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RIVER POLLUTION IN HARARE

by

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Paper presented at the
Geographical Association of Zimbabwe's 1991 Conference on
Global Environmental Issues with Special Reference to Zimbabwe

INTRODUCTION

Since Independence, Harare has undergone major growth, both in size and population density. This has led to increasing pressure being placed on rivers draining the Greater Harare area, in terms of the legal and illegal discharges to them from various sources within the Manyame catchment. Consequently, several smaller streams which drain into the Manyame, such as the Mukuvisi and Nyatsime rivers, are highly polluted: the pollution load carried in these streams has contributed greatly to the present problems with water hyacinth in Lake Chivero. The water hyacinth problem is of great concern to the City of Harare since its presence in Lake Chivero threatens the efficient operation of the Morton Jaffray Waterworks, and therefore the quality of the drinking water which is supplied to the City.

This paper will cover the nature of the pollution in Harare's rivers, the sources of pollution, what has or is being done to prevent illegal discharges to the rivers, the effect of pollution on the receiving waters, current legislation on illegal discharges, and also the current level of sewage treatment capacity in the Greater Harare area.

THE NATURE OF POLLUTION

Pollution in a river may be defined as anything which renders the water unfit for use. Generally it is possible to control and, indeed, prevent all forms of river pollution, since the pollution is usually a result of 'poor housekeeping' or ignorance.

From the definition above it is clear that there are many forms of pollution which may affect the quality of river water. Table 1 attempts to cover a wide range of possible pollutants, although it must be stressed that this list is by no means exhaustive. Also included in the table are ways of reducing or eliminating these forms of pollution.

It is clear that most forms of macro-pollution, as detailed in Table 1, can easily be prevented. Education of local populations about the benefits of careful disposal of household and related wastes is usually sufficient to create an awareness of this particular form of pollution.

Micro-pollution is a little more difficult to deal with and is usually the result of an uncontrolled discharge into a river such as the run-off from gypsum stockpiles at Gypsum Industries in Msasa, which enters the Mukuvisi river, and chicken manure from Crest Breeders chicken farm, which also enters the Mukuvisi river, but further downstream near Firle Sewage Treatment Works. Pre-treatment on site is usually required to prevent or reduce this form of pollution.

Pollutants which fall into the 'Dissolved' category should never enter a river under normal circumstances. They are the result of either industrial manufacturing processes or domestic waste production and should all be collected and conveyed in a sewerage

Table 1: A Selection of Possible River Pollutants

Type of Pollution	Examples	Effects	Methods of Removal
Macro	Plastic packets and bottles, tin cans, household and general urban waste from informal settlements.	Unsightly, dangerous to livestock.	Manual collection and disposal by dumping; education of local population about litter.
Micro	Suspended or settleable solids, particulate matter (both organic and inorganic).	Increased turbidity/reduced clarity of receiving water, solids deposition and possible anaerobic decomposition.	Pre-treatment by settling, biological treatment or flocculation/clarification. Filtration also useful.
Dissolved	Soluble chemicals and inorganic metal salts, soluble organics (i.e. BOD), eutrophic nutrients (e.g. Nitrogen and Phosphorus).	High total dissolved solids (TDS), high or low pH, eutrophication in water impoundments (e.g. algal blooms, growth of water hyacinth); untreated sewage streams; dissolved oxygen depletion.	Pre-treatment at source to remove high TDS (e.g. ion exchange or precipitation), stabilisation to neutralise Ph; sewage treatment by biological nutrient removal (MAS process).
Other	Oils, grease, fuels and other toxic organics.	Surface film prevents O_2 transfer between water and air; toxic to aquatic organisms.	Ideally zero discharge at source; alternatively separation processes, skimmers etc.

reticulation system to a treatment works for disposal. Pollutants of this type usually enter a watercourse as a result of an accidental discharge e.g. failure of a holding tank, or cracking of a sewer pipe at a river crossing, or through infiltration via contaminated ground water. In the mid-1980s, pollution of the Mukuvisi river in the Msasa area was due both to uncontrolled discharge of contaminated effluent flows from the Zimbabwe Phosphate Industries complex, and also the infiltration of contaminated ground water from beneath the factory. The methods used to deal with this form of pollution are complex, expensive and sometimes difficult to operate. Some of these treatment methods will be covered in more detail in a later section of this paper.

The final category of pollutants mentioned is fortunately not common in Zimbabwe. The author's only experience of this kind of pollution is in the Kwekwe river, downstream of the ZISCO works in Redcliff, where uncontrolled discharges of toxic coke oven and benzol plant by-products have resulted in widespread fish kills and also livestock deaths.

Some garages and related industries are known to occasionally discharge used oils and fuel wastes to municipal sewers, but fortunately the existing sewage treatment works are able to remove these pollutants before discharging treated effluent to the Manyame River. Continued vigilance of the City's Trade Waste Inspectors is essential in keeping this type of pollutant discharge to a tolerable minimum.

SOME CASE HISTORIES

The Mukuvisi River and the Hatfield Stream

The Mukuvisi River rises in the Chikurubi/Manresa area and flows generally west and southwest through Harare to its confluence with the Manyame River just downstream of Firle Sewage Treatment Works (STW). The Hatfield Stream is in fact a tributary of the Mukuvisi rising in the Epworth Vlei, just south of the Zimbabwe Phosphate Industries (ZPI) complex, and merging with the Mukuvisi near Sunningdale.

The Mukuvisi has been considered to be heavily polluted for many years; most of the pollutants are soluble, although in the wet season there is always a carryover of finely divided gypsum into the river near ZPI. In a survey of uncontrolled effluent discharges from the ZPI factory carried out in late 1986, test samples were analysed to determine pH and pollutant concentrations. The results are summarised in Table 2. The relevant prescribed standards (GN 687/77 for Zone II) are included for comparison - the standards are the maximum permissible concentrations for pollutants in streams discharged to watercourses.

Table 2: Sample analyses for discharges to the Mukuvisi River from ZPI complex.

Parameter	pH	TDS	Ca^{++}	Mg^{++}	F^-	PO_4^{3-}	$SO_4^=$	Fe_3^+	NO_3^-	Al
Standards (GN 687/77, Zone II)	**6.0–9.0**	**500**	**-**	**-**	**<1.0**	**<1.0**	**200**	**0.3**	**10**	**-**
STREAM 1	3.27	2500	264	270	31	108	238	3	98	326
STREAM 2	6.09	1600	297	234	54	7	266	5	29	22
STREAM 3	2.71	2000	315	310	22	24	238	8	26	114
STREAM 4	1.75	4150	661	175	203	33	173	42	29	90
STREAM 5	2.50	1300	300	200	40	18	600	50	50	–
STREAM 6	3.21	850	142	34	6	9	101	7	3	43

Note: (i) All concentrations in mg/l
(ii) TDS = Total Dissolved Solids

As can be seen from the results of the sample analysis, all of the effluent streams entering the Mukuvisi from the ZPI complex were highly polluted; as a result, the Mukuvisi river was essentially 'dead' for some considerable distance downstream of the factory.

The ZPI complex has been regarded as one of Zimbabwe's worst polluters for many years. Products manufactured by ZPI and associated industries include phosphate and nitrate fertilisers, sulphuric acid, aluminium sulphate and various arsenic based insecticides and animal dips. The original layout and construction of the complex did not provide adequate underdrainage and effluent collection facilities, resulting eventually in severe groundwater contamination and uncontrolled effluent discharges to the river.

Another source of pollution is the gypsum slimes dam behind the ZPI complex; the waste products of the production of phosphate fertiliser are pumped here for disposal by dumping and evaporation of leachate from the dam. The groundwater in the Epworth vlei area has become heavily contaminated with high calcium (C^{++}), sulphate ($SO_4^=$) and fluoride (F^-) concentrations, by contact with subsurface leachates from the slimes dam which have escaped from the underdrain network beneath the dam. The groundwater in the vlei eventually finds its way into the Hatfield stream and then into the Mukuvisi River.

The Epworth vlei is especially vulnerable to pollution because of its proximity to the gypsum slimes dam, and the possibility of accidental spills of leachate from the associated evaporation pond into the vlei. Three spills have occurred in the past two years; in one major spill the fluoride concentration was of the order of 10^6 mg F/l. Table 3 shows the measured concentrations of pollutants in the evaporation dam and also those in an uncontrolled side stream, which, in late 1986, was draining into Epworth vlei. Several boreholes in the Epworth area have been closed because of the high level of contamination of groundwater.

Table 3: Sources of Pollution in Epworth Vlei and Hatfield Stream

Parameter	pH	TDS	Ca^{++}	Mg^{++}	F^-	PO_4^{3-}	SO_4^-	Fe_3^+	$NO_3^=$	Al
Standards (GN 687/77, Zone II)	**6.0–9.0**	**500**	**–**	**–**	**<1.0**	**<1.0**	**200**	**0.3**	**10**	**–**
EVAPORATION POND	1.92	5665	976	746	1843	1224	493	65	26	885
EFFLUENT	1.72	7440	1035	1029	818	3291	446	142	33	98

Note: (i) All concentrations in mg/l
(ii) TDS = Total Dissolved Solids

As a result of pressure from the Water Pollution Advisory Board and also the City of Harare, ZPI have taken steps to reduce effluent and contaminated groundwater discharges to both the Mukuvisi River and Hatfield stream. Groundwater interception reticulation has been installed, the effluent collection system has been upgraded and a new extended effluent treatment facility is due to be commissioned before the end of 1991. The level of contamination of the Mukuvisi River and Hatfield stream should decrease with time, and therefore reduce the pollution load on Lake Chivero. This is discussed in more detail later in this paper.

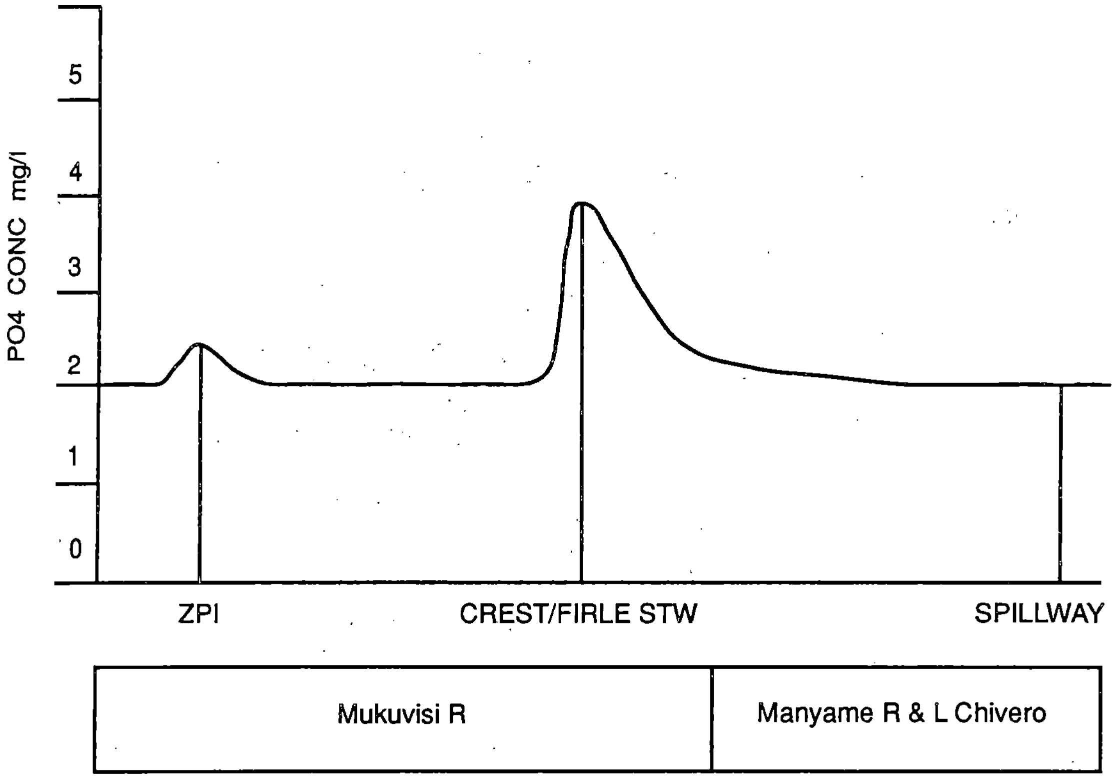
Recently a possible new source of pollution in the Mukuvisi River has emerged. Crest Breeders Chicken Farm is situated on the southern bank of the river near Firle STW. Analysis of the river water has shown that at this point the phosphate level in the river rises dramatically, as shown diagrammatically in Figure 1, implying that Crest Breeders is a significant contributor of phosphate to the Manyame River system.

Chicken food and waste is high in phosphate and it seems that run-off from cleaning out of battery soil pits is either directly entering the river or contaminating groundwater which infiltrates the stream. Since phosphorus is a eutrophic nutrient this is potentially a very serious source of pollution, because of the effect on the water hyacinth problem in Lake Chivero.

The Nyatsime River

The Nyatsime is a tributary of the Manyame River, entering this river approximately 3 km west of Chitungwiza, as shown on Figure 2. Chitungwiza is a 'satellite city' south of Harare which has grown rapidly since Independence, with the result that existing

Figure 1: Phosphate levels in the Mukuvisi river



sewerage reticulation and sewage treatment facilities have become seriously overloaded. Chitungwiza is a Town Council which has to deal with a city's problems; it appears that at present the Town Council has difficulty coping with the sewage disposal situation, let alone making improvements and constructing new facilities.

Notwithstanding the limited resources of Chitungwiza, the area has posed a significant pollution threat to the Manyame River for several years. One particularly serious source of pollution at present is a set of waste stabilisation ponds, on the banks of the Nyatsime River, which receives raw sewage from the Tilcor industrial area in Chitungwiza. The sewers conveying the raw sewage to the ponds have failed on several occasions, and it appears that the existing ponds are heavily overloaded, so much so in fact that raw sewage is being discharged directly into the Nyatsime River.

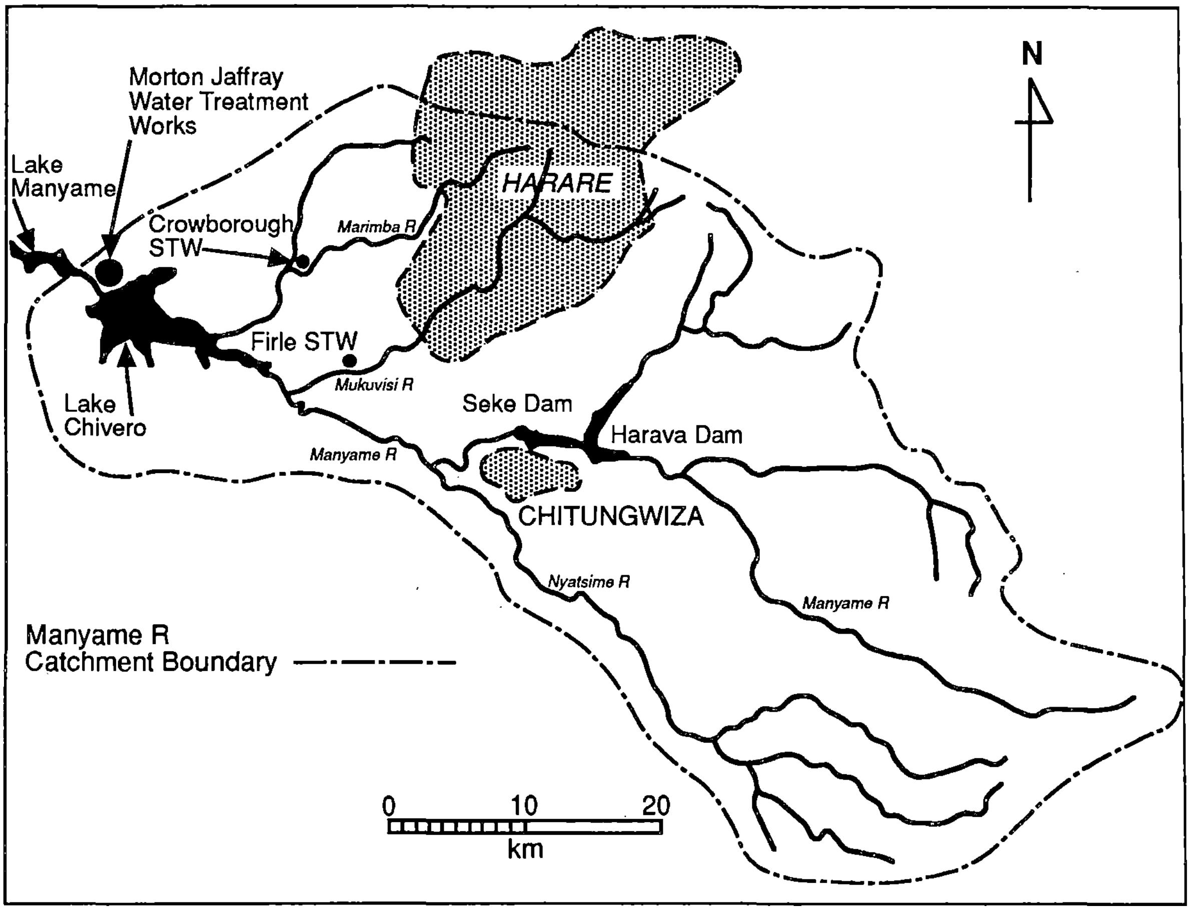
Raw sewage of domestic/industrial origin generally has a high organic pollution content and contains significant concentrations of the plant nutrients nitrogen and phosphorus. As has been previously noted, this has very serious implications for the receiving water, Lake Chivero, and this is discussed in more detail in the next section of the paper.

THE EFFECT OF RIVER POLLUTION ON LAKE CHIVERO

Lake Chivero is Harare's principle source of drinking water. Raw water abstracted from the lake is treated and purified at Morton Jaffray Waterworks and then pumped to Harare for distribution. Although the clarification, filtration and chlorination processes used at the Works are capable of producing very high quality potable water, the quality of raw water is an important factor in the efficient operation of the waterworks.

The quality of water contained in Lake Chivero at present is poor and the main reason for this is the pollution of the rivers which discharge into the Lake. Figure 2 illustrates the Manyame River catchment upstream of Lake Chivero.

Figure 2: The Manyame river catchment



The nitrogen and phosphorus carried into the lake from the Mukuvisi and Nyatsime rivers are responsible for the growth of water hyacinth. Limnological research has shown that the eutrophication limit for phosphorus in the lake is as low as 0.02 mg/l. If the phosphorus concentration is greater than this, and there is sufficient nitrogen as well (which is always the case), eutrophication will occur.

It may be useful at this stage to provide a few facts and figures about the water hyacinth (*Eichhornia crassipes*). The water hyacinth is a vascular aquatic plant which can absorb large quantities of both nutrients and pollutants from an aquatic environment. It multiplies faster than any other known freshwater plant (only ocean kelp can grow faster) and this growth rate can increase by 2 – 4 times the normal growth rate in a nutrient-enriched environment.

The growth rate and viability of the water hyacinth are staggering:

- water hyacinths can double their size every ten days;
- ten plants can multiply, over a period of ten months, to 900 000 individual plants, which will cover an area of approximately 0.5 ha.;

- during its usual eight months growing season, a single plant can produce more than 70 000 'daughter' plants; and
- water hyacinths annually produce as many as 90 million seeds per hectare. These seeds can remain viable and able to germinate for up to 20 years.

It is a known scientific fact that the water hyacinth cannot be eradicated, only controlled. Plant hormone herbicides such as 2–4–D and glyphosate ('Roundup') are the only effective means of controlling water hyacinth, as mechanical methods simply cannot cope with its explosive growth. After several years of delay, during which time the hyacinth virtually took over Lake Chivero, Cabinet finally recognised this in 1990 and authorised the use of herbicides on the weed.

Although the water hyacinth removes both nutrients and pollutants from an aquatic environment very effectively, it is a pollutant itself for several important reasons:

- a dense canopy of hyacinth plants will prevent oxygen transfer to the water from the atmosphere. It will also block out sunlight and prevent production of dissolved oxygen by algal photosynthesis. Dissolved oxygen is vital for the maintenance of a normal aquatic ecosystem;
- when the plants die, they quickly sink to the lake floor where they decompose. Conditions in the deeper water near the lake floor very quickly become anaerobic because the rotting plant debris and aquatic organisms, which depend on dissolved oxygen, can no longer inhabit these areas of the lake. Furthermore, if high concentrations of sulphate are present, either in the lake water or within the vascular cells of the plants, anaerobic decomposition can result in the production of toxic hydrogen sulphide gas;
- an adequate level of dissolved oxygen is also an important factor in the treatment of the lake water in Morton Jaffray Works. Very low dissolved oxygen concentrations require greatly increased doses of alum (aluminium sulphate) to clarify the water by flocculation and sedimentation of suspended solids. A significant amount of the aluminum will also go into solution, instead of forming insoluble precipitates. As a result, not only is the water more expensive to purify, but aluminium levels could exceed the recommended safe limits. The extra treatment cost will inevitably be passed on to the consumer, and the higher alum does greatly increase the volume of alum sludge which must be disposed of; and
- Lake Chivero is an important recreational water body and the presence of the water hyacinth has severely curtailed power boating, yachting and angling.

There is another important pollutant in Lake Chivero, about which the public is not generally aware, – fluoride. As discussed previously, fluoride enters the Manyame river system via surface and groundwater contamination of the Mukuvisi River and Hatfield stream. Generally the concentration in Lake Chivero remains below 1.0 mg F/litre, which is the maximum permissible concentration in drinking water for health reasons. However, a serious spill from ZPI several years ago raised the concentration to between 1.6 – 1.8 mg F/litre, forcing the waterworks to switch over to more expensive water from the downstream Lake Manyame.

The problems associated with dental caries due to fluoride deficiency are well known but high levels of fluorine can also be toxic: in severe cases it can result in brittle and discoloured teeth, muscle stiffness and arthritis. Fortunately the fluoride concentration in the lake generally remains less than 1.0 mg F/l and therefore presents no threat to public health. However, it is ironic that Harare's water supplies are now fluoridated by pollution, while those who took part in the great public debate of several years ago about deliberate fluoridation are apparently totally unaware of this.

REGULATION OF EFFLUENT DISCHARGES

The Government regulations which control the discharge of effluents or polluted waters to a receiving water (Government Notice 687 of 1977) are among the strictest in the world.

All sewage treatment plants in Zimbabwe are required to operate within the limits of these regulations and in general, most do so. The sewage treatment plants which receive, treat and dispose of Harare's sewage range from relatively simple waste stabilisation pond systems to complex biological nutrient removal modified activated sludge (MAS) plants. The MAS plants at Firle and Crowborough Works are especially important in that they are able to remove sufficient nitrogen and phosphorus from the raw sewage to allow the treated effluent to be discharged direct to the river. It has been calculated that the efficient operation of these two MAS units allows up to 25% of Harare's potable water to be recycled.

The older treatment processes cannot comply with these standards, and so their effluents have to be disposed of by irrigation, which is increasingly expensive as nearby land comes under pressure for housing developments.

The Water Pollution Advisory Board (WPAB) which was set up by the Water Act and operates under the auspices of the Ministry of Energy, Water Resources and Development (MEWRD), is responsible for the 'policing' of illegal effluent discharges to water courses or water impoundments in Zimbabwe. The construction of suitable groundwater interception networks and a new effluent treatment plant at Zimbabwe Phosphate Industries has been due almost entirely to pressure from the WPAB on ZPI to reduce their level of contribution of pollutants to the Manyame river system. The WPAB is also able through MEWRD to refer cases of persistent illegal discharges to the Attorney-General's office for further action and probable criminal proceedings against the responsible individual or organisation.

CONCLUSIONS

This paper has attempted to give an insight into the nature of the pollution problems currently being experienced in Harare's rivers. It is clear that the security of Lake Chivero as the main source of supply of raw water for the Morton Jaffray Water Treatment Works is being seriously threatened by the continuing high level of illegal polluting discharges to rivers and watercourses within the Manyame river catchment.

Much has been said, and will continue to be said, about the need to control the spread of the water hyacinth and the use of herbicides, especially 2–4–D, to do this. However, given the tenacity of the plant and the scientific fact that it is impossible to eradicate once established, the pollution problem must be considered at source. In the author's opinion the only way to control the growth of the water hyacinth is to prevent the discharge of nutrient rich effluent into the Manyame river system, from either industrial or domestic sources. In all cases prevention is better than cure. Clamping down on one or two major offenders, in particular Chitungwiza, will have a significant impact.

Unfortunately, experience in other countries has shown that even if all point-source discharges of nutrients can be reduced to zero, a significant amount of nutrient will still enter the Manyame river system from non-point sources such as agricultural run-off and public health. However, it is ironic that Harare's water supplies are now fluoridated by pollution, while those who took part in the great public debate of several years ago about deliberate fluoridation are apparently totally unaware of this.

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Unfortunately, experience in other countries has shown that even if all point-source discharges of nutrients can be reduced to zero, a significant amount of nutrient will still enter the Manyame river system from non-point sources such as agricultural run-off and atmospheric fallout. Controlling these sources of pollution is likely to be much more difficult than controlling nutrients in effluent discharges, hence it is important to tackle the latter first.

Attaining a phosphorus concentration of less than the eutrophication limit of 0.02 mg P/l may well be impossible in the short term, but strict application of control measures, enforcement of pre-treatment of industrial effluent on site and better understanding of the nature of the problem by all levels of the population should go a long way to achieving this goal.