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sewerage sulphides and corrosion in venezuela

INTRODUCTION

The Republic of Venezuela, one of the few democratic countries of South America, is bounded by the Caribbean to the North, and by Guyana, Brazil and Colombia. It is located between the latitudes of 12°N and 30°N. The climate is tropical with temperatures ranging between 25° and 35°C although in the Andes temperature is dependant upon height (15° to 25° in the capital Caracas which is 1000 m above sea level). Humidities range from 80% to 90% with a slight variation according to the season.

Venezuela is also one of the few democratic oil-rich nations: both President and Government are elected by obligatory universal suffrage.

POPULATION

With the greatly increased income from oil revenues in the last twenty years the migration from the rural areas to urban centres has accelerated as the agricultural workers and illegal immigrants from neighboring countries seek their fortune and a more comfortable life in the cities, with the result that the urban population is now 80% of the total.

Table 1 compares the growth rates of some of the larger cities. From the table it is evident that most of the cities have increased their population more than six-fold in thirty years. As can be imagined this rapid growth has placed a tremendous burden on all urban services.

Public sector housing could by no means keep pace with the demand for low-cost housing accommodation with the result that large numbers of 'Ranchos' or shanties have sprung up around the larger cities. The ranchos bring with them a multitude of evils such as those caused by the complete lack of basic sanitary facilities, high infantile mortality, crime, access problems, etc, but the most serious and far reaching problem of all is the social disorder brought about by such developments. Illegitimacy rates and the incidence of venereal diseases are extremely high in these districts and the literacy rates of some of the larger cities have actually fallen in recent years. It is estimated that half a million people live

under these conditions in the capital. Despite the poor living conditions, however, most of the ranchos have electric light and television, motor cars and water at nearby standpipes. Some enterprising ranchos even have direct piped water supplies.

TABLE 1: Population and growth rate of six major cities

(Population in thousands. Growth rate - geometric per annum)

CITY	POP. 1941	% P.A.	POP. 1950	% P.A.	POP. 1961	% P.A.	POP. 1971
CARACAS	354	7.8	693	6.1	1336	5.0	2183
MARACAIBO	122	7.6	236	5.4	422	4.4	650
VALENCIA	55	5.5	88	5.8	164	8.3	366
BARQUISIMETO	55	7.6	105	6.0	198	5.3	334
MARACAY	33	7.8	65	7.0	135	6.5	255
MATURIN	11	9.9	25	7.3	54	8.38	121

ADMINISTRATION OF WATER SERVICES

On the death of General J V Gómez in 1936 his thirty years of relatively brutal dictatorship came to an end. With the establishment of a democratic government attention was turned to the much neglected social and health needs of the nation. In 1943 the INOS (Instituto Nacional de Obras Sanitarias), an autonomous government institute for public health engineering works, was set up with its president directly responsible to the Minister of Public Works. INOS is charged with the provision of public water supplies in urban and, as of recently, rural areas, and with the provision of urban sewerage, both foul and surface water.

The water supplied is either derived from underground sources which receive chlorination or from surface sources which receive sedimentation aided by coagulation and flocculation followed by rapid sand filtration and chlorination. Unfortunately, owing to overloading of treatment plants, rationing, the shortage of adequately trained personnel and certain shortcomings in the distribution systems, the water is not generally relied upon for drinking and so bottled water or British candle filters are the order of the day. In 1976 INOS estimated that 85% of the urban population was served by a piped water supply direct to each house. Metering is universal and the tariff includes the cost of sewerage whether provided or not.

SEWERAGE

House drainage

The construction of sewers, though started in the capital at the turn of the century, was only started in earnest relatively recently with the creation of INOS. Since 1943 construction of foul sewerage has been rapid and last year it was estimated that sewers were available for 70% of the urban population.

There is, however, a considerable difference between population for which sewers are available and the population actually connected. This is due to certain practical difficulties involved in connecting houses of the single storey Spanish Colonial type which predominate throughout Latin America. In the larger cities this type of housing is being displaced by tall buildings as land prices rise.

The typical Venezuelan town is laid out in gridiron fashion arranged about the church and 'plaza' or central square. Each block is about 100 metres square and the houses front directly onto the street with no side access, with only the main front door and two or three characteristic barred windows shown to the street. Frontages are usually between 10 to 15 metres and the 'depth' of the plot may be up to half the block or 50 metres. Living accommodation is arranged about a central 'patio' or courtyard with a colonnade and verandah on two or three sides. The average Venezuelan in the coastal areas sleeps and takes his siesta in a hammock strung in the verandah area whilst in the cooler areas of the Andes and in the modern housing, the bed is more popular.

The kitchen is normally halfway down the length of the plot and lavatory facilities are at the bottom i.e. the part most distant from the street. This arrangement presents two drainage difficulties.

- a) Inconvenience: the floor of the hall, front room and part of the verandah have to be broken up to allow the new house drains to be laid.
- b) Because of the distance from the street of existing sanitary facilities, there is not usually enough fall unless the ground is dead level or there is a natural fall towards the street, which means that houses on the other half of the block have no chance of draining at all.

What generally happens when sewers are provided depends on the means of the householder. If he is well off, one of the rooms nearest the street will be converted into a bathroom and the kitchen drain diverted into the new house drain. In the case of a poorer family things will remain as they are, especially if the soakaway under the pit latrine is working satisfactorily.

Traditionally the patio is provided with a drain to remove rainwater to the street. Previously, when water was supplied from rainwater tanks or from a distant standpipe, the small amount of wastewater produced soaked away or was irrigated on the kitchen garden. However with the provision of direct piped supplies, the per capita water use rises considerably with the result that wastewater has to be diverted through the patio drain to the street. This results in small streams of grey water flowing in the gutters each side of the street, creating an excellent breeding ground for mosquitoes and flies. INOS therefore gives priority to those districts where this occurs.

The solution available to many householders is simply to tap the patio drain into the lateral provided by INOS in the pavement outside the house resulting in the connection of the surface water from the patio and making the system only partially separate.

Another problem occurs when a septic tank has been constructed to serve the owner's new WC. It is often the overflow from the septic tank which is connected to the sewer on the reasoning that the house drain is less likely to choke. What is overlooked is that an extremely septic liquor is discharged to the sewerage system with consequences that will be discussed later. Much of this work is done at weekends by a practical member of the family, with the result that inspection by the hard-pressed public health inspectors of the Ministry of Health is the exception rather than the rule.

In conclusion, the poorer the district the lower is the percentage of houses connected, except in the case of government housing when it is 100%.

Sewerage practice

Sewerage practice follows very much that of the USA. The minimum public sewer size is 8" diameter usually in precast concrete pipes with yarn and mortar joints. Where the water table is high clayware pipes with flexible joints are specified for sizes up to 16" diameter, whilst concrete pipes with rubber joints are specified for larger sizes. Circular manholes 1.20 m diameter are provided every 100 m maximum. Manhole covers are circular 0.6 m clear opening and the practice for a while was to perforate the covers with six 25 mm diameter holes, but this was discontinued on the grounds that children could not resist poking sticks down the holes and that with the characteristically heavy rains, too much water and sand entered the system. Sewer ventilation therefore relies on the rather small 2" diameter vent pipes required as minimum by the Ministry of Health code from the sanitation of (new or altered) buildings.

Gradients have to be sufficient to provide a velocity of 0.6 m/sec full (or half full). Mannings formula with $n = 0.015$ is used for design of sewers up to 21" and $n = 0.013$ for pipes 24" and over.

Sewer capacities are based on estimated 30 year growth using an average flow of 300 litres per person per day water consumption and assuming 80% of that reaches the sewerage system. The design flow is the average flow multiplied by a factor of three for population less than 20 000, reducing gradually to two for populations in excess of 200 000. Infiltration is taken at $20 \text{ m}^3/\text{day}$ per km of sewer depending on the height of the water table. If the above gives a theoretical sewer capacity lower than 1.5 litres/sec ha then this figure is used.

Sewage disposal

Since the foundation of INOS and the provision of a regular piped water supply to the greater part of the population, the amount of sewage produced has increased considerably. Sewerage systems constructed by INOS discharge either to the nearest water course, some distance below the town served or through long outfalls in the case of coastal cities and those on the banks of the Orinoco.

Where insufficient dilution is available and if topography and land prices permit, an oxidation pond system may be built. If not, then what is called a 'temporary discharge' has to be made into the receiving course. There are over fifty inland towns with populations over 10 000 but only about ten oxidation pond systems have been built. There is much to be done, therefore, in the field of sewage treatment. However it cannot be over-emphasized that many of the problems of sewage treatment plant operation stem from the sewerage system itself.

So it is essential for the success of schemes of sewerage and sewerage disposal that sufficient attention be paid to minutest of details, especially regarding standard designs or procedures in which the same

mistake could be repeated many times (the perforated covers for instance). It is also important that the person directly involved on-site, be he inspector or foreman, knows why he is doing certain things which to him may seem unnecessary and to be sure that it makes sense to him, otherwise with the best will in the world, less effort will be made. This calls for considerable ingenuity and patience on behalf of those in charge, to whom a course in public relations would not go amiss.

THE SULPHIDE PROBLEM

Introduction

The author's office during the last three years has been preparing schemes of sewerage for the Island of Margarita which lies off the north coast of Venezuela about seventy miles from Trinidad. The island was created a free port in 1968 since when the development of towns and commerce has been rapid. For instance, the largest town, Porlamar, has a population of 40 000 rising by 6% per annum. At this rate the population will double every twelve years.

The island is relatively arid with rainfall and evaporation around 400 mm and 2000 mm respectively. This has meant that water for domestic use has to be supplied to the island from the mainland through a submarine pipeline 25 km long. An international contract has just been let for a new pipeline to raise the capacity from 800 l/s to 3 m³/s.

At present the sewage from Porlamar and adjacent areas is discharged to the sea. It is the wish of the state government that no sewage should be discharged into the sea in resort areas and that if possible it should be treated and reused for irrigation of agricultural areas, golf courses etc. The intercepting sewer system to divert flows from existing outfalls is now under construction and design of the main pumping station, rising mains and treatment plant are under way.

One of the problems foreseen at an early stage was the possibility of septic conditions in the sewers and especially in the 3 km long rising mains to the treatment plant. This would present the possibility of damage to the interceptors and possible difficulties with the treatment process due to a high sulphide content⁽¹⁾. This would apply particularly to the early years of the system which has to have a fair amount of spare capacity to accommodate the rapid growth-rate. The author's office therefore presented INOS with proposals for a study of sulphide generation in the existing system, especially in the rising mains, and the means for its control.

Historical background

As with many engineering problems, somebody has usually encountered them before. A survey of the literature was therefore carried out; the more interesting points are as follows.

Pinson⁽²⁾ has described the corrosion of Cairo's original main outfall sewer. The sewer was 1.6 m diameter in local cement concrete laid at a gradient of 1:2500 and received the discharge from rising mains served by the many ejector stations. The government chemist describing the corrosion phenomenon in 1920 mentions the formation of calcium sulphate in the body of the concrete caused by "gaseous sulphur compounds from the sewage penetrating into the concrete and there becoming oxidised to acid bodies, which attacked the lime of the cement. Since the formation of gaseous sulphur compounds cannot be avoided in the collector, the only possibility of preventing further damage is to get rid of these compounds

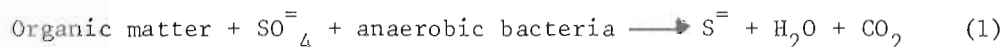
as fast as they are formed by artificial ventilation and at the same time to make the walls of the collector at and above the water line as impermeable as possible by means of some protective coating. Any ventilation to be efficient must be very thorough since a small amount of air only would probably accentuate the mischief by providing facilities for the oxidation of the sulphur gases to sulphur acids".

The chemist recommended trial repairs by plastering with neat portland cement and also with one part portland cement and two parts of finely ground brick powder. He also recommended the periodical removal of the silt deposit from the sewer. The plastering was tried but after a year both coatings had deteriorated. The removal of the silt, which was between 300 and 600 mm deep proved extremely difficult. A flushing water supply was laid from a nearby canal and the sewer was flushed once a fortnight throughout 1922. This resulted in considerable removal of the silt. Forced ventilation of the sewer with a 32 hp fan accompanied by gas analyses of the sewer air was also carried out and a marked reduction in the hydrogen sulphide content was noted after the start of flushing and forced ventilation. However, the corrosion of the sewer continued. By 1922 roughly 100 mm of the concrete in the crown had deteriorated, this depth of damage being maintained evenly throughout its 13 km length. By 1930 deterioration had reached 150 mm, nearly half the thickness of the crown. By this time the sewer was overloaded and a new outfall sewer was constructed lined with "blue bricks in cement 1:1 pointed with gas proof material", horseshoe in section 1.8 m x 1.9 m at a gradient of 1 in 2200. It would be most interesting to know how this sewer has fared. Although the actual mechanism of hydrogen sulphide corrosion was not fully understood, the chemist's report of nearly sixty years ago exhibits a remarkable understanding of the problem and the practical means for its solution.

Between 1930 and 1960 studies of the sulphide corrosion problem were undertaken in the USA, South Africa and Australia simultaneously(3,4,5). It was Parker(3) who identified the bacteria *desulphovibrio desulphuricans* living in the submerged slime layer of sewerage systems as being responsible for the reduction of sulphates to sulphides, and the bacteria *Thiobacillus Concretivorus* as the organism responsible for the oxidation of hydrogen sulphide to sulfuric acid on the wall of the sewer above the water line, with its remarkable capacity to survive conditions of pH1. The reader is referred to the very excellent work of Thistlethwayte(5) for a more thorough treatment of the subject.

The mechanism of sulphide production

The sulphide ion is produced bacteriologically under anaerobic conditions:



Depending on the pH value of the sewage the sulphide ion may combine with free hydrogen ions to give hydrogen sulphide according to:



Principal factors affecting these reactions are:

a) Total sulphur concentration

Sulphur exists as sulphates and organic sulphur. Human beings excrete approximately 2.6 g of sulphate as SO_4 per day.

b) Sewage strength

The oxygen demand has a direct influence on the production of H_2S . As the strength of the sewage increases, the rate of oxygen utilization increases and so the time taken for the system to reach anaerobic conditions decreases. The strength also indicates the amount of food available for biological reactions.

c) Sewage temperature

Biological reaction rates are said to double for every $10^\circ C$ temperature rise.

d) Sewage velocity

High sewage velocities prevent deposition, and sufficient boundary shear stresses cut the sulphide producing slimes from the submerged surfaces. High sewage velocities also increase the rate of transfer of oxygen into solution thus limiting anaerobic bacterial action. High velocity, however, also increase emission of any H_2S from solution.

e) Dissolved oxygen concentration

A high dissolved oxygen concentration precludes the presence of hydrogen sulphide both by inhibiting anaerobic bacteria and also reoxidising any sulphide entering the sewage from the wall slimes.

f) Sewage retention time

Long retention times in sections of the system where septic (i.e. anaerobic) conditions occur lead to high sulphide concentrations. Thus rising mains are the most vigorous procedures of sulphides.

Corrosion of sewers

Whilst hydrogen sulphide remains in solution it is inoffensive. However, the following factors encourage its emission from sewage:

- high concentrations of dissolved H_2S ;
- high velocity or sudden turbulence e.g. at drops or junctions;
- high relative velocity between sewage and sewer air;
- absence of surface films, oil, grease, etc.

Once in the atmosphere of the sewer H_2S may dissolve in the moisture of the walls where the sulphuric acid producers may begin their activities. The following are the main factors conducive to the formation of sulphuric acid on the sewer walls:

- high concentration of H_2S in the sewer air;
- high wall moisture pH;
- high relative humidity of sewer air;
- high rate of transfer of H_2S to wall moisture caused by rapid air movements, surface roughness etc.

The chain of processes which lead eventually to sulphuric acid production on the walls of sewers may be summarised as follows:

LOW VELOCITIES, LONG RETENTION IN RISING MAINS

leading to:

SEPTIC (ANAEROBIC) CONDITIONS

leading to:

PRODUCTION OF SULPHIDES IN SUBMERGED WALL SLIMES AND SILT

leading to:

RELEASE OF HYDROGEN SULPHIDE INTO SOLUTION (under low pH conditions)

leading to:

EMISSION OF H_2S INTO SEWER ATMOSPHERE (under conditions of high turbulence)

leading to:
 ABSORPTION OF H_2S INTO WALL MOISTURE
 leading to:
 CONVERSION OF H_2S TO SULPHURIC ACID

SULPHIDE INVESTIGATIONS IN VENEZUELA

Sulphide production

Most of the corrosion cases cited in the literature have been due either to rising mains or siphons or to gravity sewers which run full during the greater part of the day. Investigation was therefore directed at existing rising mains known to be producing significant amounts of sulphides.

There are five existing rising mains in the Porlamar area, three of which have retention times in excess of one hour. One was not available for investigation for administrative reasons. The other two had been the subject of complaints because of smells in the vicinity of manholes on the sewers into which they discharge. One serves a government housing estate of 10 000 people and lifts the sewage sufficiently in order for it to gravitate to the Porlamar system 7 km distant. Its details are as follows:

Pumps: 2 FLYGT CP3151 IMP.480

Rising main: 10 inch diameter asbestos cement 2210 m long,

Static head 14.0 m

Sampling and gauging were carried out over several weeks and sulphide productions of the order of 6.0 mg/l were encountered, sulphide production being the difference between the sulphide contents entering and that leaving the rising main. Peak sulphide production was found to coincide with the peak BOD which was around 400 mg/l at 8 a.m. when retention time was one and a quarter hours. Sulphide production between the hours of 2 a.m. and 6 a.m. was practically zero whilst the BOD remained around 40 mg/l.

An interesting item of information arising from the gauging was that the sewage flow averaged 202 litres per head per day and the daily BOD contribution averaged 46 g/person. Sewage temperature averaged 30°C during the day whilst 29°C was registered at 6 a.m. Investigation revealed that the high sulphide values in the sewage entering the sump was due to the protecting screen having become blocked and the sewage backing up 300 m or so in the inlet sewer. The screen was blocked by an inordinate amount of rubbish and also because it was almost impossible to clean due to poor design.

The other pumping station serving approximately 1000 people in an old town called Pampatar has the following details:

Pumps: 2 FLYGT3126 IMP 460

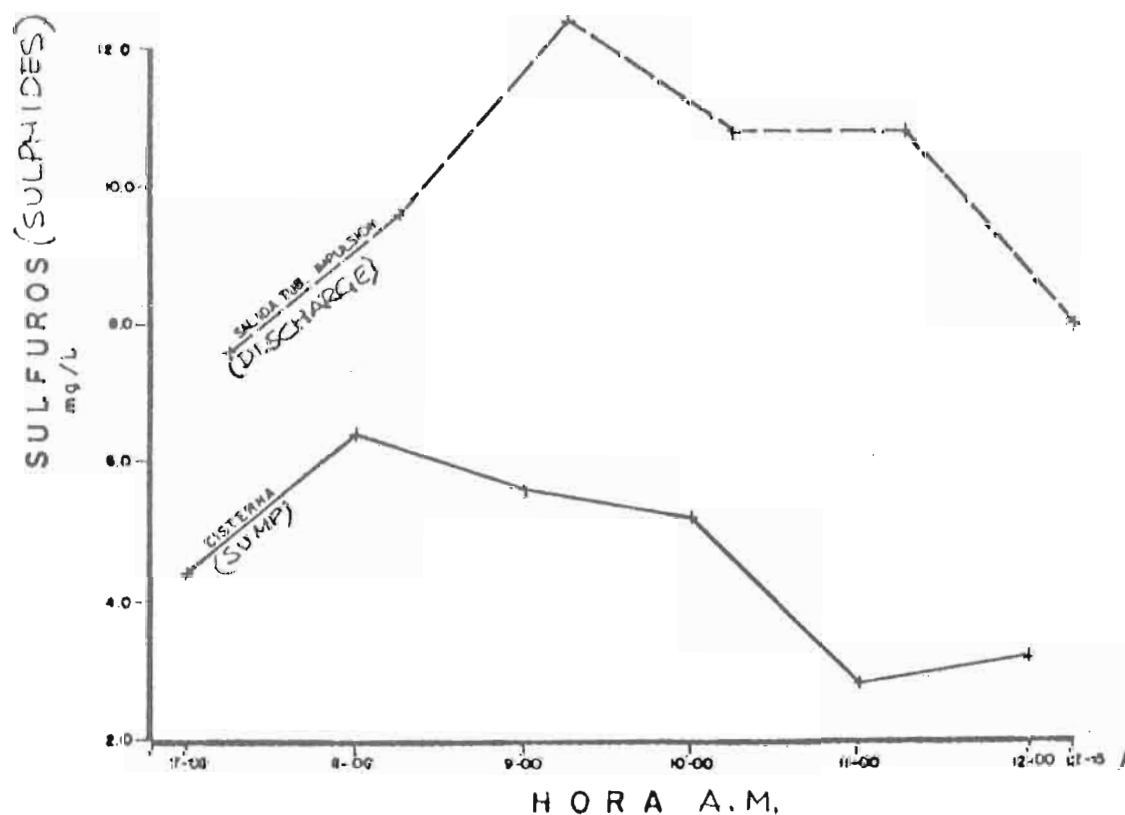
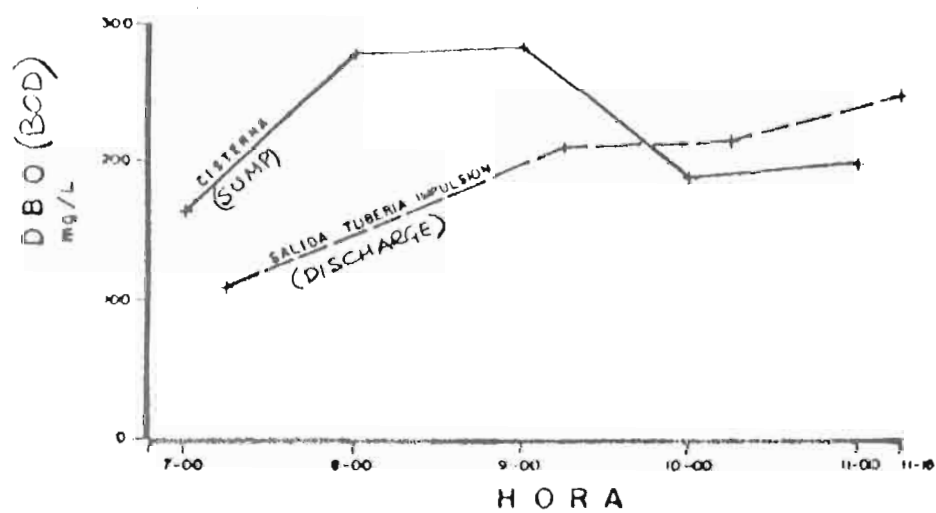
Rising main: 6 inch diameter asbestos cement 875 m long

Static head 8.10 m

Sampling revealed high concentrations of sulphide in the sewage entering the pump well with a maximum of around 6 mg/lS⁻² at 8 a.m. This was increased to 12 mg/l by production in the rising main which also had a retention time of about one and a quarter hours at morning flow rates.

Pampatar is an example of an old town with a newly installed sewerage system. The high sulphide content in the sewage entering the well is due to the overflows from septic tanks which have been connected. Figure 1 shows the typical pattern of strength and sulphide concentrations.

FIGURE 1:



MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
DIC. 10/76 (SIN AERACION)

Corrosion investigations

In the case of the first system studied (Villa Rosa) severe damage had occurred in the first 300 m of 18" sewer downstream of the rising main in only fifteen months of service. Approximately 20 mm of the crown of the sewer had spalled away whilst walls of the manholes had been affected up to 50 mm in depth. These conditions persist up to a manhole 300 m from the rising main discharge at which point a drop of 1.5 m occurs. This manhole is the most severely affected due to increased liberation of H_2S at this point. Investigation further downstream revealed only slight blistering. The sewer is laid at 1 in 500.

Sampling of the sewer revealed the following (using floats):

TIME AT	DISTANCE m	VELOCITY m/s	TOTAL SULPHIDES mg/l	BOD mg/l
9.42	0 + 290 (upstream of drop)	0.54	8.0	290
10.2	0 + 940		6.2	247
10.35	01 + 940		5.6	240
10.57	2 + 840		4.8	240
11.22	3 + 940 (slight obstruction in M.H.)		4.8	302

The reduction of sulphides caused by emission at the drop is evident as is the progressive reduction of sulphides afterwards until the flow is held up by a slight obstruction causing slight septicity.

In the case of the Pampatar system the rising main discharges over the benching in the receiving manhole which has suffered considerably. The sewers, however, are of clayware and do not appear to have been affected. The benching concrete in manholes downstream has turned to a paste up to a depth of about 7 cm in eighteen months of service. The tapers do not seem affected, however. The residents in the streets along which the receiving sewer passes have sealed nearly all the manhole covers with putty to avoid the escape of H_2S from the system.

Sewers known to have flat gradients but not receiving rising mains were also sampled, including 2 km of 16 inch sewer laid at 1 in 670 but none have values higher than 1 mg/l sulphides at peak hour. A rising main with only 10 minutes retention time based on dwf showed a sulphide increase of 1 mg/l in the sewage which first issued when a pump started.

Control of sulphide production

It was evident that rising mains were responsible for significant production of sulphides and that if this could somehow be controlled then conditions in the downstream sewers would improve considerably. The literature cites many methods of control for existing rising mains, such as

- dilution
- aeration and oxygenation
- chlorination
- addition of: lime
 - nitrates
 - zinc and iron salts
 - hydrogen peroxide

Any proposal involving the dosing of reagents of any description is fine in theory. Unfortunately there is a lot more to dosing equipment than appears in those glossy catalogues. Knowing the problems associated with the dosing equipment and supply of reagents in the water treatment plants which are continuously manned, it was felt that the installation of such equipment in the 'automatic' pumping stations which receive relatively unskilled attention would be a complete waste of money. This left dilution and aeration as alternatives. As there is a shortage of water for domestic purposes, dilution had to be ruled out leaving aeration as the only possible practical answer.

The next question was, how much air? Most of the literature quotes 1 cfm per inch of diameter as a guide, although Boon and Lister⁽⁶⁾ have described a more scientific method for determining the amount of oxygen to be injected under UK conditions. It was decided to use various small compressors (the type used with paint sprayers) of known delivery at the service pressure and increase their number until desired results were obtained.

In the case of Villa Rosa considerable difficulties were experienced with the blocking of the pumps and inadequacy of the electricity supply with the result that only three compressors of 2.5 cfm each could be used, equivalent to 0.75 cfm per inch diameter. Samples were taken three days a week for three weeks at 8 a.m. in the pump well and 9.15 a.m. at the discharge end of the rising main. These are the approximate times that sewage with peak BOD passes these two points and the most crucial test for aeration. It was found that the aeration reduced the sulphide production from 6 mg/l to 1.5 mg/l i.e. the concentration of total sulphide leaving the main was still higher than that entering by 1.50 mg/l.

In the case of Pampatar it was possible to inject more air and the results were much more encouraging as figure 2 shows. The BOD peak in this case is not so definite and so sampling was carried out every hour. Figure 2 shows the results of one compressor (2.5 cfm) in operation continuously. Figure 3 shows the results of starting the compressor at 9 a.m.; figure 4 shows what happens when two compressors were started at 9 a.m. Control was established within an hour and an actual reduction of total sulphides occurred.

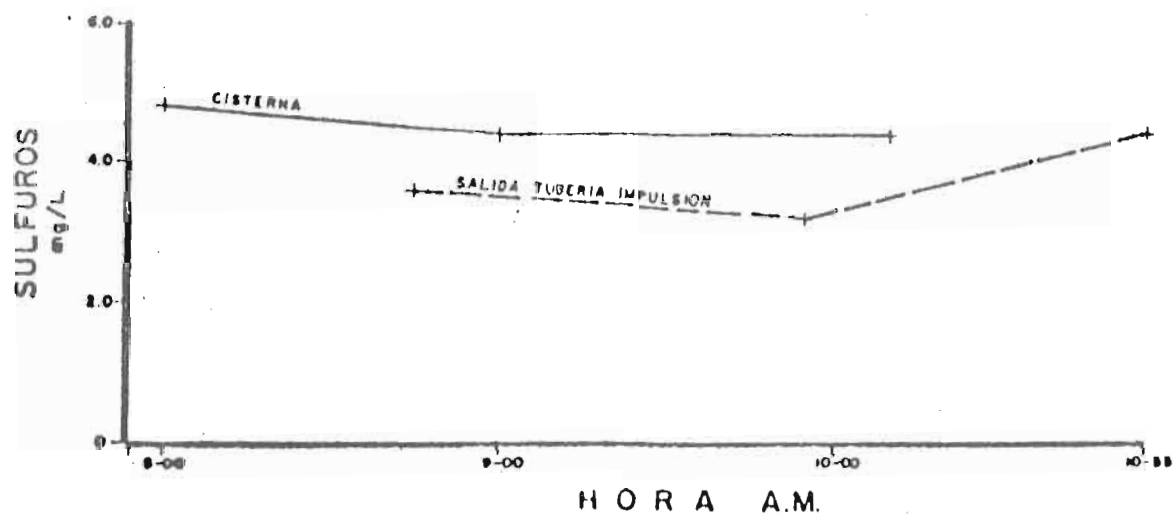
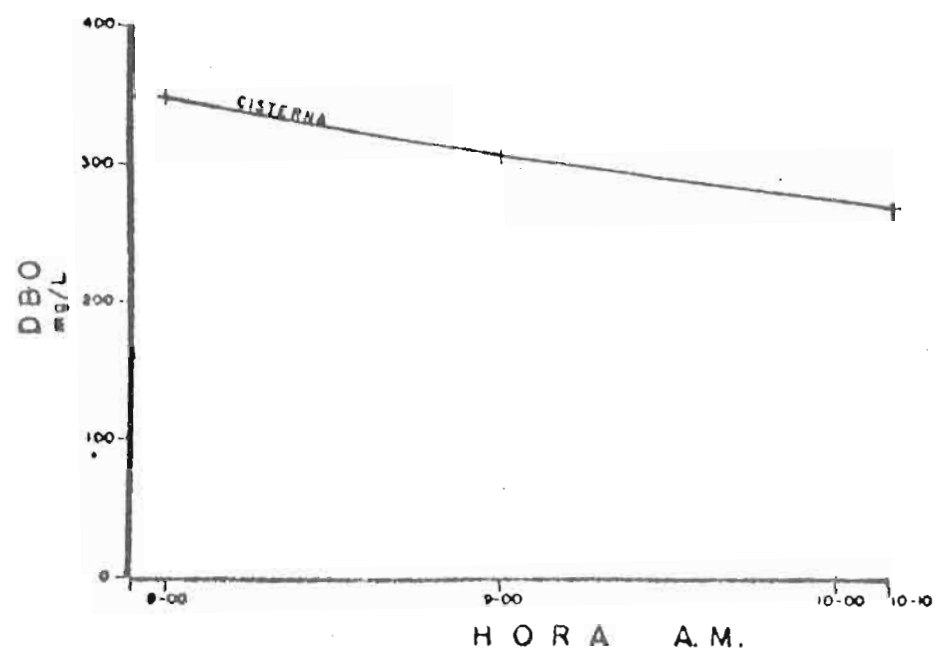
On March 1 a dissolved oxygen meter was available and figure 5 shows the result of three compressors (7.5 cfm) started at 9 a.m. on the dissolved oxygen in the discharge from the rising main and figure 6 shows the effect of one compressor started at 9 a.m. All these should be compared with figure 1 which shows average conditions without aeration.

Boon and Lister indicate the need to consider oxygen requirements as related not only to diameter of the main but to its wall (i.e. slime) area and volume as well. These parameters are presented in Table 2 and explain the lack of success in the case of Villa Rosa when the amount of air injected is related to volume and internal surface area of the mains.

TABLE 2: Comparison of aeration intensities used in sulphide control studies

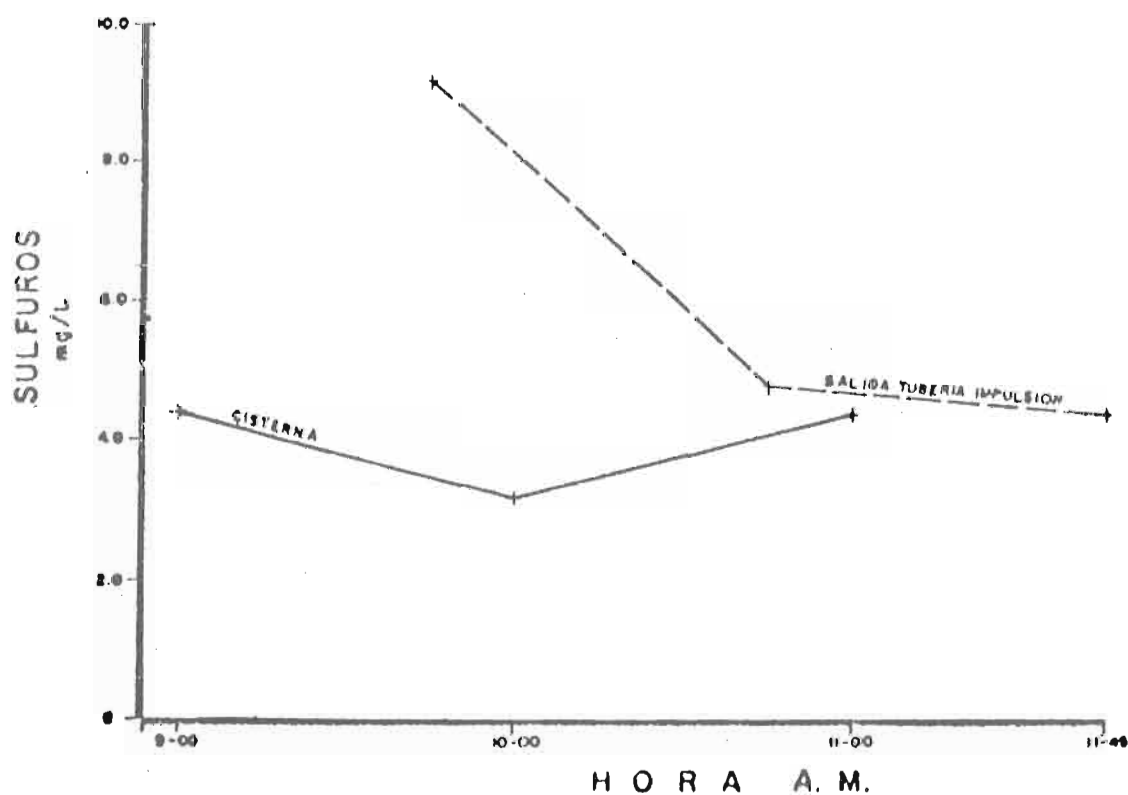
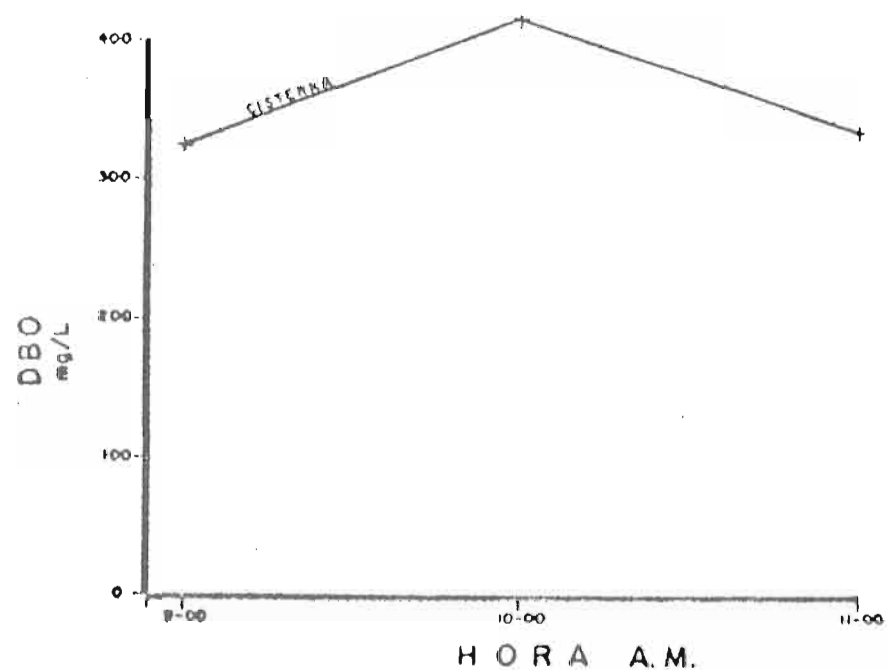
Number of compressors	Volume of air cfm	cfm/inch diam.	m ³ air/m ² surface per day	m ³ air/m ³ per day
Villa Rosa				
3	7.5	0.75	0.8	2.7
Pampatar				
1	2.5	0.42	0.25	6.7
2	5.0	0.83	0.49	13.3
3	7.5	1.22	0.74	20.0

FIGURE 2:



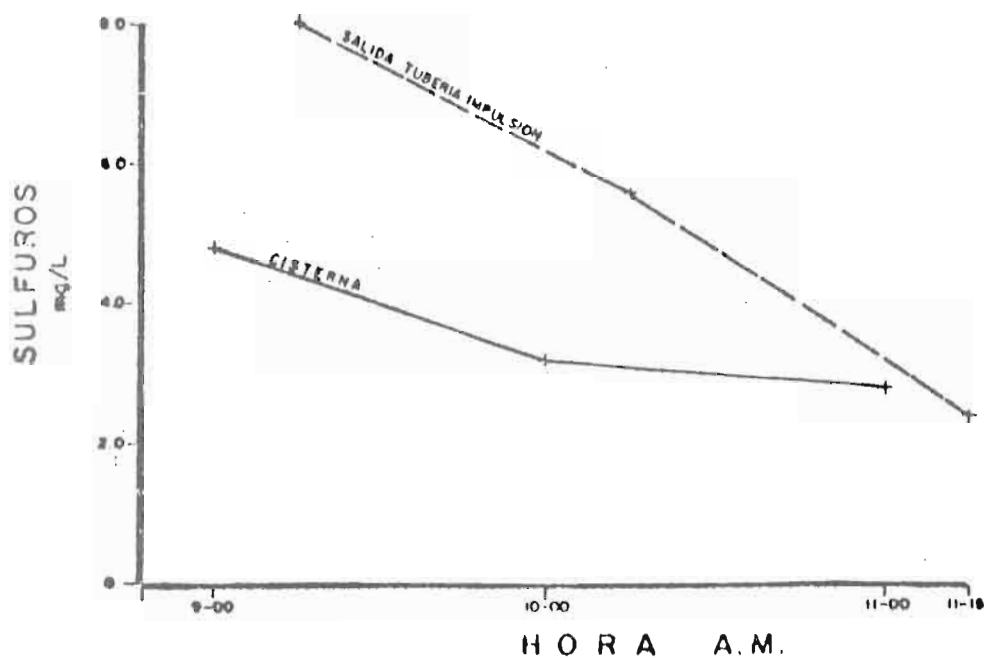
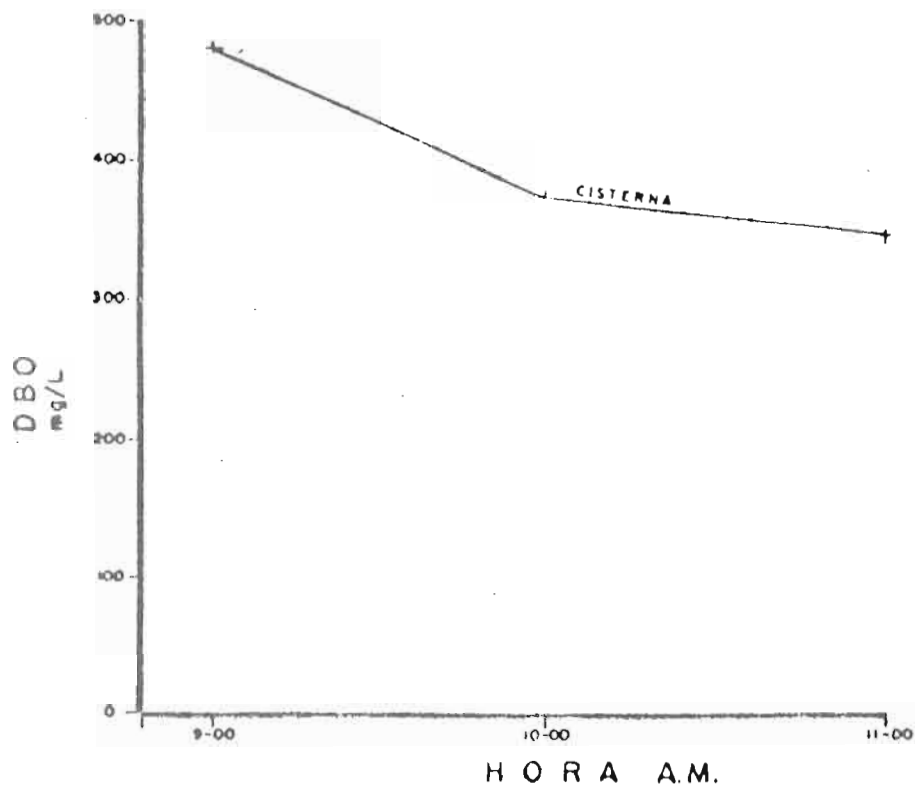
MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
FEBRERO 18/77 (CON AERACION CONTINUA)

FIGURE 3:



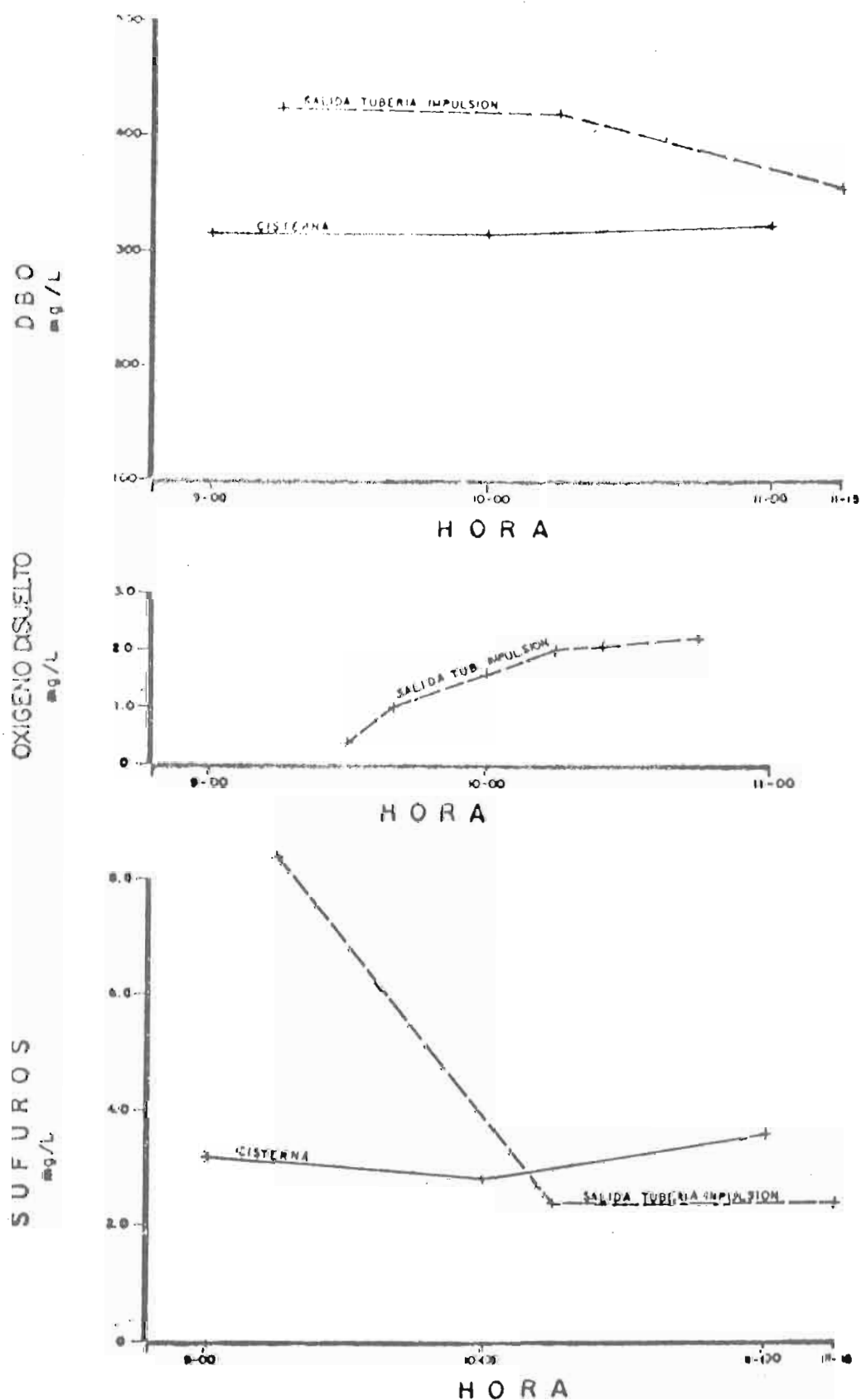
MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
FEBRERO 21/77 (CON AERACION A PARTIR DE LAS 9-00 A.M.)

FIGURE 4:



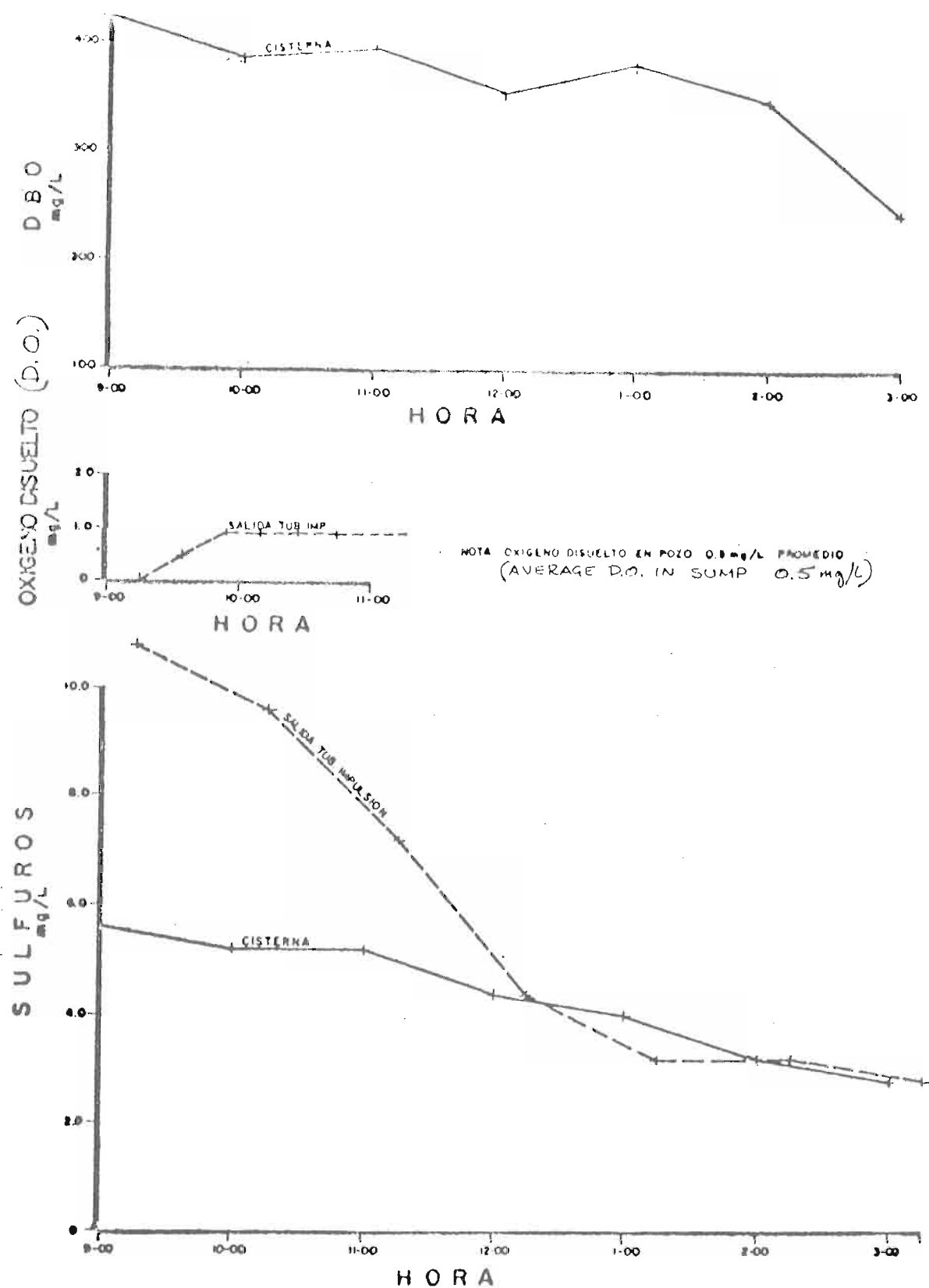
MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
FEBRERO 23/77 (CON AERACION A PARTIR DE LAS 9-00 A.M.)

FIGURE 5:



MUESTREO CONTINUO ESTACION DE BOMBEO 'PANPATAR'
 MARZO 1/77 (CON AERACION A PARTIR DE LAS 9-00 A.M.)

FIGURE 6:



MUESTREO CONTINUO ESTACION DE BOMBEO 'PAMPATAR'
MARZO 7/77 (CON AEREACION A PARTIR DE LAS 9-00 A.M.)

Although one compressor in Pampatar gave about half the intensity of Villa Rosa based on diameter, the superficial and volumetric intensities were about double. With injection of $13 \text{ m}^3/\text{m}^3$ of volume per day, a D.O. of 1 mg/l could be maintained. It should be stressed that the total oxygen demand of a rising main is the sum of that due to the respiration of organisms in the sewage plus that of the organism in the wall slimes. Unfortunately the relative contributions of these are very difficult to determine, hence the need to take the worst case.

It is interesting to note that if the sewage respiration rate is taken at 10 mg/l per hour (found respirometrically) and the slime respiration taken at 2.1 g/m^2 per hour (using the figure of 700 mg/m^2 per hour given in reference 6 for 15°C and allowing 7% increase per 1° rise in the temperature), the theoretical air demand is 2.2 cfm.

CONCLUSIONS

Recommendations to INOS included the following:

- a) The majority of the cases of corrosion and odours are due to sulphide production in rising mains.
- b) Rising mains should be kept as short as possible, preferably no longer than 200 m.
- c) Where long rising mains are unavoidable, continuous injection of air at the pump end of the main should be contemplated.
- d) The amount of air required in such cases may be estimated from the following:
 1 cfm per inch diameter
 OR
 $0.5 \text{ m}^3/\text{m}^2$ internal surface per day
 OR
 $10 \text{ m}^3/\text{m}^3$ volume per day
 The maximum figure given by the dimensions of the main is that to be used. These parameters should be updated with experience of their use in practice.
- e) Great care should be taken in the design of the manhole at the discharge of rising mains to avoid splashing and minimise turbulence.
- f) A vent shaft at least 10" diameter and 10 m high should be provided for manholes receiving rising mains. Care should be taken in its location to avoid odour nuisance.
- g) Sewers receiving rising mains should be designed with the utmost care to avoid turbulence. If this is not possible then acid resisting materials should be used with adequate ventilation.
- h) INOS should discuss with the Ministry of Health the possibility of raising the minimum vent pipe diameter specified in the Building Code to 4 inches.
- i) Main sewers should have minimum gradients to afford an average boundary shear force of 0.2 kg/m^2 at average flow conditions and the use of the minimum velocity criterion of 0.6 m/s should be discontinued. (This recommendation was in the light of research by the U.S. Environmental Protection Agency⁽⁷⁾ and the work of Yao⁽⁸⁾, and takes into account the necessity not only for self-cleansing velocities but also 'self-aerating' velocities).

- k) The feasibility of diluting the sewage flow during the early years of a new sewerage system should be investigated in order to secure better flow conditions.

These recommendations were intended to draw to the attention of INOS the necessity for preventing sulphide problems at design stage rather than having to cure them later at a greater cost.

The study described has no great scientific merit, but the findings have some practical value and it is to be hoped that this paper will serve to spark off interest and, hopefully, more detailed research into sulphide problems in other 'hot' countries where funds are available. The knowledge gained may then be applied in poorer countries in order that such funds that are available for sewerage may be more securely invested.

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