

The production of public supply drinking water from Rutland Water at the Wing Treatment Works

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Abstract

The paper describes the treatment facilities and processes at the Wing Works where Rutland water is treated to potable standards. It summarises the experience gained in the operation of the works since it opened in 1977 and includes a brief account of an investigation into the production of haloforms.

Introduction

The Wing Treatment Works forms part of the joint Empingham project initiated by the Welland and Nene River Authority and the Mid-Northants Water Board. It was designed and constructed by Degremont Laing Ltd. and was commissioned in June 1977. The finished water is supplied to the Northampton and Peterborough Water Divisions of the Anglian Water Authority and to the Soar Division of the Severn Trent Water Authority. The works is designed for an average output of $205 \times 10^3 \text{ m}^3 \text{ day}^{-1}$ with a peak output of $285 \times 10^3 \text{ m}^3 \text{ day}^{-1}$.

Source of water

Water is taken from Rutland Water via a pumping station at Empingham for treatment to potable standards at the Wing works which is situated on high ground some 7.6 km to the south west of Empingham. The water in the reservoir consists of water from the natural catchment (principally the flow in the river Gwash) plus water pumped from the River Nene at Wansford and the River Welland at Tinwell.

Since the first filling in 1976/77, the proportions

of Gwash, Nene and Welland water have been about equal. As the works output increases more Welland and Nene water will be pumped, the latter predominating. Chemical and bacteriological samples of the three component waters from the rivers Welland, Nene and Gwash were examined from 1964 onwards. Prolonged reservoir storage was expected to produce improvements in the chemical, physical and bacteriological characteristics of the river waters but the extent of these changes could not be predicted with certainty. There was also the possibility that raw water might, on rare occasions, have to be drawn direct from the river intakes, e.g. in the event of repairs to or inspection of the valve tower or associated pipework.

Description of the works

A plan showing the block layout of the works with water and chemical flows is given in Fig. 1.

Primary clarification

Three Degremont Pulsator Clarifiers are provided for this process (Figs. 1 and 2). Each pulsator has a three-compartment inlet chamber. Water emerges from the raw water pumping main into the

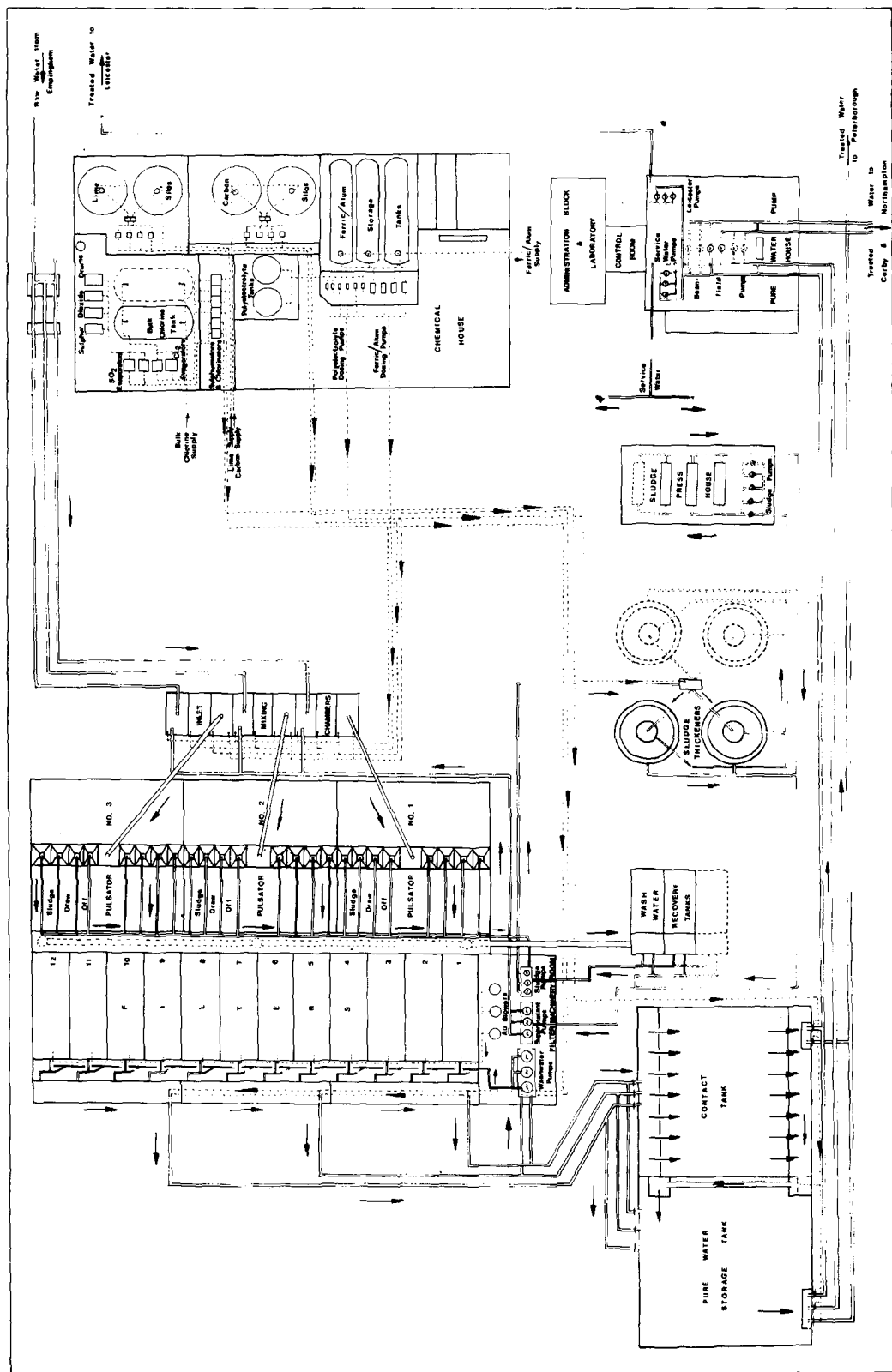


Fig. 1. Plan showing the block layout of the Wing Treatment Works.

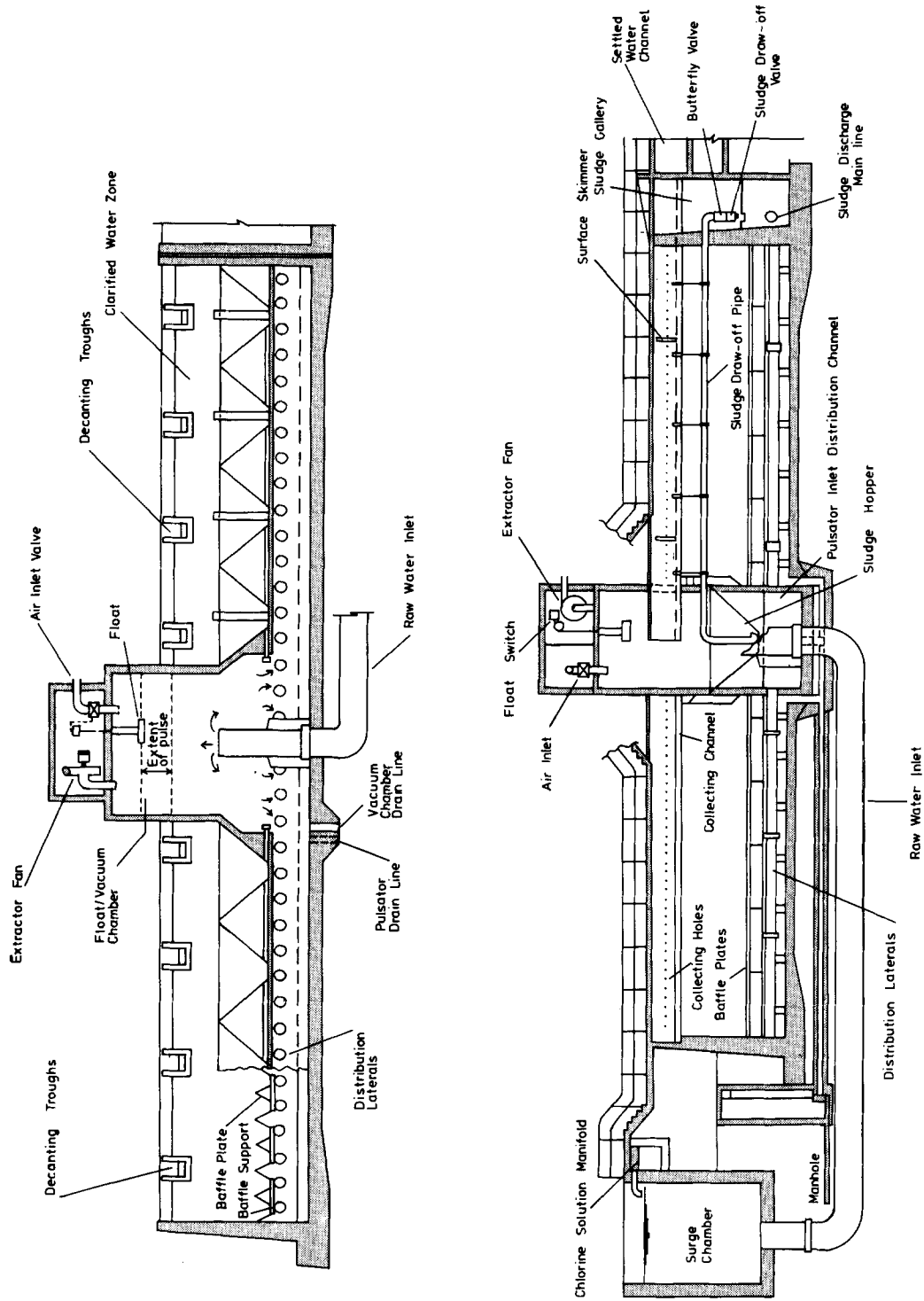


Fig. 2. Cross-sections of the Degremont pulsator units.

first compartment and passes underneath a curtain wall into the second compartment where it is vigorously stirred. After passing over a weir into the third compartment the water enters a 1050 mm diameter pipe and flows to the centre structure of the pulsator. An important function of the inlet chamber unit is the thorough mixing-in of the chemical doses which are applied as follows:

a) First chamber, a marginal dose of chlorine. (This is normally set to give a total chlorine residual of 0.5 mg l^{-1} at the pulsator outlets.)

b) Second (stirrer) chamber. Doses of ferric sulphate and lime.

c) Third chamber. The activated carbon dose and the polyelectrolyte dose.

The pulsator is basically a rectangular tank in which water is introduced near to the bottom and decanted off into troughs at the top. To obtain an equal vertical flow through unit area at all places within the tank the incoming water has to be introduced evenly over the bottom. This is achieved by a system of 400 mm diameter lateral pipes set into and on each side of a broad rectangular sectioned culvert which runs along the middle of the floor of the tank. The laterals, spaced at 1.025 m intervals, have numerous 30 mm diameter holes along the underside and the ends furthest from the culvert are closed.

The incoming water having been dosed with a coagulant, a sludge blanket eventually forms in the lower part of the pulsator, building up to the level of the sludge concentrator hoppers which are situated on top of the inlet culvert. Excess sludge discharges over the edges of the eight sludge hoppers and falls to the bottom where, being in a still-water zone, it concentrates. The sludge is periodically drawn off via the sludge discharge pipework. Although water enters at constant flow, the action of the vacuum chamber and fan at the centre of the pulsator imposes a pulsating effect on the flow of water into the bottom of the tank. The water level in the vacuum chamber rises as air is sucked out by the fan. When it reaches a predetermined height, a valve opens allowing air to enter the chamber and causes the water level to fall rapidly. The valve closes when the water level has fallen to that of the water outside and the next cycle commences as the fan once again begins to extract air.

The downward part of the cycle usually takes about 8 seconds but the time taken for the water

level to rise can be varied, as also can the amplitude of the pulse. The upward pulse typically takes about 40 seconds and the maximum rise in water level is about 0.65 m. The pulse helps to maintain the blanket in a homogeneous condition and prevents the channelling of water through it. On each downward pulse excess sludge is eased over the edges of the sludge hoppers. Average rise rates for normal and peak flows are given below. They indicate the effect of having one pulsator out of use at normal flow rate.

Total plant flow $10^3 \text{ m}^3 \text{ day}^{-1}$	Rise rates m h^{-1}			
	3 pulsators		2 pulsators	
	Blanket	Clarified	Blanket	Clarified
Normal 205	2.82	2.50	4.23	3.74
Peak 285	3.92	3.47	—	—

The highest rise rates likely to be encountered are therefore not at peak load but at normal load if one pulsator is out of use. The settled water decants into launders which run at right angles to and discharge into a common filter inlet channel which runs the whole length of the twelve filters.

Pulsator operation

The maximum design treatment capacity for one pulsator is $95 \times 10^3 \text{ m}^3 \text{ day}^{-1}$ and the present chemical dosing maximum allows for $68 \times 10^3 \text{ m}^3 \text{ day}^{-1}$ per stream. During plant trials at Wing however, the pulsators were operated for short periods at their maximum hydraulic design of $114 \times 10^3 \text{ m}^3 \text{ day}^{-1}$ and with necessary adjustment to chemical dosing plant, continued to produce an acceptable clarified water, using either aluminium sulphate or ferric sulphate as the primary coagulant. Chemical control of the pulsator depends on information from a number of sources; raw and clarified water analyses, laboratory jar tests and condition of the sludge blanket. Degremont recommend three tests for controlling the production and maintenance of a stable sludge blanket. Firstly, laboratory jar tests to determine optimum coagulant doses. Secondly, a

settlement test using sludge samples drawn from the top and bottom portions of the pulsator blanket, the results being used for regulation of the pulse. Thirdly, a sludge cohesion test (Test No. 705, Degremont Laing Water Treatment Handbook) the result of which indicates blanket condition and serves as a check for optimum coagulant and polyelectrolyte doses and pulse operation.

It has been found that laboratory jar tests using a normal bench stirrer/flocculator give a good indication of the optimum coagulant dose but not of the optimum polyelectrolyte dose.

A sludge settlement test is recommended for pulse regulation, when the settled volumes of samples from the top and bottom of the blanket should be within 5% of each other after a 10 minute settlement period.

The sludge cohesion test depends upon the fact that a layer of sludge subjected to a rising current of water expands to an apparent volume related to the velocity of the water, and the cohesion of the sludge. The numerical expression of this relationship is known as the sludge cohesion coefficient, and may vary from 0.3 in a very fragile flocculate to over 1.0 for a well constituted sludge blanket. For optimum pulsator operation, a figure of 0.8 to 1.0 is desirable.

An opportunity to assess the practical effects of the pulsing action was afforded when the extractor fan on one pulsator was out of action for repairs; the other pulsator was working normally and the chemical doses were the same to both clarifiers. It was found that the settling characteristics of the two sludges were very similar even after five days and the 10-minute settled volumes were all within 5% of each other. The blanket condition in the non-pulsed clarifier was however markedly worse than in the other with fissuring visible at the blanket surface. The clarified water was also worse, turbidity and iron levels rising from 1.2 to 2.4 F.T.U. and 0.74 mg l^{-1} to 1.1 mg l^{-1} respectively. The sludge cohesion coefficient for the pulsator in normal operation was 0.75 whereas the value was 0.39 in the unpulsed blanket.

Filtration

There are twelve Degremont 'V' type rapid gravity filters (Figs. 1 and 3). The main items of filter data are as follows.

Bed size (2 No. per filter): $14.0 \times 3.5 \text{ m}$

Filtration area per filter: 98 m^2

Number of nozzles per filter: 5292; spacing $130 \times 143 \text{ mm}$

Filtration media: Gravel, sizing 6–10 mm; depth 50 mm

Sand, effective size 0.95 mm; uniformity coefficient 1.5; depth 1.2 m.

Normal filtration rate ($205 \times 10^3 \text{ m}^3 \text{ day}^{-1}$, 12 filters working) 7.3 m h^{-1}

Maximum filtration rate ($285 \times 10^3 \text{ m}^3 \text{ day}^{-1}$, 11 filters working) 11.0 m h^{-1}

Duration of filter run: 36 h

Maximum head loss: 2 m

Depth of water over sand during run: 1.22 m

Backwash cycle

Maximum draindown discharge volume: 69 m^3

Backwash water flow $1470 \text{ m}^3 \text{ h}^{-1}$ 12 min duration: 294 m^3

Crosswash water flow $698 \text{ m}^3 \text{ h}^{-1}$ 5 min duration: 58 m^3

Typical water per wash: 421 m^3

For the first 6 minutes of the backwash there is a simultaneous application of the air scour, the air flow being at the rate of $5390 \text{ m}^3 \text{ h}^{-1}$. The air scour then ceases and the crosswash begins and continues for the remainder of the filter wash. The backwash times given above are typical for normal conditions but can be extended to suit more extreme conditions.

Principal features

(i) The sand grading is relatively coarse compared to conventional 16/30 filter sand. (The effective size of the Degremont sand is 0.95 mm compared to about 0.5 mm for the 16/30 sand.) Messrs. Degremont maintain that for filtration rates between 5 and 10 m h^{-1} there is no appreciable difference in filtrate turbidity for sands between 0.5 and 1 mm effective grain size. The coarser media however allows greater flow per unit area for a given head loss. There is also more opportunity for the removed solids to penetrate into the bed, so utilising the available pore space more effectively and preventing the filter from merely acting as a sieve with consequent surface blocking and rapid rise of head loss.

(ii) The depth of sand, 1.2 m, is greater than in previous rapid gravity filter design. This is rendered possible, without incurring unacceptable head loss,

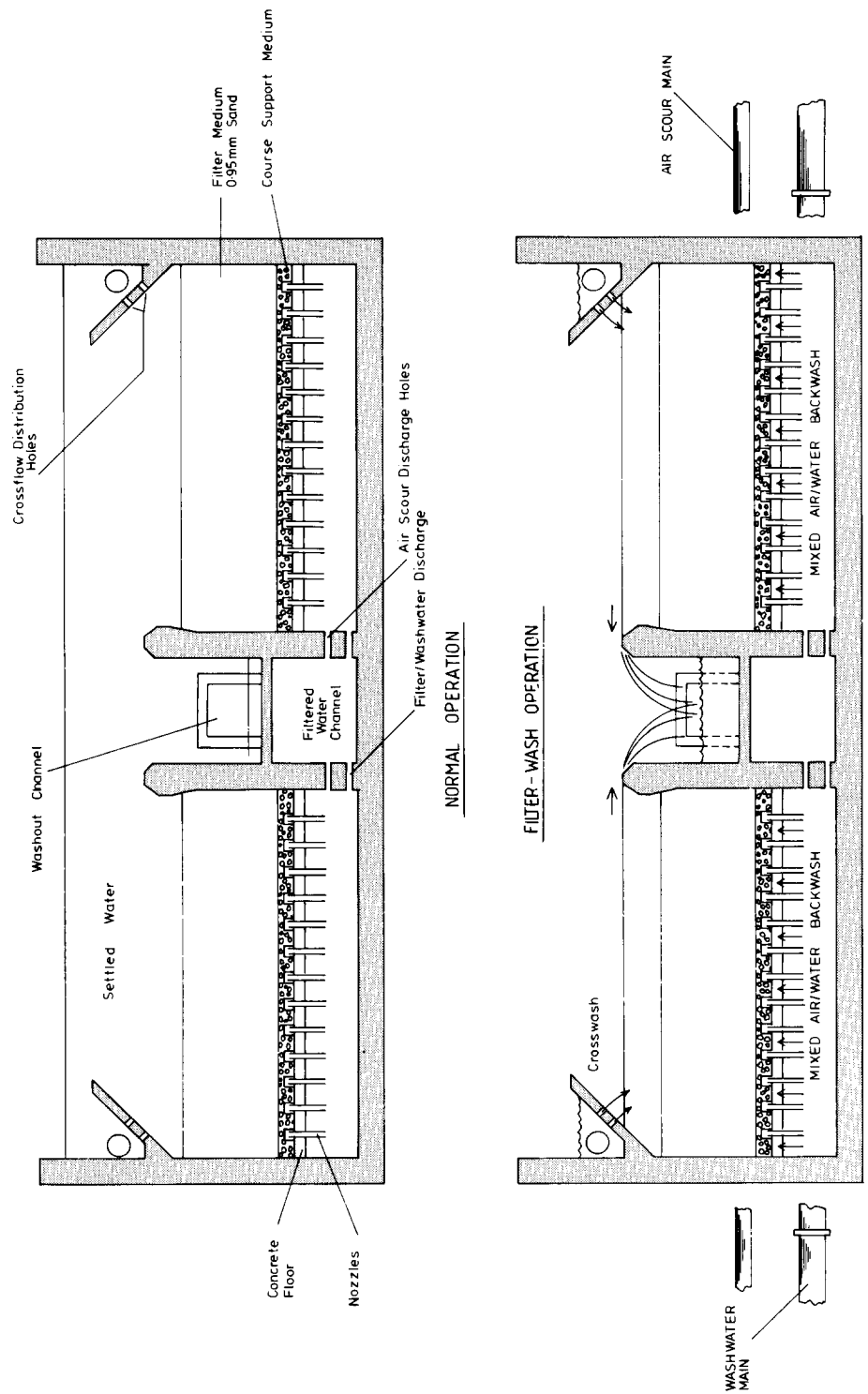


Fig. 3. Cross-section of the Degremont 'Aquazur' filters.

because of the coarser sand. However, it is also rendered desirable because the smaller filtration area would otherwise reduce the total volume of the bed and therefore its dirt holding capacity.

(iii) Washwater requirements are kept to a minimum by the use of a simultaneous air scour and backwash during the first part of the filter washing sequence. This technique also prevents the migration of dirt to the base of the filter and the formation of mud-balls in the sand.

The economy in clean washwater does however mean that an efficient crosswash is needed during the second part of the wash sequence, when the air has stopped, to convey the released dirt across the surface of the filter to the washwater discharge channel. This is achieved by allowing settled water to flow into the perforated V shaped channels running along each long side of the filter.

(iv) The sand-bed is not expanded during backwashing. The simultaneous air scour and water-wash is very efficient and renders bed expansion unnecessary.

(v) Filter outlet control. The dual requirement of maintaining a constant depth of water on top of the filter sand and an equal flow of water through each filter irrespective of head loss is achieved as follows. The water level in the filter inlet channel is measured and compared electrically with a value selected so as to maintain the correct depth of water over the sand in the filters. Any error between these two values is used to adjust electrically the set point of the individual filter outlet valve controllers. The latter receive a signal proportional to the individual filter flow and any error between the set point and the filter flow value is used to open or close the outlet valve.

(vi) The filtered water collecting channel is divided into three sections, the outlets of four filters discharging into each section. Three 1067 mm diameter mains convey the filtrates from each section to the contact tank. (Fig. 1). The post filtration chlorine is dosed separately into each section of the filtered water channel.

Contact and storage

The contact and storage tanks (Fig. 1) lie side by side and are of equal size, 11 000 m³. The contact tank gives a contact time of approximately one hour at 284×10^3 m³ day⁻¹ flow. Short circuiting effects are minimised by the provision of a screen

wall at each end of the tank. The walls are perforated by 22 No. 470 mm diameter holes over each of which is fitted a mushroom-shaped baffle. At the outlet end of the contact tank, the water receives a dose of sulphur dioxide for chlorine residual correction and then passes over a weir into a 2 m diameter pipe which conveys the water into the north end of the storage tank.

Chemical dosing

Electrical signals in the range 4 to 20 mA are generated proportional to the following flow measurements (4 mA corresponds to zero flow).

- (i) The raw water flow to each pulsator.
- (ii) The flow from each filter outlet.

Summated signals are also produced proportional to the total water flow to the pulsators and to the total filtered water flow.

The above signals are used as the basis of control for much of the chemical dosing and for filter outlet control.

a) *Chlorine dosing.* Storage arrangements for chlorine at the works consist of a single tank bulk storage installation of 30 tonne capacity. A pre-sedimentation chlorine dose sufficient to maintain a total chlorine residual of approximately 0.5 mg l⁻¹ in the clarified water is added to the raw water in the inlet mixing chambers. This dose is normally between 2.5 and 3.5 mg l⁻¹, but may be greater at times when activated carbon is being dosed for odour control. A post filtration chlorine dose normally about 1 mg l⁻¹, sufficient to maintain a free chlorine residual of 0.8 mg l⁻¹ at the end of the contact period, is added to each filtered water stream. The raw water chlorine dose is metered by a single chlorinator which responds to the summated milliamp signal proportional to the total raw water flow to maintain a constant dose at all flows. The split of chlorine between the three pulsators is made manually by the adjustment of the three valves which control the flow of chlorine water from the injector.

The post filtration chlorine dose is again metered from a single chlorinator. The latter is controlled overall both by the summated flow signal from all the filter outlets and by a closed-loop control system which compares the free chlorine residual measured after a limited contact period (about 6 minutes but depending on flow) with a

preselected residual level and adjusts the chlorine dose accordingly.

b) Ferric sulphate/aluminium sulphate dosing. These chemicals are stored as the 40% w/w $\text{Fe}_2(\text{SO}_4)_3$ solution and the 8% w/w Al_2O_3 solution respectively. Three rubber lined steel storage tanks each of 31.5 m³ are provided, two being used for the liquid ferric and one for the liquid alum.

The undiluted coagulant solution is metered separately for each pulsator by positive displacement, variable speed and stroke dosing pumps. The speed of each pump is governed by the milliamp signal proportional to the flow in the appropriate pulsator. The stroke of each pump is set manually to obtain the appropriate dose of coagulant (normally 5 to 6 mg l⁻¹ as Fe or about 3 mg l⁻¹ as Al.). The coagulant solution is considerably diluted by 'carrier' water soon after it has been metered and is conveyed to the dosing points in the inlet mixing chambers in the diluted form.

c) Lime dosing. Storage facilities consist of two 20 tonne silos each of which is fitted with a variable speed screw feeder which conveys the lime directly from the bottom of the silo to a 0.30 m³ slurry mixing tank fitted with a propeller type stirrer. Each of the two slurry mixing tanks is gravity fed with water from a side tank fitted with a ball valve. Lime slurry can be fed from either tank to a bank of four variable-speed Mono pumps (three duty plus one standby) which transfer the slurry to the pulsator inlet chambers.

The reaction between the lime and the bicarbonate alkalinity in the make-up water taking place within the pumps and dosing lines resulted in a crystalline-form of calcium carbonate being deposited tenaciously on all surfaces, particularly at points of high turbulence, and build-ups and blockages could not be prevented even by frequent flushing.

Treatment of the make-up water to remove the bicarbonate ions was seen as the answer to the problem although softening by base exchange was ruled out as this would only have replaced the calcium with sodium leaving the bicarbonate unchanged: on contact with an excess of lime precipitation of calcium carbonate would still have occurred. The treatment adopted was to reduce the pH of the lime make-up water to 4.0 with hydrochloric acid and remove the free CO₂ by aeration. The problem of the blocking of lime

dosing lines was effectively solved by the installation of equipment to treat the water passing to the lime mixers in this manner.

The original intention to dose lime slurry to the three filtrate streams for pH correction to pHs + 0.2 was abandoned as it gave rise to unacceptable turbidity in the final water. As ferric sulphate is used as coagulant for most of the time, the lime dose can be applied at the coagulation stage (not so if alum is being used); however it has been found that there is still a need for further pH adjustment upwards at the final water stage. It was therefore decided to install caustic soda dosing for final water pH correction and at the time of writing, this equipment is about to be commissioned. It will be capable of effecting the full pH correction even when alum is being used without the presedimentation lime dose.

The possibility that alum coagulation might be required at times of high raw water pH due to algal activity, necessitating the use of sulphuric acid for downward pH correction, has been given some attention in the works laboratory. Heavy algal blooms were induced by the illumination of 10 l samples of raw water and increases in pH were obtained. The acid doses required to reduce the pH to 7.6 were determined experimentally. It was found that doses increased up to initial pH values of 9.2 but declined at higher pH values. The sulphuric acid dose at pH 9.2 was 49 mg l⁻¹ and at pH 10.2 it was 27 mg l⁻¹. It was found that the alum dose itself was sufficient to further reduce the pH to 7.3, the assumed optimum value for alum coagulation.

The doses of acid indicated by this investigation are high and the conditions which would call for their use have so far not been encountered. Consideration of the acid bulk storage facilities which would be required is therefore in abeyance until a clear need is indicated.

d) Powdered activated carbon. Storage, dosing and dose control facilities for this material are similar to those for lime. The make-up water is not however treated, dosing lines being kept clear by regular flushing and occasional acid dosing.

Powdered activated carbon (P.A.C.) – normally Ness Anthrasorb CC100 – has been dosed at Wing each year since 1977 for taste and odour control. Dosing levels have varied between 5 and 25 mg l⁻¹ and dosing has normally been necessary between May and October but exceptionally up until

December 1980. Raw water and final water Threshold Odour Numbers (T.O.N.) are determined at 40 °C and P.A.C. is dosed to reduce the level of the raw water T.O.N. (which has been as high as 132) to a figure of 8 or less in the final water. It has been our experience that reducing T.O.N. to this level considerably reduces the number of consumer complaints attributable to odour.

e) Polyelectrolyte. Polyelectrolyte can be dosed to the main water treatment stream and to the sludge thickeners, normal doses being 0.01 mg l⁻¹ and 0.2 g kg⁻¹ dry sludge solids respectively. The chemical is made up as a 0.1% solution in 4.8 m³ mixing tanks.

f) Sulphur dioxide. This chemical is used to reduce the residual of chlorine in the water leaving the contact tank. It is controlled by a closed loop residual controller which takes its sample at the point where the water enters the clear water storage tank.

g) Ammonium sulphate. An ammonium sulphate storage, make-up and dosing system is at present being installed in order to convert the portion of the final chlorine residual present as free chlorine into a combined residual to ensure the maintenance of a chlorine residual further into the distribution system.

Wastewater and sludge treatment

Overflows to waste exist at various places in the plant but these are only intended for use in the case of difficulty or emergency and the works is designed so that there is no effluent discharge resulting from any of the treatment processes. The only treatment waste which leaves the site is the pressed ferric hydroxide sludge which is transported to the Pilton tip some 2 km from the works.

The following wastewater and sludge treatment processes are provided.

(i) Washwater recovery. There are two settling tanks, each of 600 m³ capacity, into which the filter wash water is discharged. The volume of washwater from a normal filter wash is about 421 m³, comprising 294 m³ from the washwater pumps, 58 m³ of crosswash water and 69 m³ of draindown water. After 2 hours settlement, the supernatant water is decanted off through a floating arm draw off and gravitates to a sump underneath the filter machinery house. This reclaimed water is then

pumped back to the head of the works. The settled sludge is discharged to a sludge sump from which it is pumped to the inlets of the sludge thickeners.

(ii) Pulsator sludge. The contents of the pulsator sludge hoppers are bled off at intervals and drain to the same sludge sump mentioned in (i) above.

(iii) Sludge conditioning and thickening. This operation is carried out in two cylindrical sludge thickening tanks, each 148 m² in area and 4 m deep with a peripheral clear water decanting trough. The sludge thickeners were designed to produce 6% sludge solids with a loading of 18.5 kg m⁻² day⁻¹. At present, the solids loading is approximately 7 kg m⁻² day⁻¹. The bottom of each tank slopes towards a central sump, towards which the settled sludge is gradually moved by angled scrapers fitted to a slowly rotating diagonal arm.

Polyelectrolyte is added at the inlet to the thickeners at a normal dose of 0.2 g polyelectrolyte (Magnaflow LT25) per kilo of sludge solids. The thickeners operate well at the low solids loadings to give a sludge of 5–6%, and their successful operation depends on the careful regulation of the polymer dose and thickened sludge draw-off rate (and consequently the level of thickened sludge in the thickener) in order to prevent either over-pressing or over-thickening.

(iv) Filter presses. The three filter presses, by Manor Engineering Ltd., have a design filter cake capacity of 5 m³ each. There are 79 plates per press, each measuring 2 × 1.5 m, and the normal thickness of the filter cake is 25 mm. The pumps which transfer the thickened sludge from the thickeners to the presses are specially controlled so as to ensure a steady pressure of 7 bar within the press. The press run is terminated after a predetermined period, usually about 6 hours, and the press is then opened. As the plates are mechanically separated, the filter cake drops into a trailer positioned underneath the press. The filter cake has a solids content of between 25 and 30% (dried at 180 °C) and is disposed of at the Pilton tip about 2 km from the plant. Current daily sludge production is about 8 to 12 tonne day⁻¹ (depending on whether powdered activated carbon is in use), the corresponding dry weight being 2.2 to 3.2 tonne day⁻¹. Sludge production will increase pro rata as the volume of water treated increases.

Table 1. Average analysis of Wing raw and final water 1977-1980.
Units are mg l^{-1} unless otherwise stated

	Raw water			Final water		
	Max.	Min.	Mean	Max.	Min.	Mean
Colour (Hazen)	30	<5	10	12.5	<5	<5
Turbidity (Formazin)	6.5	0.25	1.7	2.3	0.10	0.22
pH	8.8	7.5	8.2	8.3	6.9	7.7
Conductivity ($\mu\text{S cm}^{-1}$ 25 °C)	1040	510	780	1140	520	808
Total dissolved solids	655	399	533	661	402	548
P.V. (4 h, 27 °C mg l^{-1} O)	2.9	1.6	2.1	1.5	0.71	1.1
Ammonia F. & S. (as N)	0.18	0.01	0.03	0.13	<0.01	0.03
Ammonia Albd. (as N)	0.46	0.19	0.30	0.42	0.08	0.20
Nitrite (as N)	0.125	0.001	0.015	0.005	<0.001	<0.001
Nitrate (as N)	9.7	1.1	3.9	9.2	1.4	3.9
Total hardness (as CaCO_3)	372	285	325	392	290	335
Alkalinity (as CaCO_3)	176	116	155	166	100	142
Calcium as Ca	133	101	114	142	102	119
Magnesium as Mg	18.5	4.9	10.9	18.0	4.8	10.6
Sodium as Na	55	32	41	54	32	41
Potassium as K	9.7	5.7	7.9	9.1	5.7	7.9
Phosphate soluble as P	0.125	<0.001	0.039	0.080	<0.001	0.003
Fluoride as F	0.38	0.30	0.36	0.47	0.30	0.39
Chloride as Cl	68	51	59	76	52	63
Sulphate (as SO_4)	177	124	152	188	141	166
Silicate (as SiO_2)	6.0	0.3	1.5	4.0	0.3	1.2
Iron (total)	0.30	<0.01	0.03	0.38	<0.01	0.02
Manganese (total)	0.22	<0.02	0.02	0.08	<0.02	0.02
Aluminium as Al	0.01	<0.01	<0.01	0.10	<0.01	0.04
Zinc as Zn	0.04	<0.02	<0.02	0.05	<0.02	<0.02
Copper as Cu	0.04	<0.02	<0.02	0.11	<0.02	<0.02
Lead as Pb	<0.03	<0.005	*	<0.03	<0.002	*
T.O.C. as C	7.3	5.7	6.3	5.8	4.2	5.2
Chlorophyll 'a' ($\mu\text{g l}^{-1}$)	112	0.7	12.4	-	-	-
Metals:						
Cadmium as Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium as Cr	<0.03	<0.02	*	<0.03	<0.02	*
Cobalt as Co	<0.02	<0.02	<0.02	<0.03	<0.02	*
Mercury as Hg	<0.001	<0.0001	*	<0.001	<0.0001	*
Arsenic as As	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium as Se	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pesticides ($\mu\text{g l}^{-1}$):						
Y.B.H.C.	0.027	0.018	0.021	0.015	0.007	0.011
Dieldrin	<0.005	<0.002	*	<0.005	<0.002	*
Aldrin	<0.002	<0.001	*	<0.002	<0.001	*
Endrin	<0.005	<0.002	*	<0.005	<0.002	*
p.p' D.D.E.	<0.005	<0.002	*	<0.005	<0.002	*
p.p' D.D.T.	<0.010	<0.005	*	<0.010	<0.005	*
Haloforms ($\mu\text{g l}^{-1}$):						
Chloroforms	<0.8	<0.8	<0.8	19	15	17
Dichlorobromomethane	<0.4	<0.4	<0.4	27	20	24
Dibromochloromethane	<0.8	<0.8	<0.8	20	16	18
Tribromomethane	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total haloforms	<4.0	<4.0	<4.0	65	52	58
Polyaromatic hydrocarbons	None detected <40 ng l^{-1} .					

* Different limits of detection in the determinations. None detected in any test.

Plant performance and aspects of treatment

Analytical data

The extensive analytical data which has been obtained on the Wing raw and final waters since treatment began in 1977 is summarised in Table 1.

Those parameters reflecting the efficiency of coagulation and filtration namely colour, turbidity and residual iron have all been low with a very high degree of consistency. Nitrate and sulphate were both fairly high when the reservoir was first filled owing to the severe drought in 1976 and pumping from the River Nene was in fact curtailed as Nene water had both the highest nitrate and sulphate, (Low 1982).

The nitrate level has steadily declined from its initial level of between 9 and 10 mg l⁻¹ N and has now levelled off at between 1 and 2 mg l⁻¹. Sulphate has also eased to lower values as the sulphate content of the pumped river water has fallen. The use of ferric sulphate at current doses of about 5 to 6 mg l⁻¹ as Fe unavoidably increases the sulphate level through treatment by about 14 mg l⁻¹.

At the time of writing, the total hardness of the raw water is about 305 mg l⁻¹. The use of lime in the coagulation process raises the hardness through treatment to about 325 mg l⁻¹.

Examination of raw and final water samples for the six most persistent organochlorine pesticides has revealed minute traces of only one – gamma B.H.C. This compound is routinely found in most lowland surface waters and the concentration found is well below the acceptable level. The figures so far obtained suggest about a 50% removal by the treatment process.

Trihalogenated methanes (haloforms) in Wing water

Attention has recently been focussed on the possibility of trace quantities of haloforms being present in drinking waters. Haloforms can be produced when the chlorine used for disinfection reacts with humic substances in the water. The haloforms most frequently found are chloroform (CHCl₃), dichlorobromomethane (CHCl₂Br), dibromochloromethane (CHBr₂Cl) and bromoform (CHBr₃).

At the time of writing no formal limit for haloforms in drinking water exists in the U.K.; nevertheless it is obviously desirable to minimise

haloform production during and after treatment if this can be achieved without prejudicing the disinfection process. An investigation into haloform formation in the water at various stages of treatment at Wing and in the distribution system is therefore being undertaken, the results obtained to date being illustrated graphically in Figs. 4 to 6. They indicate the following:

(i) Trace quantities of haloforms are produced in the treatment process at Wing. The predominant one is dichlorobromomethane; chloroform and dibromochloromethane are also produced at lower and roughly similar concentration but bromoform has not been detected.

(ii) With the present regime of prechlorination, haloform production within the works is about 90% complete by the end of the clarification process.

(iii) There is evidence of further haloform production in the water after it leaves the works but in much smaller quantity than within the works.

(iv) The use of a monochloramine instead of a free chlorine residual would much reduce haloform production. Commissioning of the ammonium sulphate dosing plant in the near future will ensure that the final water will not contain a free chlorine residual and this should curtail haloform production in the distribution system. However, more work is required to assess the effectiveness of chloramine disinfection within the works before this could be safely adopted as a haloform-limiting measure.

(v) Although no formal limit exists, a tentative guide level of 100 µg l⁻¹ for total haloforms has been suggested. None of the samples examined so far in this investigation has exceeded this level.

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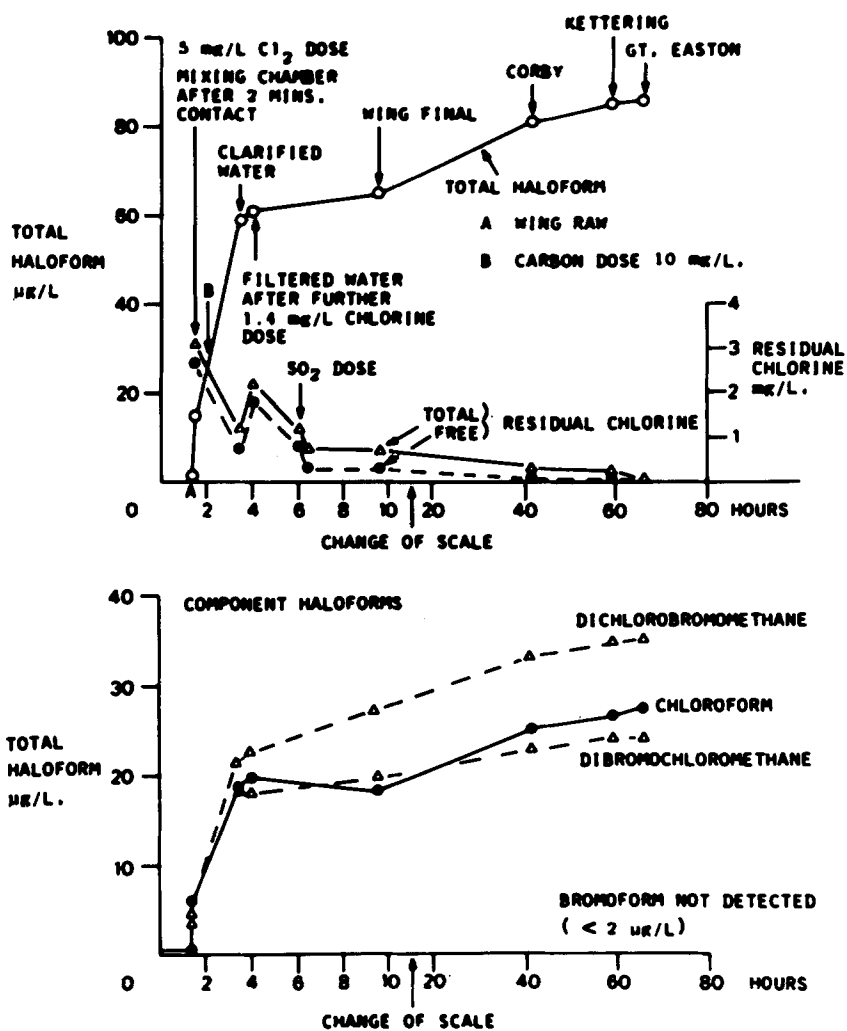


Fig. 4. Total haloform concentration (upper graph) and component haloforms (lower graph) through Wing Treatment Works and distribution.

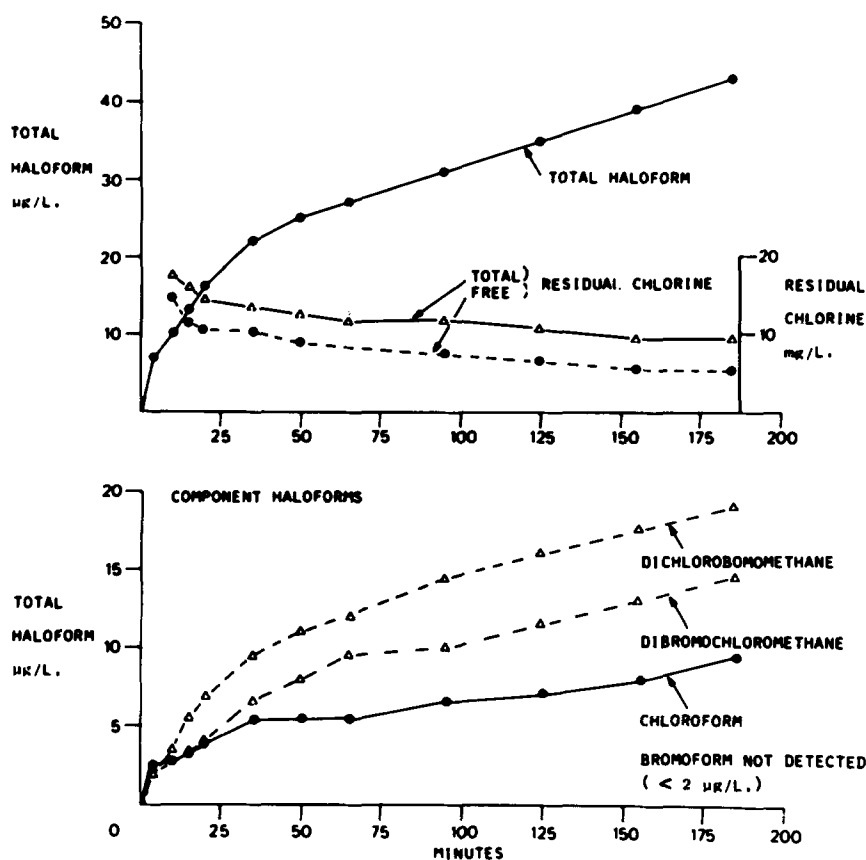


Fig. 5. Total haloform concentrations (upper graph) and component haloforms (lower graph) during pre-chlorination (chlorine dose 3 mg l⁻¹).

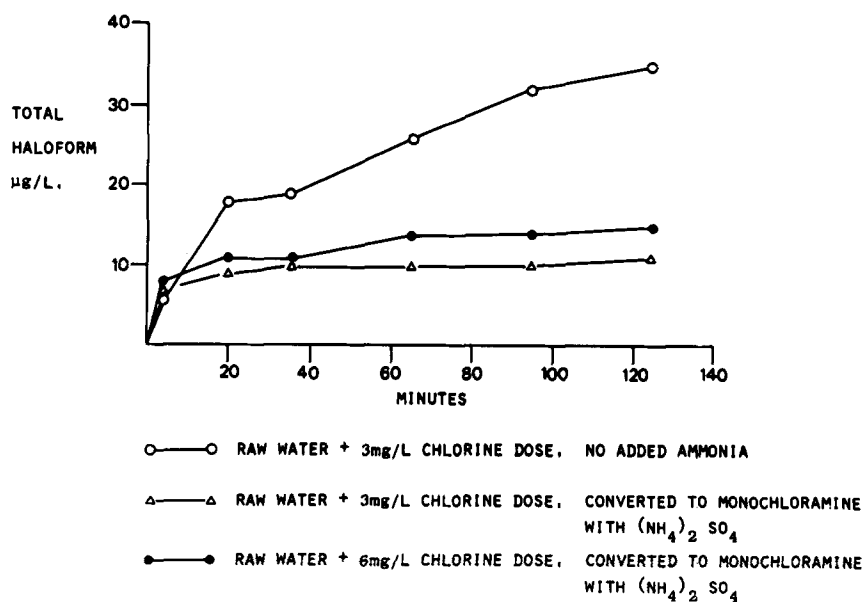


Fig. 6. Comparison of haloform formation during chlorination with free and combined chlorine.

Discussion

Mr. Ford stated that water treatment works were designed with little or no prior knowledge of the chemical or biological problems with which they must cope. He considered that one of the most striking features of the Wing plant was that it had, to date, been able to treat all water drawn from the reservoir without any problems. He drew particular attention to pulsator clarification, and gave details of the major processes involved.

Mr. Robertson then commented on the performance of the plant, drawing particular attention to the consistently good quality of the water (conforming in virtually all respects to W.H.O. European Standards and E.E.C. directives 1980), particularly in those parameters reflecting filtration and coagulation. The only notable departure from standards had been when a filter malfunction caused iron residues to reach 0.36 mg l^{-1} .

Mr. Drage outlined the study of the trihalogenated methanes (haloforms) which appeared following chlorination. Four major factors affected their formation: quantity of chlorine, contact time, occurrence of carbon dosing, and form of chlorine (free or combined). He offered evidence that combined chlorine residuals reduced haloform incidence, but were less effective disinfectants than free chlorine. If control of the formation of haloforms was needed, free chlorine disinfection followed by combination of the residuals seemed a promising solution.

Mr. Gardiner opened the discussion by enquiring why caustic soda treatment had not been preferred to lime in the initial operation of the plant. He went on to ask when pre-treatment at the Empingham off-take would be implemented. Regarding the use of the pulsator, he asked if supernatant water was recycled and what effect this had on operation of the pulsator. He questioned whether the use of polyelectrolytes at normal flows was necessary and suggested that other alternatives might have been considered.

In water treatment, he asked why the quantities of iron and manganese were presented as joint values. He also drew attention to data presented in Table 3 where values for alkalinity/chloride balance suggested that the specification that water should not be supplied that would remove zinc from brass taps had been ignored; he asked if there was any evidence for this occurring. On the matter of the

specifications again, he was disturbed by the failure to reduce organics by 80% as had been specified, but noted that the additional criterion of a maximum load of 1.5 mg l^{-1} savoured of being a convenient 'let-out' clause.

Regarding the removal of manganese, he pointed out that free chlorine at 0.7 mg l^{-1} or more will oxidise manganese and enable it to be precipitated at the clarification stage. This could be extended to applying chlorine between clarification and filtration when the precipitated manganese would be filtered off and would then catalyse further manganese. This could reduce the quantity of chlorine and hence the problems of haloforms. In closing, he warned against delaying a decision to install an acid doser to reduce pH, and hence algal growth.

Mr. Ford said that when he was appointed, the works were nearing completion and one of the features he criticised was the lime post-treatment. Attempts to make it work failed, and attempts to add it with ferric sulphate at coagulation presented problems. Caustic soda would be used for final pH trimming. Turning to pretreatment at the off-take point, he said that this had proved difficult because of the head of reservoir water.

The use of polyelectrolyte was recommended by the contractors, but it was difficult to discern any real benefit to water quality. Other aspects which had been built into the system included the combined iron/manganese value, the specification for 'dezincification' and the potentially contradictory requirements for organic reduction. He noted the comments on the control of manganese and elaborated the problems of the acid doser.

Mr. Waller welcomed the study on haloforms and asked about the increase in haloform concentration when there was no free chlorine present. Mr. Drage replied that he could not comment. Mr. Warren enquired what arrangements had been made for cleaning the raw water main and what would happen to water used in cleaning. Mr. Ford replied that a twin mains system with several cross connections would be installed soon so that the mains could be cleaned in sections. Cleaning water would be diverted into an empty pulsator.

Mr. Youngman asked what was the nature of the taste and odour which necessitated the frequent use of powdered activated carbon, and to what source this was attributed. Mr. Ford replied that it was the usual earthy, musty odour. This did not *always* coincide with algal blooms.