AN ASSESSMENT OF THE POSSIBLE HEALTH AND ENVIRONMENTAL IMPACTS OF RAW SEWAGE SPILLS IN MANYAME PARK RESIDENTIAL AREA- (St MARY'S) CHITUNGWIZA.

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Abstract.

The possible ecological and health implications of raw sewage spills in St Mary's, Chitungwiza were assessed by analysing the biological and chemical composition of the sewage water. The levels of bacterial pathogens, namely *Escherichia coli*, *Shigella* spp, *Salmonella* spp, faecal Streptococci and coliform (bacterial pathogen indicators) indicate that there are health and ecological risks within the study area. The most immediate health risks are potential widespread outbreak of waterborne diseases such as cholera, dysentery, diarrhoea, gastroenteritis, hepatitis and respiratory illnesses. In addition to waterborne diseases, there are also health problems caused by toxic sewage gases such as hydrogen sulphide, carbon dioxide, methane and ammonia.

Ecological hazards range from groundwater and surface water contamination, algal blooms in Manyame River and Lake Chivero, fish kills, proliferation of macrophytes and supporting of toxic algal species. Continuous nutrient loading into Lake Chivero, which is already hyper-eutrophic, can unset the ecological balance of the river and the lake. The raw sewage also exacerbates the problems of water scarcity faced by the country.

There is thus an urgent need to establish proper disposal methods for the raw sewage in this residential area in order to abet these impacts. The most immediate call is to improve/upgrade the efficiency of the operations of the sewage treatment works.

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1. Introduction

Zimbabwe, like most other African countries, is facing rapid unplanned urbanisation and population explosions. This in turn exerts serious pressure on infrastructure and service provisions. The rapid development and expansion of urban areas, concentrating people and their wastes and the development of industries is reported to have led to the deterioration of water quality and the degradation of urban environments in Africa. This degrading influence is due to increased intensities of urban storm water run-off, motor vehicle repairs in the open, rubbish dumping in drainage trenches, and the discharge of domestic and industrial effluent into urban streams. As a result, most urban areas in Africa face a myriad of environmental problems ranging from air and water pollution and poor waste disposal and management practices which all combine to create health hazards for the residents.

The risks and dangers from sewage are well documented and sewage treatment is often advocated to mitigate the public health and environmental risks. In the high-density area of St Mary's, Chitungwiza, however, raw sewage continuously spills and floods the neighbourhood, streets, drainage trenches and gardens of residents. Raw sewage is mainly water containing excretement, industrial effluent and debris. Problems experienced by this residential area escalated when New St Mary's housing units were connected to the old St Mary's' Sewage Treatment Plant without an enlargement of the reticulation system. As a result, the current operations are more than 100% overloaded. Bypassing due to overflow has occurred regularly since then. This problem of too high an inflow load results in continuous spilling of raw sewage into the neighbourhood. The regular malfunctioning of the reticulation system means that within a few days, overflow occurs and wastewater has created permanent pools in the low-lying sections and trenches. These pools have become favourable breeding ground for the mosquitoes and houseflies as large numbers of their larvae are found in the pools. These pools also give off offensive smells due to the decomposing organic matter deposits. Excess sewage collects into the storm drains and discharges in the Manyame River, which finally discharges into Lake Chivero.

Although the residents report that the sewage problem has almost become a perennial problem since 2001, the potential health and environmental implications of these continued spills in Chitungwiza have not been documented yet. The Zimbabwe Environmental Law Association is

concerned about these health and environmental impacts. It is against this background that the current study is based.

The objectives of the study were:

- To assess the potential health and ecological impacts of the raw sewage in Chitungwiza.
- To come up with possible mitigatory measures to abet the problems.

2. Methods and Materials

Twelve raw sewage samples were collected over a period of one week in order to analyse for the biological and chemical composition of the sewage. Four sampling stations were selected at random and three replicates were taken from each site at three-day intervals.

Biological composition:

Indicator organisms were used for monitoring the presence of pathogens in the sewage. Faecal indicators (*i.e*. bacteria and phage) indicate faecal pollution, which indicate the potential presence of water borne pathogens. The indicators used for assessment of possible health hazards in the study include:

Faecal coliforms:

Refers to all bacteria which produce both an acid (media turns yellow) and a gas (which collects in Durham tube) in McCkonkey broth within 24-48 hours of incubation at 37^{o}C. They are indicators of faecal pollution of water. They are used to evaluate the quality of wastewater effluents, river water, raw water for drinking water supply, recreational water as well as water used for irrigation, livestock watering and aquaculture. Faecal coliforms are used primarily to indicate the presence of bacterial pathogens such as *Salmonella* spp., *Shigella* spp., *Vibrio cholerae*, *Campylobacter jejuni*, *Campylobacter col*i, *Yersinia enterocolitica* and *Escherichia coli.* The presumptive coliform test (which indicates the number of coliforms) was done. 10ml of sample was added to three double strength tubes, 1ml of sample was added to three single strength tubes and 0.1ml to three single strength tubes of McConkey broth. Three tubes were uninoculated to act as the controls. All tubes were incubated at 37^{o}C for 48 hours. All tubes that showed production of an acid (media turns yellow) and gas (collects in Durhum tube) were regarded as presumptive positives (i.e. they presumed to contain coliform organisms). The most probable number per 100ml was estimated.

The confirmatory test for coliforms was done by taking 0.1ml from all tubes showing both acid and gas production and inoculating a tube of Brilliant Green Bile Broth (BGBB) which were then incubated for 24hrs at 44.5^{o}C. Reduction of the BGBB and production of gas indicated the presence of faecal coliforms.

Total bacterial numbers.

The total bacterial numbers were determined by the spread plate method. 0.1ml aliquots of the 10^0, 10^{-1}, 10^{-2}, 10^{-3} and 10^{-4} were inoculated onto yeast extract agar (YEA) and counts made after incubation at 37^{o}C for 48 hours. Three plates were prepared per each dilution.

Enterococci (Faecal Streptococci).

Refers to bacteria which produces typical reddish colonies on m-Enterococcus agar after 48 hours of incubation at 35 ^{o}C. These pathogenic bacteria often occur in human faeces and are more resistant than coliform bacteria. The presumptive faecal streptococci test was done as for the coliform test except that Glucose Azide Broth (double and single strength) was used instead of McConkey Broth. Production of an acid after 24hrs of incubation at 37^{o}C was regarded as presumptive positive.

The confirmatory test was done by plating taking a loop-full of inocula from the tubes which tested positive and plating on Bile Aesculin Azide Agar. The plates were incubated at 44^{o}C. Development of a black or brown colour confirmed the presence of faecal streptococci.

Salmonella and Shigella.

These are also pathogenic bacteria. Bacterial culture techniques were used for the detection of virulent *Shigella* spp and pathogenic *Salmonella* spp. Salmonella produces red colonies whilst Shigella produces cream colonies with a black dot in the centre.

Chemical composition.

The heavy metals, Lead (Pb), Zinc (Zn) and Iron (Fe) were measured by the Atomic Absorption Spectrophotometry (AAS) method. Aluminium was also detected by the same method. The concentration of phosphorus was measured by the colourimetry method.

3. Results

There were no significant differences between the sites and sampling days with respect to the total viable faecal coliforms, streptococci, Shigella and Salmonella spp detected from the sewage samples. The levels of these bacterial pathogens were quite high and exceeded the permissible ranges according to the Zimbabwe Government (1997) Water (Effluent and Wastewater Standards) Regulations. All the tubes tested positive for faecal coliforms and faecal streptococci, giving total viable counts of greater than 1100 throughout the monitoring period. This indicates continuous presence of fresh sewage. These results are shown in tables' 1a to 3c.

There were elevated levels of the limiting nutrient, phosphorus (P). The levels of P, iron (Fe), and aluminium (Al) fell outside the permissible limits whilst lead (Pb) and zinc (Zn) were overall not detectable (Table 4).

Table 1a: Total viable coliform counts of raw sewage samples from Chitungwiza on Saturday 24/11/03

	Coliform count				Faecal Streptococci			
Site	10ml	1ml	0.1ml	Count/100ml	10ml	1ml	0.1ml	Count/100ml
A	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
B	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
C	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
D	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100

Table 1b: Plate count results

Site	**10^{-2} dilution**	**Total count /ml**
A	161	$1.61 * 10^5$
B	364	$3.64 * 10^5$
C	97	$9.7 * 10^4$
D	47	$4.7 * 10^4$

Table 1c: Confirmatory test results.

Site	***Escherichia coli***	***Faecal Streptococci***	***Shigella spp***	***Salmonella spp.***
A	+	+	+	+
B	+	+	+	+
C	+	+	+	+
D	+	+	+	+

Table 2a: Total viable coliform counts of raw sewage samples from Chitungwiza on Wednesday 26/11/03.

	Coliform count				Faecal Streptococci			
Site	10ml	1ml	0.1ml	Count/100ml	10ml	1ml	0.1ml	Count/100ml
A	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
B	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
C	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
D	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100

Table 2b: Plate count results

Site	**10^{-4} dilution**	**Total count**
A	164	$1.64 * 10^5$
B	290	$2.9 * 10^5$
C	103	$1.03 * 10^5$
D	36	3.6 * 104

Table 2c: Confirmatory test results.

Site	***Escherichia coli***	***Faecal Streptococci***	***Shigella spp***	***Salmonella spp.***
A	+	+	+	+
B	+	+	+	+
C	+	+	+	+
D	+	+	+	+

Table31a: Total viable coliform counts of raw sewage samples from Chitungwiza on Saturday 29/11/03.

	Coliform count				Faecal Streptococci			
Site	10ml	1ml	0.1ml	Count/100ml	10ml	1ml	0.1ml	Count/100ml
A	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
B	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
C	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100
D	3+ve	3+ve	3+ve	>1100	3+ve	3+ve	3+ve	>1100

Table 3b: Plate count results

Site	**10^{-4} dilution**	**Total count**
A	120	$1.20 * 10^5$
B	123	$1.23 * 10^5$
C	134	$1.34 * 10^5$
D	103	$1.03 * 10^5$

Table 3c: Confirmatory test results.

Site	***Escherichia coli***	***Faecal Streptococci***	***Shigella spp***	***Salmonella spp.***
A	+	+	+	+
B	+	+	+	+
C	+	+	+	+
D	+	+	+	+

Table 4: The concentrations of the heavy metals and nutrients measured during the study period.

	DATE											
Site	**22/11/03**				**26/11/03**				**29/11/03**			
Parameter	A	B	C	D	A	B	C	D	A	B	C	D
Aluminium (mg/l)	1.2	9	0.9	1	27	12.8	1	0.9	1.9	2.1	1.2	1.2
Iron (mg/l)	10.6	1.4	1.5	1.7	1.5	9.6	0.7	0.4	8	21.3	1.4	1.1
Lead (mg/l)	0.01	0.03	ND	ND	0.1	ND	ND	ND	ND	ND	ND	ND
Tot P (mg/l)	20.94	11.9	13	8.2	31.41	27.2	8.2	6.46	20.94	23	21	13
Zinc (mg/l)	0.06	0.22	ND	ND	0.41	0.49	ND	ND	0.05	0.05	0.2	0.02

4. Discussion.

The elevated numbers of viable faecal coliforms throughout the monitoring period confirms that there is continuous spilling of raw sewage in St Mary's. This is so because if bacteria are left in the sun for too long a period, they will die. These faecal indicators indicate faecal pollution, which implies the potential presence of water-borne pathogens. Faecal pollution does of course also have aesthetic implications by virtue of its presence in the residential area. The results presented here indicate that there are large numbers of different risks out there right now, with the most immediate one being potential widespread outbreak of water-borne diseases such as cholera, typhoid, diarrhoea and dysentery.

Fly populations, which are vectors for most of the water-borne diseases, have risen to intolerable numbers and they have become a huge public health menace. The fly swarms accumulate on vegetables, walls, kitchen utensils and grass in very large numbers. Houseflies are vectors for the following bacterial pathogens; *Shigella* spp., *Salmonella* spp., *Vibrio cholerae* and *Streptococci* spp., all which were found in elevated levels in the raw sewage. The results thus indicate that the presence of raw sewage and the large numbers of pathogen vectors expose the residents to a variety of pathogenic micro organisms, viruses and intestinal worms that can cause serious illnesses. Sensitive populations such as children and the elderly and those with special health complications such as pregnant women, are especially at risk. One of the most common and dangerous pathogens isolated in this study is *E. coli.*

4.1.0. Health impacts of raw sewage.

Health risks imposed by *Escherichia coli (E. coli).*

E. coli is a gram-negative rod, motile and aerobic. It is a pathogenic bacterium with the disease being located primarily in the colony (invasion of epithelial cells of colony), fever, and can cause blood loss and diarrhoea. The most severe form may result in hypertension with severe toxemia. It can also cause kidney infection, haemorrhage and even dearth. This pathogen have very low infectious dose, only 10 organisms by ingestion. Thus the elevated levels of *E. coli* in this study greatly exposes the residents to the risks and hazards mentioned above.

Health hazards imposed by *Shigella* spp.

The genus *Shigella* is composed of four species, *Shigella dysenteriae*, *S. boydii*, *S. sonnei* and *S flexneri*. The infective dose of *Shigella* spp is very low, from 10^1 to 10^4 organisms (Rowe and Gross, 1984). *Shigella* spp causes acute diseases of large and small intestines, diarrhoea, fever, nausea and sometimes toxemia. Virulent *Shigella* spp organisms cause bacillary dysentery (shigellosis), which may lead to death in some cases if effective intervention strategies are not used. *S. dysenteriae* is the most fatal as it may produce enterotoxin (shiga toxin). Most deaths would occur in children under 10 years of age especially during the weaning period. It has a wide range of transmission ranging from direct or indirect faecal-oral route; poor hygiene practices spread infection, fly and cockroach borne infections are quite possible in the study area as a result of direct faecal contamination.

Health hazards imposed by *Salmonella* spp.

This is yet another pathogenic bacteria isolated from the raw sewage during this study. The species, *Salmonella typhi* is known to cause typhoid fever, enteric fever, anorexia and enlargement of the spleen. Some complications include patches in the ileum; can also produce haemorrhage or perforations, diarrhoea and dehydration problems. The residents are at a greater risk of infection by this pathogen as it is transmitted by the flies, which infect foods in which the organisms may multiply to achieve the infective dose.

The detection of the organisms, *E. coli, Shigella, Salmonella*, faecal *Streptococci* thus indicate the potential risks and hazards faced by the residents and the nation as a whole. Continuous presence of raw sewage within the residential area also gives greater chances for the flourishment of more virulent strains of bacteria and viruses. High levels of faecal coliforms in this study indicate the presence of some bacterial pathogens such as *Campylobacter jejuni, Campylobacter coli, Yersinia enterocolitica* and toxigenic *Vibrio cholerae.* Toxigenic *V. cholerae* causes cholera, a highly epidemic diarrhoeal disease that continues to devastate many developing countries where socio-economic conditions are poor, sanitary systems and public hygiene are rudimentary. The ingestion of approximately 10^4 to 10^6 *V. cholerae* organisms can produce clinical cholera (Cash *et al.,* 1974)

Coliform bacteria, particularly *E.coli,* along with Streptococci, have also been widely used as indices of faecal pollution and thereby the potential presence of human enteric viruses. Thus the elevated levels of Coliform bacteria and Sterptococci bacteria in this study probably indicate the presence of coliphages and thus the concurrent presence of pathogenic viruses. Coliphages are bacterial viruses, which infect and replicate in *E.coli* and may infect related coliform bacteria. Viruses are important causative agents of waterborne diseases and can cause illnesses such as gastroenteritis, hepatitis, poliomyelitis and respiratory illnesses. Viruses have a considerably lower minimum infectious does than bacteria, with a single viral particle being capable of causing infection.

It was noted that the residents are also using the raw sewage water for irrigation. This practice predisposes them to infections caused by enteric viruses. Enteric viruses are excreted in faecal matter and have been found to cause fatal infections in man. The enteric virus group includes enteroviruses (that is polio, cox sackie A and B and echo viruses), hepatitis A and B viruses. The possible effects of the raw sewage in Chitungwiza includes **paralysis, meningitis, hepatitis, respiratory illnesses and gastroenteritis, all which are associated with presence of enteric viruses.** Enteric viruses can be transmitted via the consumption of raw vegetables, which are irrigated with raw sewage.

There are also a number of protozoan parasites that are excreted by humans and are thus found in raw sewage. These include Giardia and Cryptosporidium, which are infective to humans. The infections occur by ingestion of the cysts or oocysts and diseases take the form of gastroenteritis, diarrhoea and anorexia.

4.1.1. Environmental impacts of raw sewage.

Raw sewage has several undesirable ecological impacts. Untreated sewage is the major source of groundwater and surface water pollution. It should however be stressed that water (both surface and groundwater) is a very scarce commodity in Zimbabwe. This is because Zimbabwe is in a drought prone region and thus the replenishment of these water resources is low. The raw sewage in Chitungwiza thus exacerbates the problems of water scarcity in the country.

The sewage that originates in Chitungwiza finally drains into the Manyame River. The Manyame River is one of the tributaries that feed Lake Chivero, the others being Mukuvisi and Marimba. Pollution in any of the Lake's tributaries consequently results in adverse effects in the lake especially as the rivers' self purification capacity has continuously been lowered with the rise in pollution levels in the rivers (Machena, 1997). The discharge of the limiting nutrients (i.e. the high Phosphorus levels) favours the growth of the noxious weed, *Eichhornia crassipes* (water hyacinth) and other aquatic macrophytes such as *Azolla* and *Nymphea.* In this study, the levels of phosphorus consistently fell outside the permissible limits (i.e. ranged from 6.46 to 31.4mg/l) when the maximum permissible concentration of this nutrient is 0.5mg/l (Zimbabwe Water Regulations, 1977).

It was noted that there is a dense overgrowth of aquatic macrophytes in the Manyame River just downstream of the point where the drain, which carries wastewater from the affected residential area, joins the river. The dominant weed was the water hyacinth (*E. crassipes*). Aquatic weeds (macrophytes) such as water hyacinth (*E. crassipes*), Kariba weed (*Salvinia molesta*) and carpetweed (*Azolla ficuloides*) can cause serious problems in the aquatic ecosystem. They can cover the water bodies and smother habitats, reducing light and oxygen and ultimately eliminating fish populations. Recent data from the Gwebi River near Harare showed that the diversity and abundance of fish, amphibian and invertebrates was much reduced under floating mats of *Azolla filiculoides* (Gratwicke and Marshall, 1998). The Manyame River may thus be rendered incapable of supporting a rich fish biomass because macrophyte overgrowth (due to excessive nutrient loading from raw sewage) could lead to a pronounced decline in fish diversity. Apart from the macrophytes destroying habitats and spawning grounds, excessive pollution loading also kills invertebrates, which are essential fish food. Excessive plant growth suffocates fish and irritates gill membranes thereby contributing to fish stress and increasing their susceptibility to diseases.

When human waste is discharged into water, bacteria decompose the organic matter within the sewage. As the bacteria decompose the organic substances, dissolved oxygen in the water is consumed. With the large quantities of waste being discharged into the Manyame River, the bacteria's biochemical oxygen demand (BOD) can seriously deplete the dissolved oxygen levels in the water. Many cichlid fish are sensitive to oxygen levels below 3mg/l (Magadza, 1997), thus fish

death due to anoxia may result. Already, there have been several episodes of fish kills in the Manyame River and Lake Chivero as a result of raw sewage pollution.

The release of substantial quantities of raw sewage from Chitungwiza is contributing greatly to the cultural eutrophication of the Manyame River and consequently Lake Chivero. Raw sewage discharges are a major component of water pollution contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and can lead to a destabilised aquatic ecosystem. The communities of Harare, Chitungwiza and Ruwa rely almost entirely on Lake Chivero for water for a variety of purposes such as drinking, fishing, industrial and recreational purposes. Although it is possible to renovate polluted surface water to potable standards, this would be both complex and very expensive, which may make the supply unsustainable. As a result it is of paramount importance that the rivers feeding into Lake Chivero, Including the Manyame, remain in a health state.

The high concentrations of limiting nutrients in the raw sewage may support the proliferation of algal blooms in the receiving water bodies. For example the water in the Manyame River and Lake Chivero actually have a dirty green tinge because of the dense algal mats (personal observation). It is reported that recreational activities in and around Lake Chivero have decreased substantially because of the algal blooms coupled with the factors such as the water hyacinth. Continuous spilling of raw sewage from Chitungwiza will inevitably amplify these problems. Another problem associated with algal blooms is the formation of scums that are unsightly and also decrease the aesthetic value of the waters. Algal bloom outbreaks can also kill livestock due to the production of lethal toxins. They can also reduce the germination of seeds when polluted water is used for irrigation (Moyo pers. com).

Other problems likely to be caused by algal blooms include the clogging of filters and water purification difficulties. In the case of a large city like Harare, the clogging of filters would lead to erratic water supplies.

Besides reducing the aesthetic value of the water bodies, dense phytoplankton can shade the plants below them and reduce their photosynthetic capacity. This would consequently reduce the

oxygen for other aquatic species such that overall, the species diversity of the aquatic ecosystem is adversely affected.

The heavy nutrient loading can also support dense algal blooms of species that can produce organic waste namely geosmin and isomethylborneol that impart unpleasant odour in drinking water. This is noticeable in the tap water of Harare. The process of removing the algae and the associated odour and tastes from the water means an added cost of water purification to the residents. Algal blooms are also a threat to public health as algal toxins may cause diseases. Cyanobacteria have been found to produce toxins that are hepatotoxic, carcinogenic and tetratoxic to both humans and aquatic organisms (Lawton *et al*., 1994). For example the massive fish kills reported in Lake Chivero in 1996 were not only associated with physiological stress as a result of low water quality but also because of algal toxicity and was reflected by the dead fish's enlarged livers (Moyo, 1997).

Work done on Lake Chivero on the toxicity of algae suggests that algal toxins may be responsible for the seasonal outbreaks of gastro-enteritis in the city of Harare (Marshall, 1991). This is because in the treatment process, chlorination water with numerous algal cells results in the lysis of the cells that releases toxins and microcystins into the water thus putting the consumers at risk of being exposed to the toxins and their adverse effects on health. In addition to being hepatotoxic, microcystins have sterility inducing and tumour promoting properties, and also have carcinogenic effects (Irvine *et al*., 2002).

Wastewater effluents often contain high amounts of dissolved salts from industrial and domestic sewage. The build up of salts from domestic waste can interfere with water reuse by municipalities, textile, paper and food processing industries, and agricultural water for irrigation. Salts such as sodium chloride and potassium sulfate pass through conventional water treatment plants unaffected (Hammer, 1975). High salt concentration in wastewater effluent can increase the salinity of the receiving waters, which may result in adverse ecological effects on biota. Already there are reports that Lake Chivero is becoming endhorheic because salinity levels have progressively been increasing over the years (Magadza pers. com). The input of large quantities of domestic sewage

with high sodium and chloride content into the lake (as well as the low replenishment time due to the recent droughts) appears to have transformed Lake Chivero into a typical endorheic (saline) lake. If such a condition is maintained on long-term basis, it will have significant implications on the floral and faunal composition of the lake.

There are several other ecological consequences linked to stratification of enriched lakes. During summer stratification, the epilimnion is separated from the hypolimnion by a thermal gradient, so that mixing of the water in the two layers is inhibited. As a result the exchange of dissolved gases and chemical substances between the two layers will be retarded. High nutrient loading into Lake Chivero from the raw sewage will increase the primary productivity (in the form of algal blooms) of the lake. The decay of the rain of organic matter from the highly productive epilimnion would rapidly deplete the oxygen reserves of the hypolimnion. Within a month of the outset of stratification, the hypolimnion would become anaerobic. Under these reducing conditions, ammonia will be the dominant form of bound nitrogen. Anaerobic organisms would also reduce sulfates to hydrogen sulphide and nitrates to nitrogen gas. Aerobically precipitated iron, manganese and orthophosphates will be resolubilised. Under these anaerobic conditions, with the lack of vertical mixing into the epilimnion, the concentrations of these substances in the hypolimnion will rise. Most of these chemical changes are lethal to aquatic organisms and may also seriously detract from the usefulness of hypolimnetic water as a domestic and industrial raw water supply.

Apart from increasing the nutrient load, the high levels of nitrate contained in raw sewage also have potential health risk. Presence of nitrate in drinking water (due to inadequate treatment of polluted raw water supply) is linked to the condition known as methaemoglobinaemia in infants and pregnant women. Methaemoglobinaemia is when the oxygen carrying pigment, haemoglobin, complexes with nitrate-nitrogen so that it is no longer available for oxygen transportation. Whilst this occurs very rarely and only in water containing more than 10mgNO_3–N/l, it is still a cause for concern.

Raw sewage also contains toxic chemicals, which can directly affect aquatic life. These chemicals include disinfectants, detergents, soaps and dyes. All these chemicals are thus being discharged with the raw sewage into Manyame River and Lake Chivero, potentially intoxicating the aquatic

flora and fauna. Additionally, raw sewage contains elevated levels of steroid hormones (from use of contraceptives). The discharge of these endocrine-active substances into watercourses is known to cause testicular feminisation in fish at a level of 1mg/l. The median lethal concentration for fish is about 600mg/l (Sebastian and Claassen, 2001). There are thus two hazards posed by the raw sewage being discharged into the Manyame River from Chitungwiza. These threats are fish mortality and possible population extinction of fish through inhibition of fertility.

The levels of iron were found to consistently fall outside the permissible limits throughout the monitoring period. This is one of the heavy metals measured in this study with lead and zinc falling within the permissible ranges. The major sources of heavy metals in sewage are industrial effluent. Thus the low concentration of these heavy metals (i.e. lead and zinc) in this study indicates that the sewage is predominantly of domestic origin. Aluminium was found to be intolerably high. All heavy metals ultimately become toxic at some elevated concentration. Abnormally high concentrations of iron and aluminium in this study can cause inability of organisms to excrete, sequester or otherwise detoxify themselves (Thorp *et al.*, 1979).

The major problem with metals is that they can become strongly enriched in the aquatic food chain through a process referred to as bioaccumulation or bio-magnification (Forstner and Muller, 1976). The aquatic organisms can accumulate metals to levels above those that are required for normal physiological functioning. Humans can in turn acquire abnormally high levels of heavy metals through consumption of fish and other foodstuffs that have high concentrations of these metals. Thus metal contamination of the ecosystem has serious complications. Excessive consumption of iron, for example, results in haemochromatosis, wherein tissue damage occurs as a consequence of iron accumulation. Haemachromatosis will result with prolonged consumption of foodstuffs that have accumulated high levels of iron.

There is also a greater possibility of increasing the incidence of pests associated with sewage 'irrigated' plants. In addition, the warm climate supports the continuous growth of plants during the dry season and ensures that at a time when the land is normally barren and arid, substantial green plant mass is available which allows insect populations to thrive when they would normally encounter a seasonal decline. Such insects/pests include the mosquitoes. Mosquitoes can spread

deadly elephantiasis and malaria. Mosquitoes are the vectors for the parasites plasmodium (which causes malaria) and microfilaria (which causes elephantiasis).

4.1.2. Conclusions and recommendations.

The continuous spilling of raw sewage in St Mary's exposes the residents to a variety of **pathogenic micro-organisms, viruses and intestinal worms that can cause serious illnesses such as: gastroenteritis, dysentery, cholera, polio, typhoid and paratyphoid enteric fevers, hepatitis, infection of skin or eyes, parasitic infections such as ascaris, giardiasis and amoebiasis**. Raw sewage also has the potential to spread other serious illnesses. For instance, during the SARS outbreak, the WHO stated: "In the absence of proper maintenance and without consistent monitoring, reviewing, enforcing and updating of building standards and practices, inadequate plumping and sewage systems could continue to enhance the potential of SARS and some other diseases to spread". Bacteria in the raw sewage, after being deposited in the soil could be transported by air and spread illnesses among the people. High exposure to bacterial endotoxin may cause health effects including fever, cough and dyspnoea. Endotoxins are cell wall components of gram-negative bacteria (GNB). Inhalation of GNB cell fragments produce both toxic and hypersensitivity effects. Chronic inhalation of bacterial endotoxin causes chronic bronchitis, emphysema and may be associated with airway hyper responsiveness.

In addition to water borne diseases, there are also health problems caused by toxic sewage gases such as hydrogen sulphide, carbon dioxide, methane, ammonia and other biological agents. The major adverse health effects and hazards faced by the residents from exposure to sewer gases are: (1) Poisoning from hydrogen sulphide (H_2S), asphyxiation from displaced or consumed oxygen, (2) decreased vigilance or fatigue due to reduced oxygen levels (from carbon dioxide (CO_2) and methane (CH_4)), (3) fires and explosions from CH_4 gas, H_2S and other flammable gases and (4) phytotoxicicity.

There are several ecological impacts of the raw sewage. The sewage is degrading the environment by polluting waterways, adversely affecting fish and other wildlife species. It causes the explosion of algal growth, depleting oxygen in the water and could lead to fish deaths. The untreated sewage is a major source of groundwater and surface water pollution and is thus exacerbating the

problems of water scarcity in the country. The organic material contained in the raw sewage uses substantial oxygen for biological degradation and would certainly unset the ecological balance of the Manyame River and consequently Lake Chivero.

4.1.3. Mitigatory measures.

There is an urgent need to establish a proper disposal method for the raw sewage in St Mary's as this is seriously threatening public health. Indications so far are that close to 99% of sewage generated in the area is not reaching the treatment works. The current operations are also 100% overloaded. There is thus an urgent need to improve the efficiency of the operation of the St Mary's sewage treatment works. There is also need for the municipal authorities to consider applying for construction of wetlands to enhance the quality of their sewage effluents. These are fairly easy to construct. Constructed wetlands can significantly reduce the ecological implications discussed above as they can remove about 80% of BOD, 95% of suspended solids, about 60% of phosphorus and about 45% of nitrogen.

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