behind every range of stalls a half round channel 12″ wide shall be formed with a slope of at least 1 in 60 in every part down to a gully trap hereinafter described. (See sketch.)

59. The channel shall discharge into a catchpit through glazed S. W. gully trap. The catchpit shall be 3′ by 4′ by 5′ deep. It shall be covered with a strong cast-iron cover fitted into a rebated frame. The catchpit shall be placed immediately at the point of discharge, or lowest point of the channel, and connected with the pipe drain within the premises by

means of an inspection chamber built complete with a 6″ intercepting sewer trap. (See sketch.)

60. A horizontal and a vertical iron grating with bars not more than ½″ apart shall be fixed in the catchpit. (See sketch.)

61. The laying of the pipe drain, the construction of the inspection chamber and the connection with the street sewer shall be subject to the rules for pipe drains.

CESSPOOLS.

Drainage of premises not within 100 *feet of a Municipal drain or some place legally set apart for the discharge of drainage.*

62. As far as practicable, buildings of this description shall be drained by open drains in accordance with the rules laid down for such drains.

63. If practicable, the sullage from all nahanis shall be discharged among vegetation or used for gardening purposes, but if this is impossible, then the sullage shall discharge into a cesspool having a capacity of at least 50 c. ft.

64. The capacity of a cesspool shall be calculated below the bottom of the inlet drain.

65. The house-drain, if open, shall be connected with and shall discharge by means of a 6″ by 6″ stoneware gully trap into the cesspool. All cesspools shall be closely covered and fitted with a cast-iron air-tight frame and cover.

66. Every cesspool shall be ventilated by a cast-iron or galvanized iron pipe not less than 3″ in diameter.

67. The vent pipe shall be protected at the top by a wire dome and shall be (*a*) carried at least 15″ higher than any sky-light or window situated within a distance of 40′ therefrom ; (*b*) carried at least 5′ higher than the eave of the roof, if affixed to a wall supporting the eave ; and (*c*) erected or affixed so as to create the least practicable nuisance or inconvenience to the inhabitants of the neighbourhood.

68. There shall be a cesspool for the privies separate from that for the nahanis (if any) and it shall have a capacity of at least 3 c. ft. per every privy seat or slot, with a minimum of 25 c. ft.

69. Every cesspool must be placed in a position convenient for the access of Municipal carts.

70. Every cesspool shall be constructed of brickwork in cement laid on cement concrete and internally plastered with a 1″ coat of cement and sand (1 to 1). The walls shall be brought up to 6″ above the surface of the ground, and the cover mentioned in Rule 3 shall be placed upon them.

71. An arrangement must be made with the Municipal $\frac{\text{Head Plumber}}{\text{Inspector of Drains}}$ to attend at the premises to see the execution of the drainage work and the making of any connection that may be necessary with the Municipal drain.

72. No connection must be made with a Municipal drain nor must the same be exposed except in the presence of the Head Plumber/Inspector.

73. The whole of the work must be done under the supervision of the Municipal Head Plumber/Inspector.

74. The said Head Plumber/Inspector will see that the principles adopted by the Municipality are carried out, but no such close supervision can be given by any Municipal Officer as to relieve the house owner and his plumber from the duty of taking due care in the execution of the work and providing good and sufficient materials and workmanship.

INSPECTION OF WATER-CLOSETS.

On examination of the fittings and drains, it will be seen whether the laws and by-laws have been properly carried out.

Taking first a house on the modern system of water-closet drainage, a wash-down basin has been fitted against the outer wall discharging into a 4-inch lead soil pipe, which is connected to a cast iron soil pipe outside the wall, carried up 5 feet above the highest adjoining window.

An anti-syphon pipe has been placed on the arm leading to the soil pipe about 6 inches from the trap of the water-closet and carried above the highest window. The connection between basin and soil pipe should be a brass socket ferrule, into which cement is placed, fixed to the lead branch of the soil pipe by means of a wiped solder joint.

The trap is self-cleaning with not less than 2½ inches seal of water.

The connection between the lead arm of the soil pipe and the iron soil pipe outside the house should be a brass ferrule soldered, and lead run into the joint.

The soil pipe discharges directly into a 4 to 6-inch earthen pipe, preferably a 4-inch with a fall of 1 in 40, laid on cement.

There is an inspection chamber lined with white, glazed bricks, the floor of cement and the channels curved, a trap at the sewer end on a raking arm with fixed stopper in position.

The waste pipes from bath and slop-sink should, after discharging on to a gully trap, discharge into the inspection chamber to assist in flushing.

An inlet pipe with a mica flap valve, fitted so as to allow the ingress of air, should be fixed to the inspection chamber.

The flushing cistern, distinct from the supply tank, should be examined. The contents of the water-closet basin, with the 3-gallon flush every time the water-closet is used, pass into the house drain through the inspection chamber, and thus to the sewer.

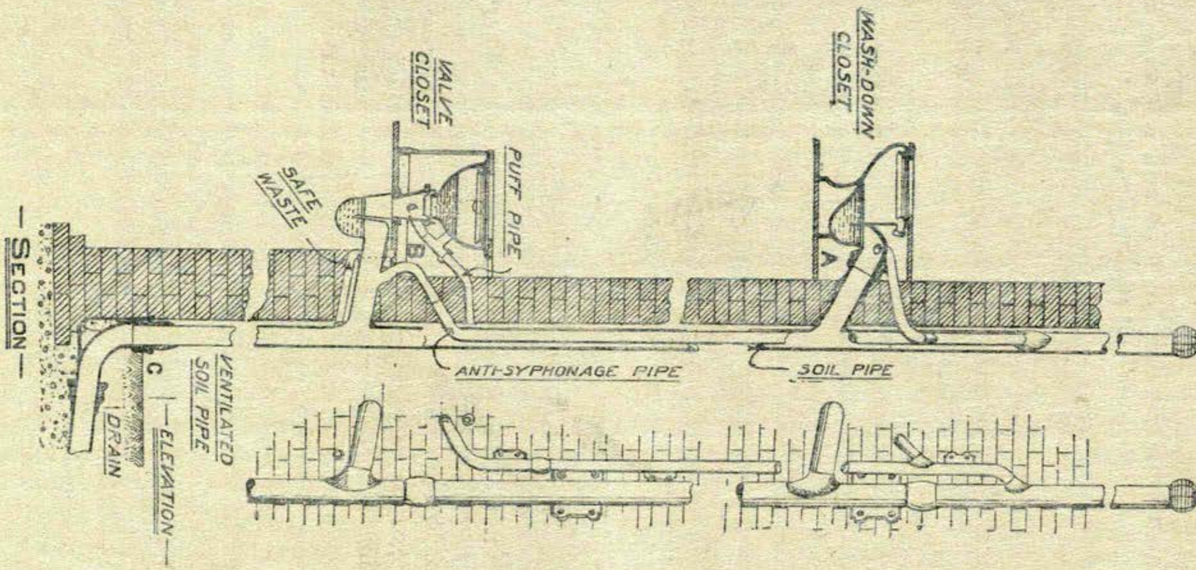
INSPECTION OF DRAINS.

"*Drain*" means any drain of and used for the drainage of one building only or premises within the same curtilage and made merely for the purpose of communicating therefrom with a cesspool, or other like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

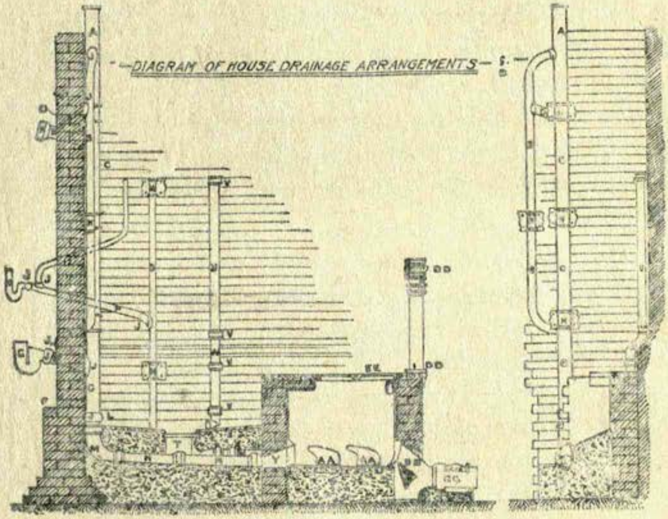
Drains must be inspected as to their bed, their fall, their jointing and construction. Note whether they pass round or under the house. If under, find of what material they are made, whether of iron as they should be or of earthenware; if of latter, they must be bedded in cement. It must be discovered whether or not a disconnecting trap provided with a fresh air inlet exists between the house and the sewer.

The drains must be tested, the smoke or hydraulic test being applied. If the *smoke test* is to be applied, the Eclipse Smoke Generator or one or other of the smoke testing machines is employed.

The *Eclipse Smoke Generator* is most widely used and consists of three parts, a double action bellows opening into


SECTION
VALVE CLOSET
WASH-DOWN CLOSET
SAFE WASTE
PUFF PIPE
A
B
C
ANTI-SYPHONAGE PIPE
SOIL PIPE
VENTILATED SOIL PIPE
DRAIN
ELEVATION

a cylinder of copper, in which the substance from which the smoke is to be generated is placed, and an out-let tube which is passed into the drain. The cylinder is placed in a tank of copper and is provided with a cover of the same metal which completely envelopes the cylinder when inverted over it. When the machine is to be used, the cover is removed, the tank surrounding the cylinder is filled with water, and the substance from which the smoke is to be obtained—either oily waste or some form of touch paper specially prepared so



-SECTIONAL ELEVATION- -CROSS SECTION-

that it shall smoulder and in smouldering give off smoke in large quantities—is set alight and laid in the cylinder. The cover is then replaced and, dipping into the water in the tank, forms an air-tight joint and prevents the escape of smoke.

The out-let tube is then placed in the drain, an entrance having been found for it at some inspection eye in connection with a trap, or elsewhere along the course of the drain. By pumping air from the bellows into the cylinder, the oily waste, etc., is set smouldering. The smoke generated is driven through the out-let pipe into the parts of the drainage system which are to be tested.

When the pumping has filled the cylinder full of smoke the connection between the cylinder and pumping bellows may be shut off. As soon as smoke is seen to issue from the top of the soil pipe or other natural out-let, further escape from these is prevented by plugging them with clay or damp cloth and the pumping is resumed. When it is concluded that a sufficient quantity of smoke has been driven into the drains, etc., pumping is stopped. This time if there is no escape of smoke from the drains, etc., the cover of the cylinder will remain stationary and show no signs of sinking. If, however, there be any flaw in the system, the cover sinks, and a search must be made till the point where smoke is escaping is found.

In the *hydraulic test* the drains are subjected to the pressure of a head of water, the system being examined in sections. The first section may extend from the first water-closet to the first inspection eye, which may or may not be the point where the drain is disconnected from the sewer. At this point the drain is plugged by means of a rubber bag inflated with air or by means of a special apparatus like Addison's Patent Drain Stopper. The system is then filled with water from the first water-closet and, when full, the level of the water in the basin of the water-closet is noted. At the end of one or two hours, the level of the water is again taken, and if it has not varied the system is sound. If the water has subsided, the point where leakage has occurred must be sought for. The remaining sections are tested in the same way, the plug being inserted just beyond the last section tested.

For old drains this is a very severe test. Moreover, since the water pressure is greatest at the lowest point, the strain also will be greatest at this point. In applying this test to waste water pipes, the pipe will be plugged at the lower end and the water turned on at a sink tap till the pipe is full and a constant level of water obtained in the sink. The further procedure is as described above. Generally speaking, for every additional foot of water in the pipe being tested, there results a ½lb. of pressure to the square inch.

Formula :— $\frac{\text{vertical Ht. in feet.}}{2\cdot308}$ = lbs. pressure per sq. inch.

AMOUNT OF WATER REQUIRED FOR WATER-CLOSETS AND THE METHOD OF SUPPLY.

The amount of water supplied to larger towns varies with the facilities of supply and the demand.

In an ordinary residential town in England, 30 gallons per head per day, including water for water-closets, is considered sufficient and is distributed thus :—

	Gallons.
Cooking	·7
Drinking	·3
Ablution	5·0
House cleaning	3·0
Laundry	3·0
Baths	4·0
Water-Closet	6·0
Waste	3·0
	25

To this should be added 5 gallons per head for Municipal purposes—flushing of drains and road-watering and fire and, if a manufacturing town, another 5 gallons per head per day, making in all 35 gallons per head per day.

In large manufacturing centres with railway and docks, another 5 gallons should be added.

In India, owing to the habits and customs of the Indian, an extra item in the allowance for waste is made, as he cannot resist letting the tap run all the time he is washing himself or his clothes, and there is besides the underground waste due to defective fittings and pipes. So that in a large city in India—Bombay and Calcutta—a supply of 50 gallons per head should be estimated for, but in other towns and cities a supply of 30 to 40 gallons is ample.

When the pressure of water in the main is not constant and varies in different parts of the city, it is necessary in the case of dwellings over 50 feet high to resort to artificial means of raising the water. This can be done by hand-pump, gas-engine and electric power. All these methods are in use in every city, and in Bombay they can be seen at work both in European houses, flats and hotels and in the native *bazar*. The town supply is delivered into tanks placed at the ground level or below it and the water forced up to a cistern on the roof.

That this practice is accepted by the public can readily be verified by an inspection of the City, and the arguments put forward by opponents of the water-closet system are immediately dispelled. In a large and crowded part of the native *bazar* in Bombay City, there is a high building of 5 storeys occupied by Hindus (Banias) as shops and dwelling rooms. The sanitary arrangements are on the water-closet system and the water is supplied by means of an electric pump. This pump is so placed that, when the tanks on the ground level are full, the water automatically brings into play the electric switch and shuts off the water and the pumps are set going to force the water to the top of the house to cisterns, which supply the cisterns of water-closets on the various floors. Everything works well. There is no nuisance from defective privies and the surrounding passages, paved and tiled, are perfectly clean.

SEWERS.

"Sewer" includes sewers and drains of every description, except the word "drain" interpreted as aforesaid and except drains vested in or under the control of any authority having the management of roads, and not being a local sanitary authority.

The sewage is carried by means of sewers to the place of disposal by gravitation or pumping.

A sewerage system may be combined or separate.

The "combined system" is that by which all rain and storm-water, as well as sewage, is carried away by one set of sewers.

In the "separate system," there is provided a separate system of drains and sewers for rain water and sewage, the sewer only receiving that part of the rain which falls on open spaces between houses and open drains which overflow into the sewer.

In India the "combined system" cannot be generally adopted because of the heavy rainfall, which is confined to a few months in the year.

The sewers would have to be made too large for the normal dry weather flow, and become defective and not self-cleansing in the dry weather season.

As it is, sewers may become surcharged in times of continuous rain of 6 to 10 inches in 24 hours, as frequently occurs in India.

DESIGNING AND CONSTRUCTION OF SEWERS.

The designing and construction of sewers is engineering work, but a knowledge of how such work should be done is valuable to a sanitary student as, in supervising the designing and construction, great care must be exercised in making the sewers water-tight, not only to prevent the sewage leaking out, but also to prevent the sub-soil water entering into the sewers and thus increasing the amount of sewage to be dealt with at the outfall. In many places, the quantity of sub-soil water is enormous especially in light, sandy soils where the sewers are laid with difficulty, owing to the height of the sub-soil water and the joints becoming defective due to subsidence of the sewer. The amount of rainfall admitted into sewers has to be considered.

Before covering in a new pipe sewer, it should be carefully tested, so that leaky joints may be avoided.

VENTILATION OF SEWERS.

There are many agents at work affecting the ventilation of sewers :—The rate of decomposition of the sewage, temperature, pressure, wind, volume of the sewage, gradient and discharge of steam into the sewers.

The principle of ventilation is, by equalising the pressure inside and outside the sewer, to cause a free current of fresh air to pass in and the foul air to pass out at the highest point well above the windows of the highest houses.

Sewers may be ventilated by open grids at the street level, well away from dwellings, by vent shafts attached to houses, or by building separate shafts at suitable points every 300 feet along the length of the sewer, every joint being made air-tight.

Open grids on the ground level are objectionable, and should be avoided if possible.

In tropical countries, the temperature of the air in the sewer is lower than the atmosphere air outside, while in England the reverse is the case. In Bombay, the mean temperature of the sewer air is 76° Fah., while the temperature outside is 79·5° Fah. At Cawnpore the temperature of the sewer air is 83° (mean air temperature).

The rate of decomposition of sewage varies with the pressure and temperature, and the gases of decomposition are therefore much more freely given off in tropical climates. The chief gases found in sewers, which are dangerous to life, are :—

Carbon dioxide, CO_2 ; marsh gas, CH_4 ; nitrogen, N. ; ammonia, NH_3 ; sulphuretted hydrogen, H_2 S. and carburetted hydrogen, C_2 H_4 ; and great care should be exercised, when examining sewers for cleansing purposes, to see that these gases are not present in any quantity.

Various methods have been adopted to purify the air of sewers : Charcoal trays, permanganate of potash (Reeves' process), gas lamps in the ventilating shafts, or street lamps used as vent shafts, fans and ejectors.

There is no hard and fast rule regarding the method of ventilating sewers ; much depends on the climate, the form and position of the sewer.

Messrs. Shone and Ault claim that efficient ventilation of drains and sewers, like the efficient ventilation of mines, can be secured only by abandoning the so-called natural system and substituting therefor adequately controlled and regulated mechanical means.

Delépine, reporting on the effects on health of the air of the High Street sewer (Manchester), states that—

"1. Taking the High Street sewer as a type of a fairly well constructed sewer, carrying moderately dilute domestic sewage of average composition, I have come to the conclusion that the air of such a sewer is free from noxious properties.

"2. This conclusion is not applicable to the air of sewers where, owing to the formation of deposits, or for some other reason, the air becomes loaded with an unnecessary amount of noxious gases which are not normally present under other conditions.

"3. It does not apply to sewers receiving certain kinds of trade effluents or waste products, poisonous in themselves, or liable to undergo changes or to produce compounds dangerous to health.

"4. This conclusion does not refer to the air escaping from foul drains or pipes, which air may be quite different from sewer air, or may contain particles of dried materaial not to be found in sewer air. The air escaping from such drains may be quite different from sewer air, and requires special study before any definite opinion can be offered as to the amount and kind of disease that may be attributed to it."

At a later stage in his report, Professor Delépine says: "The passage of sewage bacteria into sewer air does not in itself prove that sewer air is necessarily a source of material danger. The experiments made show that in the air of an efficient sewer carrying ordinary domestic sewage, the number of sewage bacteria is very small; they also show that a number of human beings and animals exposed to a large amount of that air over considerable periods did not appear to suffer from the exposure. Also that the discharge of a considerable amount of this sewer air through ventilating shafts had not caused any special outbreak of disease in the houses surrounding the ventilators.

"The results so far obtained show that in all probability the bad effects, which have at various times been attributed to sewer air, should have been considered as due to changes in the sewage which need not take place, or to admixture of noxious products which may be prevented."

Cleaning of Drains and Sewers.

1. The cleaning out of all storm-water drains and channels, catchpits and drain entrances should commence on the 1st of May in each year.

2. During the monsoon season, the Inspector should give special instructions to his Ward staff, regarding the keeping clear of refuse all gratings and openings carrying off storm-water, in order to prevent flooding so far as is possible; and during periods of heavy rain fall, special men should be told off to attend to such places as from their low-level are most liable to become obstructed.

3. All covered drains and sewers should be opened periodically and examined with a view to ascertaining their state of cleanliness, and a memorandum of the result made in

the drain-cleaning register. When a large drain or sewer is found to be in such a state as to require cleaning, a report should be made to the office.

4. In cleaning covered sewers into which it is necessary to send men, the following procedure should be strictly followed :—

(a) The manholes should be removed along the whole sewer at least two hours before any one is permitted to enter it.

(b) Ventilators should be inserted into the sewer at convenient points as soon as the manholes are opened. The ventilators should be placed in such positions in the sewer as shall give the men below the fullest advantage from the fresh air drawn into it. After the expiry of the period already fixed to elapse after the removal of the manhole covers, the state of the atmosphere in the sewer should be tested by the Inspector in the following manner :—A lighted kerosine oil lamp of the ordinary hurricane pattern should be lowered into the sewer close to the water or silt, and the silt agitated, and the lamp kept there for at least 15 minutes. If the flame of the lamp burns clearly and steadily, the Inspector may assume that the air in the sewer at this place is sufficiently pure to permit of the entrance of the work-people. But only down such manholes as have been so tested should men be sent into the sewer.

(c) The first man to enter the sewer should have a lamp and he should proceed cautiously along the sewer towards the next manhole for a distance of 20 yards, carefully observing all the time whether the lamp burns brightly or not, and then suspend the lamp in the sewer by such means as are convenient.

(d) As a rule, all sewers should be cleaned by working with the flow of sewage, and all possible expedition should be used in carrying out the work by sending gangs of men into the sewer at different places. Care should be taken that each gang is working, between lamps ; not only will this give the men more light, but it will also give them confidence and warn them of the state of the air in the sewer. On any lamp going out, the men should at once leave the sewer by the nearest manhole.

5. Before commencing the cleaning of sewers, the Inspector should see that all the necessary implements are on the spot,—buckets, baskets, powrahs, crowbars, picks, ropes and lamps ; a spare coil of ropes should be kept lying close to each manhole for use in case of an accident.

6. The Inspector should, during the day, visit the work as often as possible and satisfy himself that all precautions possible for the safety of the workmen are being taken. The work should be carried out under the direct supervision of a senior Sub-Inspector with such assistants as may be necessary.

7. The men working in the sewer should not be allowed to remain down longer than half an hour at a time ; they should be ordered up for rest after half an hour, and a fresh gang sent down to take their place.

8. Great care must be given to drain cleaning, as the lives of the workmen may be placed in danger by the neglect of precautions. Inspectors are particularly cautioned about this most important part of their duties.

9. In the event of any of the men in the sewer becoming ill, every possible endeavour should be made to bring the sufferer to the surface of the ground, and the following method of treatmnt immediately adopted :—The sufferer should at once be removed to the open air and measures to excite breathing should be commenced ; every moment of delay lessens the chances of restoration to life ; all clothes on the body should be loosened. The treatment should now con-

tinue as follows :—The sufferer should be placed prone on the face with one arm under the forehead, the mouth should be opened, the tongue drawn forward and the mouth and nostrils cleansed ; then turned on the side, the head being supported, and if breathing has not commenced, again turned on the face, and again gently round to the side (if water is at hand it should be dashed on the face) and on to the back ; the head and shoulders should be raised ; the arms should now be grasped above the elbows and drawn gently but firmly upwards above the head, and kept above the head for 2 seconds, and then lowered to the sides against which they should be gently pressed ; the raising of the arms followed by the depression of them, in the manner described should be continued until breathing has been restored or until, in the opinion of a medical man, life has become extinct.

The object of these movements is to excite respiration. On the restoration of breathing, measures should be taken to restore the warmth of the body and promote circulation. Warm clothes should be ready, the body should be rubbed dry and wrapped in dry clothes.

When the patient is able to swallow, warm water or any spirit may be given.

10. On the report of an accident, medical aid should at once be called.

11. When it is believed that an accident has occurred in a sewer, the first measure obviously is to remove all human beings out of the sewer ; the number of persons in the sewer should at once be ascertained ; the assembling of persons around the manholes or entrances to the sewer should be prevented.

MODIFICATIONS OF THE WATER-CARRIAGE SYSTEM.

In addition to gravitation and pumping, many modifications have, from time to time, been advocated, and are now in use, and it is necessary to shortly mention them here.

THE LIEURNER SYSTEM.

This is a pneumatic system and consists of collecting the night-soil and slop water only, direct from the water-closet through hermetically closed iron pipes, into chambers, by creating a partial vacuum in the chambers; the contents of the water-closet pass into an iron syphon tank, hermetically closed. From this tank the sewage is drawn, by the vacuum created by the pumping station, through iron pipes into the street sewer, and thence into iron chambers of the district reservoir, which is placed underground, in the centre of a district of about 30,000 people.

By a series of valves, these district reservoirs receive the contents of the street sewers, which ultimately pass into the central reservoir at the pumping station.

The advantages claimed are, that the sewers and house drains are air-tight and there can be no leakage and no foul air, that the pipes and sewers can be laid irrespective of gradient and no water is required, and that the whole process takes only a few minutes and can be repeated as often as necessary.

The sewage thus received at the central reservoir is manufactured into poudrette and sold as manure.

The system is at work in Trouville, Amsterdam, South Africa, and Stanstead, England, and is found to be satisfactory.

Each house connected has the ordinary sanitary fittings, water-closets, &c. No special fittings of any kind are required in the house. The sewage, however, instead of passing directly into the drain and thence into the sewer, as in the English system, is collected in an underground receptacle, a small iron tank, fitted with a syphon trap to cut off foul air from the premises and to prevent the admission of any foreign bodies, such as brushes or mops, which might tend to block the sewers. Each of these receptacles is ventilated by means of the soil pipe or a special ventilating shaft and communicates by means of an iron pipe, about 4 inches in diameter, with the street sewer. On each of the house drains there is a valve which can be used for disconnecting the house from the sewer, if ever the necessity arise. The street sewers pass directly to the receiving reservoir of the section. The mode of working is as follows: For six or twelve hours the sewage is allowed to collect in the house receptacles. A man then visits each district in succession, and by opening certain valves places all the street sewers, with their connected houses, in direct communication with the district receiver, which is kept exhausted of air. Immediately the valves are opened, the air pressure outside forces the contents of all the house receptacles into the sewers and into the collecting reservoir. This is effected in a very few seconds. When all the street sewers are thus emptied, the valves are again closed, cutting them off from the receiver. The receiver is next placed in connection with the main sewer, when the whole of the contents is with extraordinary rapidity discharged therein and passes directly to a large tank at the sewage works. The district sewers are about 6 inches in diameter, and the main sewer is 8 inches to 12 inches in diameter. Of course, all are of iron with perfectly air-tight joints.

METHODS OF REMOVAL OF SEWAGE IN SEWERS.

It must be thoroughly understood that the water-carriage system, however valuable it is for large cities in India with an adequate water supply and proper facilities for the disposal of sewage, cannot be adopted in other places where the water supply is deficient.

The cities of Bombay, Calcutta and Madras are partly sewered. Although in Bombay most of the excreta is discharged into the sewer, either by water-closets, or by pail depôts, there are still many areas undrained. The water-closet system is not universal throughout these cities.

There are no other towns in India, besides these three mentioned, where the water supply is sufficient for a proper system of sewerage and water-closet system to the houses; Cawnpore and Delhi, Ahmedabad, Poona, Lucknow, Agra and others are however progressing in this direction.

Under these circumstances, before advocating a sewage system, it will be necessary to enquire about :—

The population; the amount of water available per day per head of the population; the cost of the system and the connection of houses; the class of people who will use the water-closet; the geographical conformation of the area to be drained; the place and manner of disposal of the sewage, and the degree of purification required; the rainfall.

A sewer must be self-cleansing to be efficient; self-cleansing means that the water supply per head of the population is sufficient to carry off the sewage and silt, at the rate of 3 feet per second in hot climates; in order that this result may be achieved, the fall or gradient must be sufficient, or an artificial method of pumping must be adopted.

In most of the large towns of India, some system of drainage has been adopted for the urine and sullage water, while the night-soil is removed by hand or carts either to hopper depôts or to trenching ground.

Sewers are made of glazed earthenware or iron pipes up to 18 inches and 2 feet, and in these sizes circular; when of larger dimensions, they may be of brick or cement and of an ovoid shape.

In laying a separate system, smaller sewers and man-holes may be laid with a great reduction of expense. A man-hole should be placed at every change of direction or where two sewers meet, and on straight lengths of sewer at every 100 yards.

The size of the sewers will depend on the amount of sewage and can be ascertained by the population and the water supply per head. In rural districts the amount of water supply may be taken to be 10 to 25 gallons per head per day, in large urban and manufacturing districts 20 to 40 or more. A town of 30,000 people, without any important factories and having a water supply of 20 gallons per head, will have to dispose of 600,000 gallons of sewage per day and in addition a certain amount of rain. In English cities provision is made for 1 to 2 inches of rain per day, half of this passing off in six hours.

In India, where the rainfall is sometimes from 6 to 10 inches within 24 hours, a certain amount will find its way into the sewers, even if a separate system is provided for storm-water.

The Ministry of Health, England, allows storm-water, exceeding six times the normal dry weather flow of sewage, to be passed into a water-course, which means that all sewage disposal works should be expected to treat up to six times the normal flow of sewage.

The sewer then should be capable of conveying half the average daily flow in six hours, or in the case of a town of 30,000 people, with a water supply of 20 gallons per head, 300,000 gallons in 6 hours=50,000 gallons per hour and 834 gallons per minute.

The sewers should be laid in straight lines, from man-hole to man-hole, and have even gradients sufficient to insure self-cleansing velocities.

In English towns, when the sewers are running three-fourths full, the velocity may be as low as 2 feet per second in very large sewers (over 24″), in the main sewer (12″—24″) not less than $2\frac{1}{2}$ feet per second, and in all the contributing smaller sewers (6″—9″) not less than 3 feet.

In India the sewage should be carried at a higher velocity, not less than 3 feet per second, in order to remove silt and convey the sewage away quickly.

The minimum depth at which sewers should be laid will depend upon whether it is necessary to drain the cellars of houses ; as a rule, 10 feet from the surface of the road to the invert of the sewer is sufficient. Iron pipes laid on concrete may be used when the sewers are near the surface. When the sewer is 15 feet deep, earthenware pipes should be cased in concrete.

No sewer should be less than 6 inches in diameter. The size will depend on the amount of sewage and rainfall and gradient ; the internal sectional area can be thus calculated.

In large sewers a less gradient is required than in small sewers to induce the same velocity, but the volume of sewage will be the greater in the large sewer.

A sewer 10 feet in diameter having a fall of 2 feet per mile, a sewer 5 feet in diameter having a fall of 4 feet per mile, a sewer 2 feet in diameter having a fall of 10 feet per mile and a sewer 1 foot in diameter having a fall of 20 feet per mile, will all have the same velocity, but the volume of the sewage with the 10 feet must be 100 times that with the 5 feet sewer, and 25 times that with the 2 feet sewer, and 4 times the volume of sewage in the 1 foot sewer.

It frequently happens that in flat districts, it is impossible to so design a sewerage system that all the sewage can be conveyed to the point of outfall by gravitation. The only alternative is to pump or lift the sewage at suitably selected localities, and in cases where a number of such pumps or lifts are necessary or desirable, different systems have been devised whereby the sewage is raised from the sewers and discharged into other sewers laid at a higher level.

SHONE'S EJECTORS.

One of these is the well-known Shone system, in which compressed air is used as the power by which the sewage is lifted. At one or more places an ejector or, more usually, two ejectors are installed into which the sewage flows by gravitation.

An ejector consists of a spherically-ended container made either of cast or wrought-iron and placed in a brick-work chamber, or in a cast-iron tubing.

On the ejector becoming filled with sewage, the contents are forced by means of compressed air to a higher level through a rising main.

As soon as the ejector is empty, the compressed air escapes into the atmosphere through a high ventilating shaft and the ejector is ready for a fresh charge. The apparatus is automatic and requires only occasional inspection to ensure its regular and continuous working. An impression sometimes arises that, in the Shone system, the compressed air is in some way utilized to obtain a greater velocity in the sewers but this is not so.

The sewage gravitates to the ejectors at a velocity due to the gradients at which the sewers are laid and the ejector merely lifts the sewage to a higher level.

The efficiency of the system is low, but against that must be placed the fact that it is automatic in its action and that, unlike other pumping appliances, with the single exception of the recently invented Stereophagus pump, it will deal with unscreened sewage.

In India, the system has now been working for many years both in Bombay and Karachi, and it has been adopted in many towns in England.

Experience has proved that in a tropical city such as Bombay, considerable difficulty is encountered during heavy rainfall in coping with the unavoidably increased flow of sewage in the sewers. Although separate storm-water drains may exist, a large quantity of rain water reaches the sewer from open drains and paved spaces open to the sky. Ejectors cannot be installed of sufficient capacity to meet the heavy call that may thus be made upon them, with the result that they are overpowered during heavy storms and the sewers become surcharged. Unfortunately the ejectors are incapable of much variation in speed, and it is not possible therefore to suddenly accelerate their rate of working as can be done with other types of pumping apparatus. On the whole, however, Shone's ejector is a useful and ingenious apparatus for lifting sewage but in districts subject to tropical rainfall, storm overflows from the sewers should be arranged for wherever practicable.

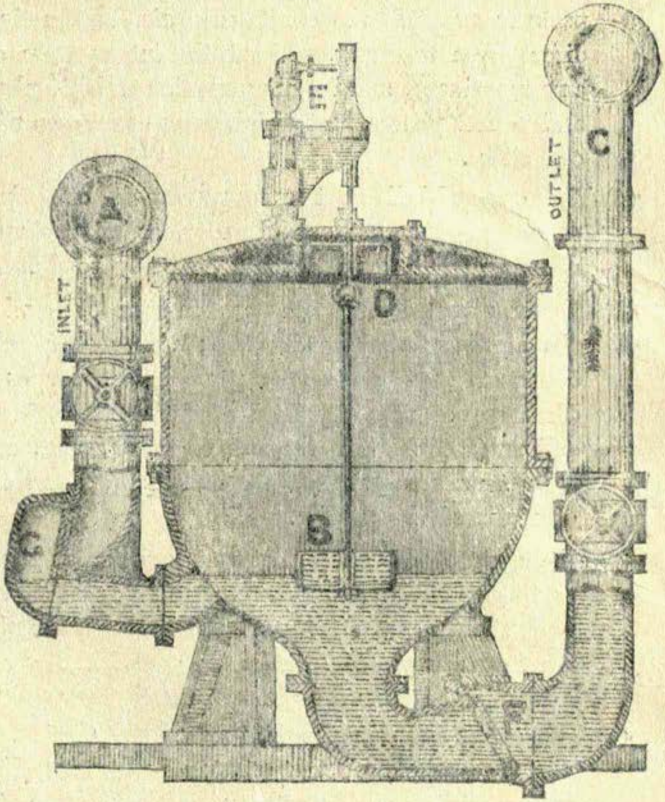
The working of an ejector is very simple, as will be seen by a reference to the figure on the following page. The sewage enters by gravitation through the pipe A, passes the flap G and enters the container. The sewage rises until it reaches the underside of the bell D; the air within the bell is then enclosed and the sewage continuing to rise compresses the air until it can raise the bell D with the rod and cup B sufficiently to slide the valve E so as to admit air from the air main. As soon as the air is admitted, it is free to act on the surface of the sewage in the container. The pressure so applied closes the back-pressure valve G and forces the sewage past to flap valve F into the pipe C and thence into the sealed sewage main, the sewage being thus driven out of the ejector.

The sewage in the cup B cannot, however, escape, and its weight, when the sewage falls below the cup, is sufficient to lower the spindle with the bell, thereby re-sliding the valve E so as to close the mouth of the air-supply pipe, and open that of the exhaust pipe through which the compressed air in the ejector escapes into a shaft hereafter described. The outlet valve F then falls on to its seat owing to the weight of the sewage in the sealed sewage main and retains the liquid in that main, and the ejector commences to fill again. This process is repeated automatically so long as there is any sewage to flow into the ejector.

These ejectors are all constructed by Messrs. Hughes and Lancaster. They are made of varying sizes, from 50-gallon capacity upwards. In Bombay there are several working from 100 to 1,200-gallon capacity each.

The compressed air for working the ejectors is produced in a central station, located in a position to suit all the ejectors, and is conveyed to them in cast-iron pipes laid in the streets at a depth of some three feet, where they are free from all danger of breakage from traffic and steam rollers.

The advantages of the ejectors as given by the Patentees may be summed up as follows :—



(1) The working parts are reduced to a minimum and such as are requisite are not likely to get out of order.

(2) The parts with which sewage comes in contact contain no machine-tooled surfaces, which are

unavoidable in pumps and get rapidly destroyed by the action of sewage, sludge and grit from the road detritus, etc. In the ejectors there is nothing but the hard skin of the original castings, coated with Dr. Angus Smith's composition, upon which the sewage can produce no detrimental effect.

(3) The friction of a pump, piston and other working parts is avoided, the compressed air itself acting direct upon the fluid, without the intervention of any machinery, and forming an almost frictionless and perfect piston, past which there can be no slip or leakage.

(4) The cup-and-bell float arrangement is one that cannot possibly get out of order, as an ordinary rising and falling float would be likely to do.

(5) The only tooled parts are those in connection with the small automatic air-valve; this makes only one movement of two or three inches for each discharge of the container of from 50 to 1,200 gallons (according to the size of the ejector), and is in contact only with the compressed air and out of reach of the sewage.

(6) The sewage inlet and outlet valves are so arranged as to give free passage-way of the full area of the pipe, allowing free passage to all solids that the pipe itself can carry. No part of the container has any depression or traps wherein solid matter may collect.

(7) The outlet is from the bottom of the ejector, so that the whole of the sewage, including solids, sludge, grit and everything brought down the sewer, is discharged out of the ejector.

(8) For these reasons no screening or straining of the sewage is necessary, as is the case with pumps, and the great nuisance caused by the cleaning of pump gratings and sump wells is avoided.

(9) The sudden rush of the whole contents of the ejector, when the discharge is into a main gravitating sewer, forms a most effective flush.

(10) The ejector forms an absolute severance of the sewers of each district from the main sewer.

The size of an ejector required for any district is determined by the estimated quantity of the sewage of the district, its capacity being equal to the number of gallons of sewage per minute at the time of maximum flow, which is one and a half times the average per minute of the total daily flow.

Each district should be provided with ejectors of the requisite size in duplicate, one being sufficient to cope with the ordinary work, the other being held in reserve. The two ejectors should be worked alternately, say, every week or fortnight, to ensure that they are both kept in working order.

Cast-iron pipes required for air and sealed sewage mains need not be of the same thickness as those used for water works, as the pressure under which they work is comparatively light.

DISPOSAL OF SEWAGE: CHOICE OF METHOD. GENERAL OBSERVATIONS.

When the town is situated near the sea, the readiest method is the discharge of the sewage into the sea, well beyond the lowest ebb-tide, by means of iron sewers. The boint of the discharge should be away from the falling tide, and not above it.

In many of the seaside towns in England, the sewage is disposed of by discharging it into the sea.

In large cities, as in Bombay, where the gradients are not suitable, there is difficulty in obtaining a continuous flow, and the sewage has to be lifted by the Shone system into the high level sewer and discharged into a reservoir and pumped up again into the sea.

In tropical climates, sewage decomposes so rapidly that a nuisance is caused by the accumulation of sewage in the reservoir, so that, in selecting the site, the direction of prevailing winds should be considered. Observations as to the set of the tide should be taken, by means of floats, to ascertain the direction of the currents.

PURIFICATION OF SEWAGE.

Sewage generally may be said to consist of a mixture of saline matter in solution, and nitrogenous and carbonaceous organic matter in solution and suspension, together with a certain amount of grit and mineral matter. The objects to be aimed at in its purification are, the removal of the suspended matter and the oxidation of the remaining organic matter and ammonia.

There is a considerable amount of evidence to show that the oxidation of the organic matter, during its passage through filters or land, is chiefly a biological process, but as to the exact nature of the action which takes place very little is known.

It is practicable to purify the sewage of towns to any degree required, either by land treatment or by artificial filters, and there is no essential difference between the two processes, for in each case the purification, so far as it is not mechanical, is chiefly effected by means of micro-organisms.

The selection of a method of sewage disposal should depend primarily on local conditions.

The two main questions therefore to be considered in the case of a town proposing to adopt a system of sewage purification are, first, what degree of purification is required in the circumstances of that town and of the river or stream into which its liquid refuse is to be discharged ; and second, how the degree of purification required can, in the particular case, be most economically obtained.

The choice of a scheme must depend on a number of considerations, but the Sewage Commission state in their report that they know of no case where the admixture of trade refuse with sewage makes it impracticable to purify the sewage either upon land or by means of artificial processes, although in certain extreme cases special processes of preliminary treatment may be necessary.

TREATMENT OF SEWAGE ON LAND.

It is generally desirable to remove from the sewage, by a preliminary process, a considerable portion of the grit and suspended matter, before attempting to purify the sewage on land or by filters.

If a sufficient quantity of good land, to which sewage can gravitate, can be purchased at a moderate price, land treatment would usually be the cheapest method to adopt. In cases where only clay land is available, it would generally be cheaper and more satisfactory to provide artificial filters.

There are many cases where crude sewage has been passed over land, but the evidence shows that land treatment of crude sewage is liable to give rise to nuisance, by the accumulation of solids on the surface of the land. Moreover, in some cases these solids are apt to form an impervious layer and so impair the efficiency of the treatment.

Given conditions favourable to each process, there is little difference as regards cost between any of the different forms of tank treatment, when these are considered along with cost of subsequent filtration.

There is *no essential distinction* between effluents from land and effluents from artificially constructed filters.

Effluents from those soils, which are particularly well adapted for the purification of sewage, contain only a very small quantity of unoxidised organic matter, and are usually of a higher class than effluents from artificial filters as at present constructed and used. Effluents from soils, which are not well adapted for the purification of sewage, may often be very impure.

VOLUME OF SEWAGE WHICH CAN BE TREATED ON LAND.

Generally speaking, the evidence points to a maximum rate of 30,000 gallons per acre, or 1,000 persons per acre, with the best land after preliminary treatment, although some put the rate as high as 60,000 gallons per acre, or 2,000 persons per acre, under similar conditions.

With unsuitable land, such as clay, not more than 3,000 gallons per acre can be efficiently treated, even after settlement of the sewage.

Table showing the approximate areas required with different soils.

——	Direct to Land.		After Precipitation of Mechanical Settlement.		After Filtration on Bacteria Beds.	
	Ratio of population per Acre.	Acres per 1,000 persons.	Ratio of population per Acre.	Acres per 1,000 persons.	Ratio of population per Acre.	Acres per 1,000 persons.
Broad Irrigation.						
Gravel	100	10	500	2	1,000	1
Light Loam ..	100	10	500	2	750	1⅓
Heavy Loam ..	75	13⅓	200	5	400	2½
Chalk	..	..	..	..	..	..
Peat	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.
Clay	50	20	100	10	300	3⅓
Intermittent Filtration.						
Gravel	150	6⅔	500	2	1,000	1
Light Loam ..	150	6⅔	500	2	1,000	1
Heavy Loam ..	75	13⅓	300	3⅓	500	2
Chalk	..	..	..	..	..	..
Peat	75	13⅓	200	5	400	2½
Clay	Unsuitable	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.	Unsuitable.

INTERMITTENT DOWNWARD FILTRATION.

After the sewage has been screened and the suspended matter removed in tanks, either by subsidence or precipitation by chemicals, the sewage may be discharged on the land. *Intermittent downward filtration* is defined by the Metropolitan Sewage Commission as the concentration, for short intervals, of sewage on suitable land, as small as will absorb and cleanse it, not excluding vegetation, but making the produce of secondary importance.

The action of the soil on sewage is both mechanical and biological. The suspended matter is removed and the organic matter broken up by bacteria or nitrification. The nitrifying organisms feed on the organic matter of the sewage oxidising it.

The most suitable land is sandy, porous soil, but clay land can be broken up and made efficient. The surface of the land must be levelled, and the sub-soil under-drained with porous pipes, at a depth of 6 feet. The surface should be ploughed into ridges and set out in plots, and the sewage equally distributed, each plot having a rest of 18 hours out of the 24. Vegetables and grass can be grown. One acre is required for 2,000 persons if the sewage is chemically precipitated, but if it is not, one acre for 1,000 should be allowed. The effluent is sufficiently pure to be discharged into a river or stream. In India less land would be required. Evaporation is faster and much sewage would be required to cover the land.

Broad Irrigation is defined as the distribution of sewage over a large surface of ordinary agricultural land, having in view a maximum growth of vegetation consistent with due purification of the amount of sewage supplied.

The land should be a loamy soil, but sandy soil, gravel or clay can be so treated as to utilize sewage. The fall should be from the town to the site selected. Chalk soil is not desirable because of the fissures. After screening, the sewage should be brought to the land as fresh as possible and diverted to the different plots by means of carriers of earth or cement concrete, so that the sewage is properly applied.

One acre of land to 300 people is required by the Ministry of Health, England, but much less is required if the sewage is precipitated before being discharged on to the land. One acre for 1,000 persons is sufficient. Much depends on the character of the soil and sewage. Vegetables and grass grow luxuriantly, and in India, especially, sewage farms if properly managed are very profitable.

In tropical countries, in the presence of sewage farms or irrigation lands, the nuisance caused by mosquitoes has to be considered and in laying out such farms and in their management, this should have every attention.

WELLS IN THE NEIGHBOURHOOD OF SEWAGE FARMS.

On general grounds, and quite apart from any scientific data, it would seem to be unsafe to sink any shallow wells in the neighbourhood of sewage farms, or to use water for domestic purposes from any such existing wells, unless the evidence as to the safety of the water were of a most convincing kind.

Deep wells sunk through an impermeable stratum are probably safe in the majority of instances, but wells not protected in this way and sunk through fissured strata cannot be relied on to yield a safe water supply, however deep they may be.

Chalk wells are, perhaps, the most dangerous in this respect, and a recent report by Dr. Copeman on an outbreak of Enteric Fever at Fulborn Asylum and a paper read at a recent meeting of the Epidemiological Society by Drs. Richards and Brinker serve to confirm this view in a striking manner. The latter mentioned that a culture of a special organism was poured into a "swallow hole" at a distance of about two miles from a well, and was recovered from the well water after 67½ hours.

PRECIPITATION.

Precipitation may be (1) by subsidence or sedimentation; (2) chemical precipitation.

Sedimentation is quiescent or continuous, etc., merely arresting the sewage and allowing the heavier particles to settle before passing on to land or over filter. The tank must be cleaned out frequently, at least once a week.

Chemical Precipitation.—The process is now considered only one form of preliminary treatment on land or biological system, and in the case of some sewage containing trade-waste is almost essential and, as a rule, aids in the subsidence of suspended matter and facilitates filtration.

The usual precipitants used are :—

Lime either by itself, as milk of lime 10 to 15 grains per gallon of sewage, or in conjunction with ferrous sulphate 12 grains per gallon; alumina ferric 5 to 15 grains per gallon of sewage, A. B. C., alumina ferric, blood, charcoal and clay, 50 grains per gallon, ferrozone 8 grains per gallon. The objections are the colour of the sewage, the supervision required in mixing, the cost and the disposal of the sludge.

Ferric sulphate and lime appear to give the best results. In trade-waste, where much fat is present, sulphuric acid is used, while in brewery towns lime is the precipitant.

The process of chemical precipitation is to a large extent mechanical; the precipitants produced by the chemicals used dragging down the suspended matter. A certain amount of chemical action takes place when lime is added, the lime combining with the carbonic acid and making an insoluble carbonate.

TIME REQUIRED FOR SETTLEMENT IN TANKS.

Continuous flow with chemicals	.. 8	hours	in tank.
Continuous flow without chemicals	..15	,,	,,
Quiescent with chemicals ..	.. 2	,,	,,
Quiescent without chemicals	.. 2	,,	,,
Septic tank without chemicals	..24	,,	,,

In India it is found that 8 to 12 hours is sufficient for septic tanks.

Production of Sludge :—On the average, domestic sewage contains about 35 parts per 1,00,000 of suspended matter.

SEDIMENTATION TANKS.

All tanks are sedimentation tanks, but it is convenient to limit the expression to tanks in which the sewage is allowed to settle without the aid of chemicals, and from which the sludge is frequently removed.

In some cases the tanks are allowed to stand full and the supernatant liquid is drawn off by a floating arm. In other cases, the sewage is allowed to flow through the tanks slowly but continuously.

Quiescent Sedimentation :—Two to three hours' quiescence is usually sufficient to produce a tank liquor fairly free from suspended solids, but owing to the fact that some sewage contains a larger proportion, than others, of solids that settle very slowly, no general rule can be laid down as to the necessary period of quiescence. With this form of treatment, the deposit in the tanks should be frequently removed.

Continuous Flow Sedimentation :—The amount of settlement effected does not depend upon the period of flow alone but upon a number of other factors. If the tank liquor is to be treated upon filters of fine materials, the period of flow should generally be from 10 to 15 hours. The tanks should be cleaned out at least once a week.

SEPTIC TANKS.

The notion that the solid matter of sewage would be digested by passing the sewage through a sealed tank is by no means novel, but it does not appear to have had any extensive practical application until Mr. Cameron, who held the office of City Surveyor of Exeter, proposed the adoption of the "septic tank treatment" for that city.

At that time it was claimed that the septic tank possessed the following among other advantages :—

That it solved the sludge difficulty, inasmuch as practically all the organic solid matter was digested in the tank.

That it destroyed any pathogenic organisms which might be in the sewers.

That sewage which had passed through a septic tank was more easily oxidised than sewage from which the solids had been allowed to settle, either with or without the aid of chemicals, in tanks which were frequently cleaned out.

As regards the first of these claims, it is now clearly established that, in practice, all the organic solids are not digested by septic tanks, and that the actual amount of digestion varies, to some extent, with the character of the sewage, the size of the tanks relative to the volume treated and the frequency of cleaning. The liquor issuing from septic tanks is bacteriologically almost as impure as the sewage entering the tanks.

Domestic sewage, which has been passed through a septic tank, is not more easily oxidised in its passage through filter than domestic sewage which has been subjected to chemical precipitation or simple sedimentation.

No definite rules can be laid down as to how long a septic tank should be run without cleaning. In the case of small sewage works (serving populations of, say, 100 to 10,000 persons), the tanks should generally be allowed to run, without cleaning, so long as the suspended matter in the tank liquor shows no signs of affecting the filters injuriously. For larger works, it would generally be advisable to run off small quantities of sludge at short intervals of time.

The rate of flow through a septic tank is a matter in which the needs of each place require special consideration, but at few places should the sewage be allowed to take longer than 24 or less than 12 hours to flow through the tank. In India 6 to 12 hours is sufficient. In no case should less than two tanks be provided, and they should be so arranged that, if necessary, one tank can be used alone.

As regards digestion of sludge and quality of the tank liquor, a closed tank possesses no advantages over an open tank. There is, however, less risk of nuisance if the tank and the feed channels to the filters are covered in.

By passing septic tank liquor through tanks of a size sufficient to hold about one-quarter of the day's flow, with the addition of from 2 to 3 grains of lime per gallon to the liquor, the suspended solids in the liquor are materially reduced, the offensive character of the liquor is largely destroyed, and a considerably larger quantity of the liquor can be treated per cube yard of filter.

CHEMICAL PRECIPITATION.

In the case of sewages which contain trade waste, and strong sewages from water-closets and towns, it is generally desirable to subject the sewage to some form of chemical treatment before attempting to oxidise the organic matter contained in it. In most cases careful chemical precipitation materially aids the deposition of the suspended solids and facilitates subsequent filtration.

No general rule can be stated with regard to the capacity of precipitation tanks. With continuous flow, an eight hours' rate is usually sufficient to produce a fairly good tank liquor from a domestic sewage of average strength.

If sewage is allowed to remain quiescent in the tank, two hours' settlement would usually suffice.

RELATIVE COST OF DIFFERENT METHODS OF TANK TREATMENT.

In the absence of special circumstances favouring a particular plan, it would appear that there is very little difference in annual cost between the various methods of tank treatment, when taken in conjunction with the cost of subsequent filtration through percolating filters, assuming that the kind of filter adopted in each case is that which is best adapted to the particular tank treatment provided.

Sewage filters may be divided into two broad classes: contact beds and percolating filters.

Contact beds are tanks filled with some filtering medium. In this type of filter, the sewage is held up before it is discharged. The bed, after it is emptied, is allowed to remain empty for some time before receiving the next filling. The length of time which the sewage is allowed to stand in the bed is spoken of as the period of contact.

In percolating filters, the sewage is not held up but is allowed to percolate through the filter.

There can be no doubt that the organic matter in solution in sewage can be oxidised by either type of filter, provided the filter is properly constructed and properly worked, but the question of the relative merits of the two types is one of some difficulty, as very few strictly comparative experiments on a large scale have been made.

Within ordinary limits, the depth of a contact bed makes practically no difference to its efficiency per cube yard. It would be generally inadvisable to construct contact beds of a greater depth than 6 feet or of a less depth than 2 feet 6 inches.

For practical purposes and assuming good distribution, the same purification will be obtained from a given quantity of coarse material, whether it is arranged in the form of a deep well or of a shallow percolating filter, if the volume of sewage liquor treated per cubic yard be the same in each case.

CONTACT BEDS.

Our knowledge of the action of a contact bed is very incomplete, and little is known as to the manner in which the organic substances of sewage are broken down, during the first stages of fermentation, into carbon dioxide, ammonia, &c. The purifying agents seem to be not only bacteria but also worms, larvæ, insects, &c., and no opinion can be offered as to the respective amount of work done by each set of agents; it probably differs to some extent according to the nature of the sewage. It has been observed that at some places large numbers of worms are present, while at others there are comparatively few.

Little is known of the kind of bacteria essential for purification, or as to their mode of action, and it cannot be stated whether they act chiefly during the period of contact or during the period of rest or æration after the filter is emptied. There are, however, grounds for thinking that the resting period is the more important phase of the cycle.

The generally accepted theory, as regards nitrogenous matter, seems to be that the ammonia is extracted from the liquid during the period of contact and oxidised during the period of rest, and that the resulting nitrate and nitrite are diffused through the liquid of a subsequent filling. All the ammoniacal nitrogen, however, does not appear in the effluent in the oxidised state, for there is always loss of nitrogen, as nitrogen gas, during the process.

The withdrawal of suspended and colloidal matter from the sewage during its passage through the bed appears not to be a simple mechanical effect of the material, for a matured contact bed, not clogged, will withdraw more suspended matter from the sewage than another bed similar in all other respects but not matured.

CONSTRUCTION OF CONTACT BEDS.

In some cases contact beds have been made by simple excavation, but the evidence shows that in the majority of cases it is desirable that the beds should be constructed of building materials.

Single contact will, generally, only yield a good effluent where the sewage to be treated is weak, and then only after good preliminary treatment. For the purification of partially settled weak sewage, and of well settled as also of partially settled sewage of average strength, if the case is one in which a good effluent is required, double contact is necessary, while if a strong sewage has to be treated triple contact is necessary, unless the preliminary treatment is exceptionally good.

PERCOLATING FILTERS.

In nearly every case a greater rate of filtration per cube yard can be adopted, if the material is arranged in the form of a percolating filter than if it is used in contact beds. In many cases the rate of filtration through percolating filters may be double or nearly double what it could be with contact beds.

Filtering Material.—The materials in general use for contact beds are clinker and coke; experience of other materials is not very great.

With percolating filters, however, many different materials have been used, and although the actual working of percolating filters is different from that of contact beds, the results are, to a large extent, applicable. At York a quantitative experiment with septic tank liquor was made on a circular percolating filter, 7 feet 8 inches deep, and constructed in four segments, one of clinker, one of coke, one of slag and one of broken brick, the material in each case being broken and riddled as nearly as possible to the same size; the bulk of the clinker was, however, distinctly smaller than of the other three materials. The results showed that the best effluent was obtained from the clinker segment, that the coke and slag segments gave very similar effluents, but not quite so good as the effluent from the clinker segment, and that the effluent from the broken brick segment was the lowest in the scale of purity. All the four effluents were of good quality.

With percolating filters there is apt to be nuisance from flies, especially with filters constructed of coarse filtering materials. In the warmer months of the year, such filters swarm with numbers of psychodidæ, which, though appearing to breed and develop in the filters, may usually be seen in large numbers on the walls of houses or buildings close to or on the works.

Size of Material.—The smaller the size of material used in a contact bed, the greater is the internal surface area exposed, and consequently, the more intimate the contact of the liquid with the material, the greater the purification and the more efficient the arrest of the suspended and colloidal matter.

The efficiency of a contact bed, however, depends very largely upon the admission of air to all parts of the filter during the time the bed is resting empty. Thorough and rapid drainage is therefore of the utmost importance.

With regard to percolating filters of fine material, if the liquid to be purified were absolutely free from suspended and colloidal solids, and if thorough æration could be maintained, the statement just made for filters of coarse material might possibly hold good for filters of fine material also. In practice, however, these conditions can scarcely be maintained with large rates of flow, and the greatest efficiency can be got out of a given quantity of fine material by arranging it in the form of a shallow filter rather than of a deep filter. But it is difficult to make an exact quantitative statement as to the difference in efficiency of the two forms. The amount of sewage which can be purified per cube yard of contact bed or of percolating filter varies, within practical limits, nearly inversely as the strength of the liquor treated. This statement is based on the assumptions that the size of the material of which the filter is composed is, in each case, suitable to the character of the liquor treated, and that the material is arranged at the proper depth to secure maximum efficiency.

Percolating filters are better adapted to variations of flow han contact beds. Effluents from percolating filters are usually much better ærated than effluents from contact beds, and, apart from suspended solids, are of a more uniform character. On emptying a contact bed, the first flush is usually more impure than the average effluent from the bed. The risk of nuisance from smell is, however, greater with percolating filters than with contact beds.

Where the liquor to be treated contains much suspended matter, it is usually advisable to construct filters, whether contact or percolating, with coarse filtering material. Where the preliminary treatment has effectively removed the greater part of the suspended matter, it is best to use fine material in the filters.

As a rule, special stand-by tanks (two or more) should be provided at the works and kept empty for the purpose of receiving the excess of storm-water, which cannot properly be passed through the ordinary tanks. As regards the amount which may be properly passed through the ordinary tanks in storm times, the rate of flow through these tanks may usually be increased without serious disadvantages to about three times the normal dry weather rate.

TESTS FOR SEWAGE EFFLUENTS IN RELATION TO STANDARDS.

According to our present knowledge, an effluent can best be judged by ascertaining, first, the amount of suspended solids which it contains, and, secondly, the rate at which the effluent takes up oxygen from water.

The Sewage Commission in their eighth Report deal with the standards and tests for sewage and sewage effluents discharging into rivers and streams and express their opinion that as a general standard—

(1) "The effluent must not contain as discharged more than 3 parts per 100,000 of suspended matter," and

(2) "With its suspended matter included must not take up at 65° F. (18·3° c) more than 2·0 parts per 100,000 of dissolved oxygen in five days."

But the Commissioners maintain that the nature and volume of the recipient waters should also be taken into consideration and special standards, which may be higher or lower than the general standard, must be fixed, as the local circumstances require. In their opinion "if the dilution is very low it may be necessary to prescribe a specially stringent standard"—on the other hand, if the dilution is very great the standard may be relaxed or suspended altogether. They think (*a*) that if the dilution is not below 150 volumes and does not exceed 300, the dissolved oxygen absorption test be omitted and the standard for suspended solids fixed at 6 parts per 100,000. (*b*) But if the dilution is over 300 volumes and less than 500 volumes, the standard for suspended solids may further be relaxed to 15 parts per 100,000. (*c*) With a dilution over 500 volumes, all tests might be dispensed with and crude sewage discharged, subject to such conditions as to the provision of screens or detritus tanks as may appear necessary to the Central Authority.

EFFECT OF TRADE EFFLUENTS ON SEWAGE PURIFICATION.

All the trade effluents interfere with or retard processes of purification to some extent, but the admixture of trade refuse does not make it impracticable to purify the sewage upon land by means of artificial processes, although in certain extreme cases special processes of preliminary treatment may be necessary.

NUISANCE FROM SMELL.

All sewage works are liable, at times, to give off unpleasant smells; they should therefore be situated away from dwelling houses, wherever this is practicable.

The nuisance is apt to be considerably greater where the sewage contains brewery refuse in any quantity; but, on the other hand, the presence of some trade effluents, such as iron-salts or tarry matters, tends to render the process of purification less offensive. The extent of the risk of nuisance depends, however, not only on the character of the sewage but also on the method of treatment adopted.

The points then to be considered, when advising on a biological system for disposal of sewage, are :—detritus, chamber, septic tank, slate beds, contact beds, filter beds, effluents and outfall.

The sewage must be screened and passed into a septic tank, which may be covered or not. After remaining 8 to 24 hours according to climate, the supernatant liquor flows off and is distributed by mechanical distributors or sprinklers, or spread over a filter bed, or the sewage after being screened and admitted into a sedimentation tank passes to slate beds and filters and after sedimentation to contact beds and percolating filters, storm-water filters being provided for the increase due to rain.

The contact bed may be upward contact and the liquor, after being in contact with the coarser material, is distributed by filtering trays or distributing gear over the percolating filter. The effluent is as a rule fit to pass into a river, but, if the river water is used for drinking purposes, it would be necessary that the effluent pass over land.

ACTIVATED SLUDGE PROCESS FOR THE PURIFICATION OF SEWAGE AND TRADE WASTE.

The purification of sewage and trade waste by an entirely ærobic process, free from objectionable odour, has always been the ideal method and has apparently at last been rendered possible by the *activated sludge process*. The raw sewage is screened and thereafter is ærated by being agitated by mechanical agitators blowing air through it; the process however consists not merely of æration or agitation of the sewage but a combination of both, with the retention in the tank of the sludge, indigenous to the sewage, but activated by the process of æration. In this process sewage organisms multiply rapidly in the sewage and their peculiar value is that in some way not yet definitely understood they induce the rapid settling of the sludge—the latter being of course in consequence changed with these organisms which are carried down along with the sludge; the sludge is thereafter spoken of as "activated" or, in other words, "ripened", and portions of it can be used over and over again for the activation of fresh sewage.

Hitherto, with any sedimentation or septic tank process, retention in the tank induced anærobic conditions, a bad smelling effluent, and a worse sludge of so little fertilizing value, that the problem of sludge disposal often became more serious than that of purifying the liquid contents of the tank.

The activated sludge process not only yields a pure effluent but it also purifies the sludge, changes its character and converts it into a valuable asset.

Activated sludge is built up by æration, gradual at first, the more or less purified liquid being drawn off and its place taken by more sewage, until about 25 per cent. of the tank contents consists of activated sludge. This proportion is then maintained and the surplus sludge can be drawn off, to settle rapidly and contain valuable fertilizing properties.

THE PROCESS OF PURIFICATION.

The crude sewage is first rough screened and its detritus settled out. The light organic matter is retained, ærated and agitated until it is in a fine state of sub-division and will pass through the fine screen. It is then mixed with activated sludge and ærated for the necessary period, passing through the circuit of the æration tank until it is finally discharged into the settlement tank fitted with Clifford inlet. Here the sludge rapidly settles and most of it is withdrawn by means of air-lifts for further use whilst the surplus passes to sludge beds or tanks for dewatering and drying. Before however the activated sludge is returned to the æration tank it is usually re-ærated, *i.e.*, air is blown through it in its concentrated state, as it flows back from the settlement tank to the sewage inlet.

Tanks which have been sufficient for ordinary sedimentation or septic liquefaction will be ample for the complete treatment of the sewage by the activated sludge process, when properly equipped.

The great circulating effect of diffusing small bubbles of air through porous plates called "diffusers", laid in and forming a small portion of the tank bottom, has proved to be a good, effective and economical method.

The advantages claimed for the activated sludge process are :—

(1) It is hygienic, ærobic throughout, without smell, ærial nuisance or fly trouble.
(2) It dispenses with filters and secondary treatment.
(3) It reduces area and cost of works required.
(4) It involves no loss of fall and often saves pumping.
(5) It makes the sludge innocuous and a valuable fertiliser.
(6) Existing tanks can be utilised.
(7) Long outfall sewers are necessary as works can be built near the town.

But there are certain disadvantages reported, *viz.*, the great bulkiness of the sludge rendering difficult the economical disposal of the sludge on account of its great volume. It is too early yet to state what is the future for this process. Already it has been tried successfully in England and the United States of America, and if the difficulties abovementioned can be overcome, it may come into more general use.

COMBINED REFUSE AND SEWAGE DISPOSAL.

It can now be determined, in the light of what has been stated under Incinerators or Destructors (in Chapter II), whether it will not be possible to utilise the town refuse in acquiring power for dealing with the disposal of sewage.

In England the steam and electricity derived from the heat evolved in destroying refuse are used for many purposes including the pumping of sewage and the working of the gear for distributing it over the filters and making the concrete for building the filters. In some towns the electricity is available for tramways and pumping water.

PRACTICAL APPLICATION OF THE FOREGOING.

In very few, if in any city in India at present, can a complete system of removal of sewage by water-carriage be adopted. But in the majority, a partial system can be installed with great advantage.

Let us take, for example, two cities in India: one with a population of about 50,000, the other with a population of about 120,000.

We are asked to advise on the best method of dealing with the sewage.

The cities are 1,000 miles apart in the Bombay Presidency. They are both situated close to rivers. One is peculiarly well situated as regards gradient, while the other is not so well favoured. The climatic and geological conditions differ. One has a scanty rainfall, is practically rainless, and has a high dry wind, while the other has an average of 29 inches per annum and during the rainy season is fairly humid.

The water supply in both cities is, or can be, made sufficient—in one case it is from a gathering ground, in the other from a river.

Beyond the primitive system of sewage disposal and sanitary arrangements, they have nothing in common; the following description of the system in vogue with slight modifications applies to both places.

At present the system of collection and disposal of night-soil and sullage water is most primitive.

The drainage system consists of innumerable open drains running either in the centre or sides of the streets and lanes into which drains from the houses run at right angles. These smaller drains passing along the streets and lanes are connected with main open drains, which discharge into private gardens, the owners of which pay the Municipality for the use of the sullage water. The drains are badly made and laid and are constantly blocked and become full of sullage water and have to be swept by hand labour.

The privy system consists for the most part of open spaces, sometimes covered, chiefly on the ground floor of a house or in a blind lane but in some instances on the terraces. In many cases there are no seats or receptacles, the night-soil being deposited on the ground which is frequently unpaved. The excreta and urine and ablution water are also deposited on the bare ground: some is dried by the sun and some absorbed by the soil. Each privy has an open drain discharging into an open drain in the lane or street and is washed down by the *bhangi* after the night-soil is removed. The open drains convey urine and some night-soil and ablution water into the main drain in the street and discharge into the outfall drains. All the washings from the houses and lanes, therefore, are dischaged indirectly into open drains.

There are many *mahals* or groups of houses in which privies are placed common to several houses. These privies are in close proximity to the windows of the houses, the entrance to which is by narrow lanes. In many of the lanes the sun is excluded. The night-soil and urine, remaining for hours, soak into the soil or are washed into the open drains or to some extent dried by the sun.

Private privies are cleaned by Municipal agency. All privies are not supplied with proper receptacles. Each *bhangi* has to clean fifty-five privies.

The privies generally abut on the open lane or street and, passing along the lane, the water from the bathing places and privies on the ground floor or upper floors can be seen discharging into open street drains. The narrowness of the lanes is accentuated by the presence of the open drains which occupy a considerable part of the space meant for walking.

Night-soil is removed to the north-east of the city where it is buried in trenches; each trench 200 feet long consists of seven partitions. It has been arranged to put the night-soil in each partition on each day of the week to facilitate early drying. Owing to the greater depth of trenches, drying takes a longer time. But the trenches have to be made deeper because of the limited space available. The dried night-soil in each trench is sold. For the removal of night-soil from the public latrines, *mahal* privies and private privies, there is a staff of *bhangis* with night-soil carts.

This system then is insanitary for the following reasons :—

The privy floors are connected to the open drains in the lanes.

The night-soil and urine and ablution water and bath water, if not removed, to some extent find their way into the open drains.

In these open drains, excreta, urine and sullage water remain close to living rooms and shops and form an obstacle to the traffic.

The night-soil and urine, if not removed, become a nuisance and danger to health. In many of the privies the floors are paved, and the *bhangi* after collecting the excreta, washes down the floor into the open drain. The urine and ablution water cannot be removed, but must either soak into the ground or discharge into the open drain.

The defects in this system are that human excreta, as well as other foul matter, are constantly being exposed in these drains. These drains overflow and discharge into the streets and lanes. They encroach on the already narrow lanes and the sides become broken and defective by the constant traffic. The lanes are so narrow that any influence the sun might have is prevented.

The ideal at which practical sanitation aims is the immediate removal and disposal of all excrementitious and polluted matter from the neighbouring dwellings without hand labour.

The present system is in every respect contrary to this.

The presence of human and animal excrement near to the dwellings is a serious danger to health, apart from the obnoxious odour polluting the air in and around dwelling houses ; there is a great danger of spread of Cholera, Enteric, Diarrhœa, Dysentery, Phthisis and infantile intestinal diseases. The food and water and milk are in danger of pollution, either directly or indirectly by flies and vermin, while a damp, polluted soil constitutes an additional danger to health.

The Indian part of the town is thickly populated. The streets are narrow with long winding passages and the houses irregularly built, almost touching each other across the narrow lanes.

The European quarters and Cantonment and the bungalows are in open compounds. The sanitary arrangements are on the dry system and have private sweepers. The bath and kitchen waste discharges into cess-pits or pails which are emptied and used in the garden, or put in a cess-pit cart which conveys it to the trenching ground. The Cantonment has latrines and urinals on various principles, on the dry and wet system, dotted about at convenient but frequently very unsightly and unsavoury positions. The night-soil drops into pails and the urine separates into buckets and the contents are conveyed by drain carts to trenches or incinerators.

In the cavalry barracks, the horse dung and litter have to be dealt with, and greater attention is necessary owing to the breeding of flies and mosquitoes.

As far as the European and Cantonment arrangements are concerned, as there is no system of sewage, the night-soil and waste are dealt with by the scavengering staff and can be properly supervised: much depending on the control and zeal of the authorities.

The European and Military population is about 3 per cent. of the whole.

In the foregoing Chapter the data required for forming an opinion are given and may be re-capitulated.

The population, geological position, class of people and trade, facilities for draining and disposal; the cost of the system and connection of the houses; the amount of water available per day per head of the population, the rateable value of the city and the annual income from all sources.

The question has been under consideration for 30 years in both places. Sanitary engineers and other experts have drawn up schemes; but lack of funds, want of pressure and passive resistance of the Municipality have deferred their application.

The Health Officer or the Civil Surgeon has reported on the necessity of doing something for improving the sanitary condition. The mortality is high, Plague, Cholera, Small-pox, Enteric and Diarrhœa are constant visitors, while Malaria is always present.

The water supply is from a gathering ground or river and is or can be made sufficient. The Health Officer has asked for and given good reasons for an increase in the staff; and improvement in the sanitary arrangement of the houses, urinals and public latrines and a system of drainage to carry off the sullage water and sewage; a septic tank installation with contact beds and percolating filters and effluent capable of being discharged into the river or on to a sewage farm.

The practical engineering and actual carrying out of the scheme is done by engineers and, although the financial aspect must be considered in advising on an improvement, it is assumed that the ways and means will be provided. Vested interests and weak administration interfere with and delay achievement—but this must be expected. It must not dishearten the sanitary official; he must continue to press and push forward schemes for the improvement of the district.

In some towns in India, schemes have been proposed, drawn up and considered for over 30 years before anything has been done.

It is a well accepted fact that the health of a community is improved by proper drainage of the soil and, although the locality is for the greater part of the year rainless and has the natural advantages of a hot sun and a high wind, the constant pollution of the soil by the sullage water from the open drains constitutes a serious danger, which the laying of underground sewers will materially reduce.

The advantages of an underground system of drains properly laid with sufficient manholes, inspection chambers, flushing tanks and ventilators are: the immediate removal of all excrementitious and polluted matter without hand labour; the soil becomes drier, the atmosphere purer and the surroundings of the houses cleaner.

In Indian towns where the habits and customs of the people have to be considered, an underground system with water-closets connected and installed as in Western cities must, to a certain extent, be modified to suit these conditions, but it is an accepted fact that in Eastern towns, in spite of the habits of the people and their disinclination at first to adapt themselves to water-closets, a great, if gradual, improvement is noticed.

It is argued that the water-closet is misused and becomes choked with stones, sticks, earth, rags, &c., and the system gets out of order and that a certain class of people will not use water-closets and that *purdah* women would be prevented from using them unless placed inside the house and that there will be a danger of sewer air entering the house.

Compared with the advantages of a water-closet system, these objections are trivial and have all been put forward before in other places.

A properly constructed water-closet can, in every case, be kept cleaner than any form of native privy; while the ablution water and urine and night-soil from these *nahanis* or bathing places can all be utilised for flushing the water-closet basins and drains. The sides of the receptacles can be kept clean and the walls of the building do not reek with the odour of stale urine and night-soil.

Practical experience shows that in public latrines frequented by all sorts of people, ignorant and wilfully careless, much trouble may be caused by the blocking of the drains by stones, sticks, rags and that a whole-time sweeper (halalkhor) must be engaged to flush and clean the basins; and the form of water-closet most suitable is the trough with automatic flush tank and inspection chambers. The blocking of the drains and water-closets with stones, sticks, rags, &c., must be guarded against by warning the people and by supervision and by provision of proper inspection chambers.

The supposed danger of sewer air entering the house is over-estimated. In a locality particularly where the water-closet will be on the ground-floor, or detached from the dwelling, no such danger is to be apprehended.

A properly laid water-closet system affords no such danger as long as the water supply is sufficient and the traps and ventilation shafts, soil pipes and inspection chambers are kept in order. The hand labour of removal of night-soil is done away with and the sewage is carried away at once.

The advice, then, on the question before us is that, for the reasons given, a system of underground drainage properly constructed would be suitable to these two cities. Public latrines and urinals should be provided on the water-carriage system. Water-closets should be provided for groups of houses with automatic flushing tanks and the waste water from baths and washing places used for flushing the drains.

A certain number of pail depôts should be provided to which night-soil can be conveyed from houses where water-closets cannot at once be installed.

The narrowness of the lanes and the congestion of the houses in the town proper naturally constitute a difficulty in dealing with the question of adopting any system of drainage, but there seems no immediate prospect of a scheme for widening these lanes. Looking at the present condition we are distinctly of opnion that the underground system properly devised and carried out would be an improvement on the present arrangement.

On going over the different schemes, it will be seen that drains of varying dimensions can be brought up to within a few feet of most of the houses. Inspection chambers, man-holes and flushing tanks should be provided and the connection of privies could then be made.

The Cost.—Although the question of cost may be outside the sphere of the ordinary sanitary student in England, unless he be surveyor or sanitary engineer or builder, this is a very important factor in India and one that delays improvements; every one interested in sanitation should have, therefore, some idea of the subject so as to guide him in advising on any particular scheme.

Much depends on the geographical position of the locality the gradient, distance, depth of sewer, nature of soil.

In one case a scheme for draining a town may cost Rs. 10 per head of population, while in another it may be Rs. 20 or more. In England the cost (pre-war) of a complete sewage system and disposal of sewage was £1 per head of the population.

The cost of installing a water-closet will be from Rs. 750 to Rs. 1,000 including tanks, cisterns, connection, &c., complete.

The cost of a house connection varies with the width of the road and depth of sewer. In the case of a street 30 feet wide with a sewer 6 feet deep, each connection will cost about Rs. 70.

The expense, if borne by the landlord of small houses in ordinary towns in India, is very high compared with the value of his property; and the cost of installing water-closets or converting privies into water-closets and making house connections should be shared by the Municipality and the landlord either by financial aid, loans or by spreading the payment over a period of time; every inducement should be offered. In many of the large towns in England, the alteration of the old privy midden or pail into water-closets has been carried out in this way.

As already pointed out, it will be some time before the open drainage system and the discharge of sullage on to the sullage ground and the trenching of night-soil can be done away with, but the tendency of sanitary engineering in India is towards that end. The general arrangement of houses in the thickly populated towns and the distance between bungalows in the wealthiest parts render this costly, but it can be done by degrees.

To briefly summarize :—

The water supply should be increased to 25 gallons per head per day as a minimum.

The out-fall on which the sewage is to be discharged should be acquired and properly laid out for a biological installation and effluent to discharge on the land.

The town proper should be drained and sewered.

Public latrines and urinals on the water-closet system should be provided and trough water-closets installed for groups of houses.

By-laws and regulations should be drawn up for the control of water-closets for private houses.

Financial assistance should be given to the landlord to provide water-closets and house connections.

Storm-water drains should be provided according to the rainfall and position of the locality, bearing in mind the prevention of mosquito-breeding places.

GLOSSARY OF TECHNICAL TERMS.

Aerobic.—"Living in contact with air." The term is applied to certain micro-organisms which live preferably in the presence of atmospheric oxygen and oxidize the ammonia in sewage into nitrites and nitrates. Aerobes are divided into facultative and obligate aerobes: the former can live in the absence of oxygen, the latter are unable to do so.

Anærobic.—"Living without air." The term is applied to certain micro-organisms which live preferably without air, and reduce the organic matter in sewage, thus preparing it for treatment by aerobic bacteria.

Anti-Siphonage Pipe.—The term given to a small pipe which supplies air to siphons and traps, and prevents their being untrapped by a partial vacuum being formed through a sudden rush of water falling in a pipe to which the siphon or trap is connected.

Bacteria.—Bacteria is a generic term applied to a number of minute unicellular organisms belonging to the vegetable kingdom which multiply by fusion only. In this book the word bacteria is used generally to include micrococci and other members of this family.

Catch-Pit.—A chamber built below the level of the invert of a sewer in which the velocity of the flow is reduced so as to collect such heavy deposit as may be in the sewage.

Combined System.—The name given to the system of sewerage in which the conduits are constructed for the double purpose of receiving both sewage and surface water.

Configuration.—The external aspect or contour of the land or district.

Datum.—Some fact or quantity granted or known from which other facts or quantities are calculated, *e.g.*, a certain step at the Town Hall, Bombay, is assumed to be 100 feet above an imaginary plane for the purpose of calculating other levels in the City.

Dhapa.—A slab of stone used for covering or spanning a masonry drain.

Disk-Valve.—A circular sliding iron door used for closing a pipe sewer.

Domestic Sewage.—The sewage derived from the habitations of men and beasts in contradistinction to that derived from factories.

Gasket.—A thin twisted or plaited rope put first into the joints of pipes to prevent the cementing materials from passing into the pipes.

Gradient.—The name given in sanitary engineering to the inclination or slope of a pipe or conduit: the vertical fall divided by the horizontal distance.

Grout.—Cement mixed with water to the consistency of cream.

Inlet.—The term applied to the higher or upper end of a pipe or conduit.

Intercepting Trap.—A trap or siphon placed on a house drain between the sewer and the house to intercept and prevent gas from the former passing up the drain or into the house.

Invert.—The name given to the lowest portion of a sewer, pipe or drain.

Jump-weir.—A name given to an arrangement made at the street end of a house-gully, which permits of a small flow of sullage from the gully to fall into a trap in connection with the house drain, but allows of a greater flow of surface water to pass over and discharge into a drain set apart for the purpose.

Liquefying Tank.—A tank in which the organic sewage matter is broken up or liquefied by bacteria.

Manhole.—A masonry chamber, with a heavy cast-iron cover, built on a sewer or drain, through which it is possible to enter and have access to the sewer or drain for cleaning and inspection purposes.

Outlet.—The lowest end of a sewer or conduit or the end through which the sewage is discharged from a manhole, tank, etc.

Ovoid.—A term used to describe sewers built in the shape of an egg.

Oxidation.—A term used in sewage purification to denote the final change which takes place in destroying organic matter: the addition of oxygen to the effluent by the admission of air to the latter.

Pathogenic.—The name given to a class of organisms which, when introduced into the body, give rise to disease (Pathogenic=Disease-producing).

Prestock.—A gate usually made of iron and built into the body, so that it can be raised or lowered at will in controlling the discharge of sewage or water.

Plumb.—Vertical or straight.

Precipitation.—The process by which a substance held in suspension in a liquid is made to separate from another or others and fall to the bottom.

Puddle.—Clay worked up by being mixed with water to a plastic or sticking condition.

Rubble.—Rough irregular stones used in coarse masonry or to fill up the interval between the facing coarses of masonry.

Scraper or Shield—An appliance used in cleaning an ovoid sewer and made in the shape of the sewer with a portion of the bottom or the top cut off; when inserted in the sewer it heads up the sewage by contracting the area of the flow, which is consequently accelerated and facilitates cleaning by softening the deposit.

Seal.—The depth of contained water in a trap which prevents the free passage of air or gas through it.

Sectional System.—The name given to the system of sewerage in which a district is divided into sections, each of which has sewers gravitating to one point within it.

Separate System.—The name given to a system of sewerage, in which there are different conduits for storm-water and sewage.

Septic.—A term denoting the promotion of putrefaction.

Shored—Propped or supported by timber.

Silt.—A term given to the deposit of solid matter found in sewers and drains.

Siphon.—A bent tube whose legs are of unequal length, used for drawing liquid out of a vessel, the shorter leg being inserted in the liquid and the larger hanging down outside; when the air is sucked from the tube the pressure of the atmosphere causes the liquid to rise in it and flow over.

Sludge—Soft mud: the term applied to the deposit in biological tanks and filters.

Socket.—The opening at the end of a pipe generally enlarged, into which is inserted the end of another pipe to make a joint. See "Spigot."

Spigot—The end of a pipe which is inserted into the enlarged end of another pipe to make a joint.

Sterilization.—By the expression "sterilization of any substance" is meant destruction or removal of all germs and their spores contained in or on such substance.

Sub-Soil.—The beds which lie below the surface soil.

Tidal Flap.—A door attached to a sewer at a manhole, by which the sewage may be retained in the sewer for flushing purposes (properly, a gate used to exclude tidal water).

Trapped.—So formed as to hold a depth of water sufficient to prevent the free passage of air or gas.

Urban.—That part of a large city or town which has been fully built upon.

Water Gully.—A trapped receptacle through which the surface water from the road flows into an underground drain.

Water Tables.—Flat dressed stones fixed at the sides of a road over which the surface water from the road flows to the water-gully or drain.

Wetted Perimeter.—The length (measured at right angles to the flow) of such parts of the sides and bottom of a conduit or channel as are in contact with the liquid.

Windsail.—A tube or funnel of canvas used to convey air into sewers or drains.

CHAPTER IV.

Water.

Water is a prime necessity of life. It assists in the building up of tissues, in the elimination of waste materials from the body and in regulating the temperature of the body under varying conditions of heat. It is composed of two elements, hydrogen and oxygen, in the proportion of two of the former to one of the latter. Water should be clear, transparent, tasteless and odourless, and, when viewed in small quantities, perfectly colourless. When seen in bulk, however, it possesses a greenish blue colour. Practically speaking, water is incompressible, but the volume of any given weight varies largely with the temperature.

As a general rule, fluids at all temperatures between their freezing and boiling points expand when heated and contract when cooled, but water is an exception to this rule, as in freezing it expands about $\frac{1}{11}$th of its volume. Its maximum density is at 4° C. and if cooled below or heated above that temperature, it expands. The standard density of water is fixed at 4° C. in France, and at 60° F. in England.

The freezing point is 0° C., or 32° F., but if many salts are present, the freezing point is lowered and the boiling point raised, the water moreover having a higher density than ordinary water. In freezing it becomes purer, as it loses some of its saline constituents and air ; ice water, therefore, is badly aerated and heavy. Water boils at 100°C. or 212° F. at the ordinary barometric pressure, but if the pressure be reduced, *e.g.*, by ascending a mountain, or by placing water under an air-tight globe the pressure of air in which is reduced by an air exhaust pump, it will boil at a lower temperature and can even be made to boil at the ordinary temperature of the room if the pressure of the air above it in the globe be reduced sufficiently.

Water evaporates invisibly at all temperatures, the amount being influenced by various factors, to which reference will be made later. It is a remarkable solvent, readily dissolving gases and solids from the air and soil. This is a most important fact necessitating precautions in a public or private supply. Oxygen, nitrogen, ammonia, hydrochloric acid, carbonic acid, etc., are easily absorbed. In addition to this power, it may hold in suspension mineral matters such as clay and sand, and also organic matter, *e.g.*, the lower forms of animal and vegetable life; finally, water may dissolve certain metals, *e.g.*, lead, iron, zinc.

When bodies pass from the solid into the liquid state, or from the liquid into the gaseous, a large quantity of heat is absorbed or rendered *latent*: thus water at 0° C. equals ice at 0° C. plus the latent heat of liquefaction. For example, if equal weights of water, one at 0° C. and the other at 100° C. be mixed, the mixture will have a temperature of 50° C., but if equal weights of ice and water, the former at 0° C. and the latter at 100° C. be mixed, the mixture has a temperature of 10·6° C. only. So also steam at 100 °C. equals water at 100 °C. plus the latent heat of vaporization, and to convert water, say one pound of it, at 212° F. into steam at 212° F., as much heat is required as would raise 965·7 lbs. of water one degree.

Water has a greater latent heat than any other substance, *i.e.*, more heat is spent in rendering a given quantity of ice liquid than in liquefying a similar quantity of anything else. These factors have a great influence in checking excessive evaporation and the too ready freezing of lakes. Water has a high capacity for heat but is a poor conductor of it. The term *specific heat* means the amount of heat required to raise a unit mass of a body through one degree in temperature. In England the standard is one pound of a substance through

1° F. In France it is one kilogramme of ice cold water through one degree C. Weight for weight, water will absorb more heat than any other substance for the same rise of temperature. The specific heat of a substance is generally greater when liquid than when solid or gaseous, *e.g.*, ice has only half the specific heat of water. The latter increases with its temperature. The specific heat of a perfect gas does not vary with its temperature or its density. For a large number of simple substances, the specific heat of equal weights is inversely proportionate to the atomic weight. In regard to solids, the specific heat is greater at a high temperature than at a low one, except in the case of platinum.

SOURCES OF SUPPLY.

Natural waters may be classified as follows:—(1) Rain water; (2) surface waters, *e.g.*, rivers, streams, lakes and ponds; (3) sub-soil waters, *e.g.*, springs and wells. From whatever source, however, our water supply comes, it is ultimately dependent for replenishment on the rainfall.

RAIN WATER.

For any given temperature, air will hold only a certain quantity of aqueous vapour or moisture; the higher the temperature of the air the greater will be the amount of vapour it will hold, and when it contains its greatest possible amount it is said to be saturated. Now, if air laden with moisture be cooled, a point will be ultimately reached when the atmosphere contains as much moisture as it can retain at that temperature and if the latter be still further reduced, then the surplus moisture is deposited as rain, mist, snow or dew and the temperature at which this deposition occurs is called the *dew-point*.

Rain water carefully collected, far from aggregations of population, is generally a very pure water, being as a rule soft and well aerated. Near towns it carries down with it many impurities, especially in the earlier portions of a downpour. Near large towns where coal fires are abundant, one may find in it traces of ammonium carbonate, nitrite and nitrate, and also nitrous and nitric acids and sulphurous and sulphuric acids, but as a rule free acids are not found in the absence of factories and large collections of private houses consuming coal. Angus Smith states that the sulphates increase in amount as we pass inland before large towns are reached, and that they are due to the sulphur in the coal consumed. He further states that the salts of ammonium increase in amount as towns increase; they come partly from coal and partly from decomposed organic substances. In the neighbourhood of the sea coast, rain carries down with it sodium chloride or common salt and also sulphates derived from the sea. As it nears the earth's surface, rain absorbs organic matter and carries with it many bacteria in suspension, as well as pollen, spores of fungi, minute particles of straw, hair, animal excrement, and sand, etc. On account of the ammonia present, the bacteria are apt to multiply rapidly: consequently, when rain water is required for internal use it should always be filtered first.

There are certain objections to the use of rain water as a source of domestic supply, among which may be mentioned:— 1. Its uncertainty. 2. The prolonged dry season experienced by some countries—this involves a very large reservoir. 3. Rain water is not very palatable, and lastly much depends on where the rain falls, *e.g.*, if it falls on to a roof, it may be very contaminated owing to soot, dust, decaying vegetable matter and the excrement of birds.

In favour of rain water is the fact that, in general, it is very pure and it is well aerated and soft. If it is used as a source of supply for a household, it must be remembered that near manufacturing towns its reaction is frequently acid and it may therefore act on certain metals, in consequence of which fact it should not be stored in lead, iron, zinc, or galvanised iron tanks. Slate tanks with cement joints should be used, or, if the storage is on a small scale only, earthenware cisterns are good. Very large tanks should be of brick lined with hydraulic cement and every precaution must be taken to prevent the entrance of surface or sub-soil water and also the earlier portion of the rainfall, as this is usually foul from having washed the air and also the collecting surface. If the water is to be used for drinking purposes, it must first be filtered. In Great Britain rain water is generally less pure than water from a deep well or spring, because of the large amount of smoke, effluvia, excremental dust and products of animal and vegetable decay, etc. Where rain water is stored for domestic use, rain water separators can be fixed to the rain water downtake pipe. They allow the earlier portions of the rainfall to flow away, but after a time, by an ingenious valve working on a pivot and actuated by the rainfall itself, the water is diverted into another pipe and passes to the storage cistern.

Part of the total rainfall that occurs is evaporated again from the surface, part flows along to form rivers and lakes, and the third portion sinks into the soil vertically or obliquely through fissures or pores until it reaches an impervious stratum, and then either finds its way laterally to the surface in the form of springs or accumulates in the porous strata overlying the impervious layer, where it may be reached by sinking wells.

The amount which sinks in depends on many circumstances, *e.g.*, the nature of the soil—in sand and gravel about 90%, in chalk 40%, in limestone 20%, and in clay none. Further, obviously the proportion which sinks in is less in hilly districts where the water flows away freely. In winter a larger amount runs off the surface by gravitation than in summer, when by reason of the increased temperature evaporation is larger and the absorbent properties of the earth somewhat greater.

Experiments carried out by Tudsbery and others over a period of 14 years gave the following results as regards loss by evaporation.

The evaporation from the surface of water exceeded the rainfall in 3 out of the 14 years. The average results of the 14 years were :—

Rainfall.	Evaporation.		
	Soil.	Sand.	Water.
25·7	18·1	4·3	20·6

The small amount of evaporation from sand presents a marked contrast to that from the less permeable soil.

The mean daily average in England is 0·08 inch and in India 0·20 inch reaching even up to 0·56 inch in 24 hours.

Throughout the year the average evaporation from roofs may be taken as 20 to 25% of the rainfall; being greatest where the rainfall is least.

The loss by evaporation from lakes providing water to Bombay City during the 8 months of the dry season may be taken as under :—

Vehar	1,700 Million gallons.
Tulsi	250 ,,
Tansa	5,200 ,,

and for the remaining 4 months of the year, one may reckon an additional loss of 25 per cent.

The average rainfall in Great Britain is about 30 inches. In certain parts of Assam, it is over 400 inches. At Mahableshwar, Bombay Presidency, it is over 260 inches; whereas in certain other parts of the world, rain seldom if ever falls, *e.g.*, in the Sahara and in parts of the interior of Australia.

We may assume that about 6/10 of the actual average rainfall is available for storage, as a certain amount sinks into the ground—the exact amount, as has already been stated, varying with the rapidity of the rainfall, the compactness or porosity of the soil, the steepness or flatness of the ground, the nature and quantity of vegetation upon it, and the existence or otherwise of artificial drains. A certain amount also is lost by evaporation, the degree of which depends much on the temperature of the air and its dryness and rate of movement.

The following data in connection with rainfall may be of use to the Inspector to remember :—

(1) That one inch of rain represents about 101 tons of water per acre, *i.e.*, about 4·67 gallons per square yard.

(2) The following formula may be used to calculate the amount of water given by rain, when the amount of rainfall and the area of the collecting surface are known :—

$$\frac{\text{Area in square feet} \times 144 \times \text{rainfall in inches}}{1{,}728} = \text{cubic feet}$$

and one cubic foot of water=6·23 gallons.

In calculating the receiving surface of the roof of a house, we need not take into account the slope of the roof but merely ascertain the area of the flat space actually covered by the roof.

(*a*) Area of roof in square feet × ½ rainfall in inches=gallons per year. Or

Inches of rainfall × 2,323,200=c.ft. per square mile.
" × 14½=million gallons per square mile.
" × 3,630=c.ft. per acre.

1 gall.=0·16 c.ft.=10 lbs.

(*b*) area of roof in square feet ×rainfall in feet=cubic feet of water,

e.g.—roof space 55 square feet per head,
rainfall 27 inches =2¼ feet,
then 55 × 2¼=124 cubic feet,
deduct 25 for evaporation=99 cubic feet,
and 99 × 6·23=gallons 6·17 per head per year.

SURFACE WATERS—RIVERS, STREAMS AND LAKES.

Rain falling on hills and cultivated and uncultivated lands in part goes to form lakes and rivers. As a rule surface water contains more dissolved matter than rain water. It is soft and the organic matters present are chiefly of vegetable origin. The chlorine present is low in amount; ammonia, nitrates and nitrites are generally absent except in such quantities as may be found in rain water, but if the surface water has come from cultivated lands which have been manured, then nitrates and nitrites may be present in considerable amounts. So also chlorides, if men or animals live on the collecting area.

Moorland waters may contain much peaty matter, sometimes in sufficient amount to cause Diarrhœa in the consumers; moreover, due probably to the presence of certain acids, such water may give rise to lead poisoning if the distributing pipes are of that metal.

If the surface water has passed over calcareous soil, it may possess a considerable degree of hardness. As a general rule, upland surface waters are good and safe to drink and good for trade purposes.

River waters are derived in part from springs, in part from subsoil water and in part from surface waters. Snow, ice and floods influence rivers greatly.

The dissolved solids vary less than in spring water. They rarely exceed 30 to 40 parts per 100,000. As the water is derived from so many different sources, it is easy to understand that the different rivers vary in composition very greatly and the same river even, in the various portions of its route. This depends largely on the tributaries, which may arise in areas of vastly different geological formations to the main stream. The dissolved organic matter is greater than in spring water, due to the influence of the surface water contribution; this may come from cultivated manured lands or from farmsteads, etc. Also in times of flood, much impurity of both animal and vegetable origin may gain access to the river. Further, when a river passes through a more or less thickly populated area, it receives a great amount of pollution from household refuse and from factories, etc. Mining operations, especially lead mines, are often the source of much pollution.

In the tropics where rivers frequently become completely or partially dried up during the dry season, there is a great risk of the bed of the stream becoming very foul from human and animal excrement and from the refuse matter of villages on its banks.

In India and certain other countries, where sacred cities are to be found on the banks of certain rivers, there is an added risk in drinking water derived from such a source, owing to the custom prevalent amongst the people, of bathing in vast crowds in the river, and rinsing their mouths with the same water in which their ablutions are performed, while others go the length of drinking the same water. Very large numbers of pilgrims annually frequent these places and, as Cholera is a most usual accompaniment of any gathering of people in India and the East in general, it is not difficult to understand that Cholera may be readily disseminated by such practices. Examples of this are seen annually at Nasik and Pandharpur resulting in the subsequent infection of Bombay.

Generally speaking, the water of a river in the lower part of its course is less hard and more saline than the water of its upper tributaries, because the chalk held in solution by CO_2 is deposited owing to the CO_2 escaping into the air in the course of the river's flow.

Whether rivers are capable of self-purification has been the source of much controversy and the subject of many experiments. The evidence on the whole appears to favour the idea that they are.

The various agencies advanced to account for their purification include subsidence, dilution, growth of vegetation, oxidation, sunlight, natural water bacteria, and infusoria. The relative degree of activity of each element has not yet been satisfactorily ascertained but sunlight is unquestionably a very powerful factor.

River water contains:—

1. Suspended matters of mineral, vegetable and animal origin. 2. Dissolved gases—nitrogen, carbon dioxide, and sometimes sulphuretted hydrogen. 3. Dissolved solids—lime, magnesia, soda and potash, iron and aluminium in combination with chlorine, sulphuric, carbonic, phosphoric, nitrous and nitric acids.

The following is a very rough method of estimating the yield of a stream:—Take a part of the stream where the channel is more or less uniform in breadth and depth. Find the average breadth and depth in four or five places. Find the mean velocity of the stream in feet per second; this is usually about $\frac{4}{5}$ the surface velocity and is ascertained by noting the length of time taken by a float in mid-stream to traverse a given length of the river. Now multiply the sectional area by the mean velocity and the result is the flow in cubic feet per second; and cubic feet $\times 6 \cdot 23 =$ gallons of water.

Lake water is water which, owing to the configuration of the country-side, has accumulated in such quantities as to form a considerable collection. *Springs* may also contribute a share in their formation. The water is usually soft and free from animal impurities but may contain vegetable organic matter.

SUB-SOIL WATERS—(1) SPRINGS AND (2) WELLS.

(1) Springs or outflows of water from the earth are of two kinds:—(*a*) *Land Springs* are formed by the percolation of water through superficial porous soils such as sand, gravel or

alluvial earth overlying an impervious stratum such as clay. If, when these two strata (the pervious and the impervious) come to the surface, the line of junction be tapped, a land spring is formed, as the impervious stratum below throws out the water from the pervious stratum above by hindering its further descent and causing it to flow out laterally. Such springs are usually found on the face of slopes; they are uncertain and precarious as a source of water supply, as their output depends on the extent of the available porous collecting area. They are replenished by heavy showers which do not appear to affect deeper springs and wells; in consequence, they are liable to become dry in prolonged dry periods. If the porous layer in one particular spot is situated too deep, a pocket may form and the level of the water in the pocket sink below the level of the outcrop in periods of drought and the spring cease to yield until a prolonged rainfall occurs.

(*b*) *Deep Springs* are those in which the source is the rain water percolating through great thicknesses of porous rock overlying an impervious stratum; the presence of some fissure or fault in the overlying stratum permits of the water below it rising to the surface. Frequently, the actual collecting area is at some distance from the spring itself. Such springs are met with in chalk and greensand. As the water has generally been well filtered, it is usually of great purity if surface drainage is excluded. The water is sparkling and palatable. They are preferable to land springs on account of their greater constancy and less liability to pollution. The character varies with the source. Water from Devonian rock, mountain limestone, new red sandstone and chalk may be too hard for domestic purposes.

(2) Wells are of two main varieties, shallow and deep. The distinction between them is differently interpreted by different people. Some term any well over 50 feet deep as a deep well, irrespective of the strata through which it is sunk,

while others restrict the term to those wells only which pass through some impervious stratum to a water-bearing layer beneath. This latter definition is the more generally accepted one.

SHALLOW WELLS.

A superficial or shallow well is a well which derives its water from a permeable stratum overlying an impermeable one, but not in itself overlaid by such. The water from such a source is always more or less suspicious and in many cases distinctly bad. For convenience wells are often sunk in the immediate vicinity of habitations, stables, etc. In Bombay City there are some thousands of wells sunk in the ground floor of houses.

There are many sources of possible contamination, under the circumstances, usually associated with superficial wells, *e.g.*, the ordinary impurities of the soil of towns, leaking drains, cesspits and cesspools, middens, neglected basket privies, manure heaps of stables, pig styes, burial grounds, decaying vegetable and animal matter. The habit of performing personal ablutions and of cleansing garments at the mouth of insufficiently protected wells is also a source of risk.

As the rain water penetrates the ground, it tends to descend until, sooner or later, it meets an impervious stratum which arrests its downward movement and tends to divert it laterally, and as the sub-soil water steadily moves in the direction of its natural outflow depending on fall of the stratum in question, the location of any cesspool, stable, burial ground, etc., above the well must naturally lead to contamination of the latter, depending of course on the distance away and on the amount of demand made on the well and porosity of the soil in question. Another frequent source of possible contamination is the custom of using private vessels to withdraw water from a well; with an ignorant and careless people much pollution may thus be introduced.

The *Koas* system of drawing water from a well also leads to contamination of the water, owing to the amount of dirt which must necessarily adhere to the rope as the bullocks walk backwards up the incline leading to the well.

Again, the custom of planting trees in such a position as to overhang wells results in pollution of the water by decaying vegetable and animal matter, birds, etc.

The organic matter found in superficial well water is generally of animal origin. Water which has soaked through sand and gravel may be impure from contained ammonia, chlorides, nitrates and nitrites.

It must always be remembered that the source of pollution may be situated at some considerable distance from the well or spring. Leaking cesspools, manure steads, etc., may through faults in the strata, etc., discharge a portion of the contents into a well far away. There are various methods of detecting any suspected source such as this. Chemical substances are introduced at the suspected source and their presence in the well water is subsequently looked for, after having taken the precaution of ascertaining that none of these substances existed in the water prior to the experiment. Lithium, chloride, flourescin and common salt are the substances most usually employed. The presence of lithium in the well water is ascertained by the spectroscope, that of salt by the silver nitrate test, and that of fluorescin by the fact that this substance gives a green fluorescence in the presence of an alkali. Dr. Beam of the Gordon College, Khartoum, has introduced a very delicate test for the slightest trace of this substance. He found that the concentrated water of the Nile was too highly coloured to permit of accurate observation under the method usually employed. His method is as follows :—Evaporate one or two litres of the water to small bulk and add a few drops of caustic soda and then over a water bath continue the evaporation to dryness. Now add 5 to 10 c. c. of strong alcohol and heat the dish bringing the alcohol into contact with all parts of the water residue. The liquid is now passed through a small filter. In the absence of fluorescin, the alcohol remains perfectly colourless, but if this substance is present, a distinct fluorescence is imparted. McCrae and Stock, experimenting in South Africa, placed fluorescin in the suspected area of contamination and pumped the neighbouring wells. They prefer a dark background to detect the fluorescence. They noted that the water required to be concentrated before the test is successful; further, that the addition of an alkali is essential, as the characteristic fluorescence is not seen in acid solution. The green colouration sometimes produced by iron must not be mistaken for that of fluorescin.

Instead of chemicals, occasionally comparatively harmless species of bacteria are introduced for the same purpose, *e.g.*, the bacillus prodigiosus, and its presence is subsequently sought for in the well or spring water.

A well drains an area like an inverted cone, the radius of which is equal to at least 4 times the depth of the well. If the well be too much drawn upon by pumping, then this area of drainage is greatly increased, thereby adding to the risk of tapping some source of contamination such as a cesspool, manure stead, etc., situated some considerable distance away.

A sudden rise of ground water may cause direct communication between a shallow well and a cesspool not previously tapped.

In peaty districts, the water from such a well may be brown due to vegetable matter.

To very roughly estimate the yield from a well, empty the well and allow it to re-fill noting the time taken. Let the well represent a cylinder. The cubic contents of a cylinder are found by multiplying the area of the base by the height. The area of the base $= D^2 \times \cdot 7854$. This gives cubic feet and cubic feet multiplied by $6 \cdot 23 =$ gallons.

By this means one can roughly estimate how many gallons will be available in a given time.

PRECAUTIONS TO BE TAKEN IN REGARD TO SUPERFICIAL WELLS.

The well should not be closer to a drain than 4 feet for every foot in depth of the well, *i.e.*, a 25-feet well should be 100 feet at least away from any possible source of contamination. A well should be 200 feet from any cesspool or cemetery.

The ground for a radius of 30 feet round the mouth of the well should be cemented, or paved with stone slabs set in cement, with a proper slope leading away from the well, and adequate provision must be made for carrying away any waste or surplus water falling on this surface, so as to prevent the water gaining access to the well and also to prevent the breeding of mosquitoes owing to the accumulation of stagnant water in the vicinity of the well. The actual edge of the well must be protected by coping stones at least 2½ feet high to prevent access of surface water to the well. No private vessels should be used for abstracting water and, where the water is for domestic use, it should not be withdrawn from the well by the usual village practice of employing oxen (*Moat* or *Koas*).

Trees should not be allowed to overhang a well or to be so near as to permit the leaves falling in.

The mouth of the well ought if possible to be closed, not only to prevent the entrance of dirt, or dirty vessels, but also to obviate the risk of mosquitoes breeding therein. By far the best measure is to permanently close the well by a concrete covering, leaving only a small trap door for purposes of inspection and cleansing (which door should under ordinary circumstances be kept locked), the water being drawn by means of a pump.

The well should be lined either with bricks set in cement, with a backing of puddle, or with earthenware tubes or cement or iron cylinders, to prevent the entrance of water except from the bottom or near it.

Moreover, behind the cement or brickwork lining, there should be a layer of puddled clay as an additional precaution.

In villages, etc., if possible, all shallow wells should be surrounded by an acre of uncultivated and uninhabited land, no privy or cesspool being allowed within this area.

Koch, recognising the danger of superficial wells in times of epidemics, strongly advised that existing shallow wells be converted into tube wells. He proposed the following method of conversion. The well to the level of high water mark should be filled in with pebbles and gravel, and above this, and reaching right to the top, should be placed sand. To obtain the water, an iron pipe must be placed in the well extending down through the sand and gravel to the bottom. This tube is connected to a pump. By this means Koch claims that much danger from Cholera can be obviated.

As a general rule, the site selected for a surface well ought to be as far removed as possible from all sources of contamination, and in a direction opposite to the natural course of the subsoil water, so as to tap it prior to its reaching any source of contamination present in the village.

DEEP WELLS.

As already mentioned, the term refers more to the fact that the well is sunk through one or more impervious strata rather than to any measure of its actual depth in feet. The water obtained is generally pure and free from organic impurities, provided proper measures are taken to render the upper portion impervious and to prevent the entrance of superficial water. The water varies in composition according to the strata it passes through.

In chalk the water is clear, sparkling, and wholesome. It contains calcium carbonate and carbon dioxide. In limestone and magnesium limestone it is good; it however contains more calcium and magnesium sulphate than that from chalk.

From granite, metamorphic and trap rock it is very pure. It contains some sodium chloride and carbonate and but little lime and magnesia.

From millstone grit and hard oolite the water is very pure, the salines present being chiefly calcium and magnesium sulphate and carbonate.

The term *artesian well* is applied by some to deep wells passing through an impervious stratum into a pervious and water bearing layer; by others the name is reserved for those deep wells from which water actually overflows.

The temperature in deep wells increases about 1°F. for every 55 feet in depth below 60 feet, at which depth it is fairly uniform at 50° F. Deep wells should be lined with bricks, stone, steel, socketed wrought iron or steel pipes to a point at least lower than the lowest water level. If with bricks, they should be hard, well shaped, and well burnt and laid in good hydraulic mortar. To exclude land and other springs, etc., concrete or clay puddle must be introduced behind this steining. The sides of the well should be steined as far down as the top of the impermeable layer.

To increase the yield from a well already executed, one or other of the following measures is usually adopted :—

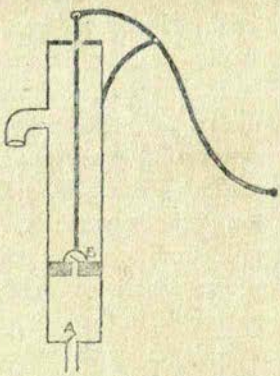
(1) Lower the water level in the well by pumping, whereby the hydraulic depth for the inflow is increased.
(2) The bore hole may be deepened.
(3) Headings may be driven laterally from the well.

ABYSSINIAN OR TUBE WELLS.

These consist of a hollow iron tube, of a diameter varying between $1\frac{3}{4}$ and 3 inches, which at its lower end, has a steel pointed projection for the purpose of boring. The tubes are driven into the ground by heavy iron weights suspended on a pulley. The lower portion of the tube is perforated to admit of the entrance of water. A tube is driven in until a water bearing stratum is reached and if necessary successive lengths of pipe are attached to the original. The water is derived from the stratum direct. Such wells are useful when the superficial supplies are known to be polluted. When a water bearing stratum is reached, a pump is attached.

The insertion here of a few notes on the general principles of action and construction of various types of pumps may be of interest.

There are two types of pumps—the suction or atmospheric and the force pump. The former answers the purpose well, so long as the distance the water has to be raised does not exceed 25 feet.



The suction pump, or atmospheric or lifting pump, consists of a cylinder called the barrel, with a valve A, in which works a piston or box in which is another valve B. Both valves open upwards. The piston is attached to a rod which is worked by a handle. When this is raised, the piston is depressed. The valve B then opens upwards allowing the water or air below it to escape into the upper part of the cylinder. When the piston is raised, the valve in it closes and the water above the valve is lifted up and discharged through the spout. The water from below, owing to atmospheric pressure on its surface, lifts the valve at A and rushes up to fill the vacuum caused by raising the piston. When the piston is again depressed, the same process is again repeated. If the valves are very dry, a little oil should be poured on them. A small quantity of water poured on the piston before commencing to work makes it air-tight. This form of suction pump is frequently used in shallow wells. It is suitable for hand power only. The surface of the water to be raised should not be more than 25 feet below the moveable valve. Where the water level fluctuates, care must be taken to measure from the lowest level reached during those fluctuations. Especially for small pumps, the suction pipe should fall all the way from the pump to the supply well, as any upward bend in the suction pipe introduces an air trap and may seriously interfere with the power of the pump.

THE SINGLE ACTION FORCE PUMP.

This pump is used to force water up to the top of high buildings, &c. In this pump the piston is made without a valve. The pipe for delivering water is at the bottom of the pump. It has a valve C which opens upwards so as to prevent the return of the water in the delivery pipe. At the bottom of the cylinder is a valve B opening upwards. When the piston is raised, valve B opens and the water rushes into the cylinder; when, however, the piston descends, valve B closes and valve C opens and the water is thus forced up the delivery pipe. In this pump the force is required for the down stroke. The top of the cylinder need not be closed, as a little water poured in above the piston renders it air-tight. Sometimes a solid plunger is substituted for the piston to avoid the expense of turning the cylinder true and also because it resists the wear from dirt and grease better. At each stroke it raises a volume of water equal to that of the plunger.