Water Pollution in Soshanguve Environs of South Africa

O. I. Nkwonta, and G. M. Ochieng

***Abstract*—**Surface water pollution is one of the serious environmental problems in rural areas of South Africa due to discharge of household waste into the streams, turning them into open sewers. In this study, samples of water were collected from a stream in Soshanguve and analysed. The result showed that pollution in the area was caused by man and its activities. The water quality in the area was found to have deterioted significantly after water runoff from farms and household wastes. The result shows, fertilizer runoff contributes 50% of the pollution while pesticides and sediments contribute up to 10% respectively in the streams, while household waste contributes up to 30%. This study gives an outline of the sources of water pollution in the area and provides a process of creating a clean and unpolluted environment for Soshanguve community in Pretoria north in order to achieve the 7th aim of the millennium development goals by 2015, which is ensuring environmental sustainability.

***Keywords*—**Fertilizer, Household waste, Pollution, Roughing filters.

I. Introduction

WATER comprising over 70% of the Earth's surface, is undoubtedly the most precious natural resource that exists on our planet. Without the seemingly invaluable compound comprised of hydrogen and oxygen, life on earth would be non-existent. It is essential for everything on our planet to grow and prosper. Although we as humans recognize this fact, we disregard it by polluting our rivers, lakes, and oceans. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. In addition to innocent organisms dying off, our drinking water has become greatly affected as is our ability to use water for recreational purposes. In order to combat water pollution, we must understand our problems and be part of the solutions.

In South Africa, which is a developing country, it can be expected that large-scale development will take place. Unfortunately an increase in mining, industrial, agricultural and domestic activities may lead to water pollution unless certain precautions are taken. The development of towns and industries in South Africa and the associated accumulation of wastes in built-up areas during the first half of the previous century induced problems concerning environmental pollution [1]. Precautions can, however, be very costly and are therefore not always enforced [2].

The term "water quality" was coined with reference to the quality of water required for human use: "good quality" water is "clean" and unpolluted and suitable for drinking as well as for agricultural and industrial purposes. Although scientific measurements are used to define the quality of water, it's not a simple thing to say that "this water is good," or "this water is bad ". The quality of water that is required to wash a car is not the same quality that is required for drinking water. Therefore, when we speak of water quality, we usually want to know if the water is good enough for its intended use, be it for domestic, farming, mining or industrial purposes, or its suitability to maintain a healthy ecosystem [3].

Water is also said to be a national asset; one on which the economic and social development of South Africa depends [2]. South Africa is the 30th driest country in the world [3]. It is shown in Fig. 1 that in South Africa, most water is used for agriculture and irrigation, forestry, industry, and domestic use. About 39% of water is protected for the survival of the environment [3].

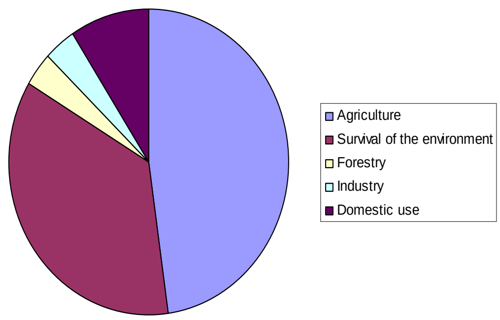

Fig. 1 Water use in South Africa

The increasing demand for water resulting from both the economic and population growth has to be met from limited resources shared by competing user groups [4].Therefore, water in South Africa, is critical and also it is the most limiting natural resource in the country [4]. With water resources in the country becoming increasingly scarce [5], more optimal management of this resource is of vital importance to ensure continued economic growth in this developing country [4].

Lack of safe drinking water supply, basic sanitation and hygienic practices is associated with high morbidity and mortality from excreta related diseases. Diarrhoeal illness remains a major killer in children and it is estimated that 80% of all illness in developing countries like South Africa is

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related to water and sanitation; and that 15% of all child deaths under the age of 5 years in developing countries result from diarrhoeal diseases [6]. Improved water management, including pollution control and actions to ensure access to adequate and safe water for poor and poorly-serviced communities are needed in Soshanguve. Actions to ensure access to improved and if possible of productive eco-sanitation for poor household in Soshanguve are recognized and this is necessary in other to achieve the 7th aim of millennium development goals that is ensuring environmental sustainability in our community.

The aim of the work is to identify the causes of water pollution in the area and to outline the process of creating a clean and quality water supply for the community in order to achieve the millennium development goals.

II. Materials and Methods

A. Study Area

Soshanguve is situated about 45km north of Pretoria. Established in 1974, it is a cultural mixes of Sotho, Shangaan, Nguni and Venda. Bad town planning and urban designs during the apartheid ensured that previously disadvantaged communities felt most of the environmental degradation [2]. Today most communities such as Soshanguve continue to be exposed to environmental hazards, without adequate access to essential services such as quality water supply, adequate sanitation and health working environment.

At block k.k., in Soshanguve north, the one source of water supply is a stream that does not provide good quality water for the community.

B. Experimental Procedure

In conducting this study, water samples were collected from a stream in block k.k. in Soshanguve. This was done in order to examine where the water quality has been exceeded and therefore where problem exist in the water quality of the study area. Standard method was adopted. Water samples were collected from the stream with 5ℓ high density polyethylene containers, previously washed with quality HNO_3 and rinsed after wards with distilled water. The samples were filtered through glass fibre filter paper. The pH of the samples was measured using an electric pH meter with glass electrode (ORION, model 410A). Nitrate was measured using the salicylate method, to a 100 mℓ glass beaker, 5 mℓ aliquot of the sample was added, followed by 2 mℓ of 0.5 % sodium salicylate and then the beakers were placed in a water bath heater; to evaporate to dryness. After evaporation, they were cooled and 1 mℓ of concentrated H_2SO_4 was added, while tilting the beakers to wet the bottom and lower edges with the H_2SO_4 completely, thereafter they were allowed to stand for 10 mins before adding 10 mℓ of NaOH (50 % w/v) solution. Each solution in a beaker was transferred to a separate 100 mℓ volumetric flask by rinsing the beakers a couple of times with distilled H_2O. Absorbance of the samples, together with those of KNO_3 standards were read at a wavelength of 410 nm, using a spectrophotometer (DR Lange Spectrophotometer, model CADAS 50 S). Turbidity was measured with a (DRT 15CE) turbidity meter. Metals like iron and manganese were determined using Atomic Absorption Spectroscopy (AAS) as described in Standard methods [7]. Table I was used to compare the water quality in the studied area.

TABLE I
THE WATER QUALITY STANDARD FOR SOUTH AFRICA

Variables	unit	Drinking water quality
pH	-	6-9
Conductivity	ms/m	0.70
Mg	mg/l	30.00
Na	mg/l	100.00
Cl	mg/l	100.00
Sulphate	mg/l	200.00
Manganese	mg/l	-
Total iron	mg/l	0.10

South Africa water quality standard for domestic use [3]

C. Water Analysis

Samples of water were collected and analysed for turbidity, metals like iron, total suspended solids, conductivity and nitrate and it was shown in Table II. Stream site 1(upstream) - flowing through an informal settlement. Water is odourous and contaminated with surface runoff from abandoned household waste.

Stream site 2 (downstream of site 1) water is contaminated through surface runoff from the farm.

TABLE II
THE WATER QUALITY OF THE STREAM

Parameters	Stream site 1 (up stream)	Stream site 2 (down stream)
Sulphate	211	234
Turbidity (NTU)	13	58
Iron (mg/l)	5.21	8.71
Manganese (mg/l)	38.0	42.10
pH	6.0	5.7
TDS (mg/l)	32.56	4.70
Conductivity	3.15	5.5
Nitrate (mg/l)	2.27	22

III. Results

In order to monitor the quality of water in the area, parameters like conductivity, turbidity, metals like iron and manganese are being compared with the standard set by DWAF. In Table II, it can be observed that great variations in water quality parameters were experienced in both two streams. The higher levels of suspended solids and turbidity in stream 2 (downstream), for instance compared to stream 1(up stream), were attributed to the effect of fertilizer runoff from the farm causing an increase in sediments in the stream as opposed to stream 1(upstream) where the major contribution to stream flow is from household waste and therefore fairly clear water is experienced. Average percentage type of pollution in the area is shown in Fig. 2.

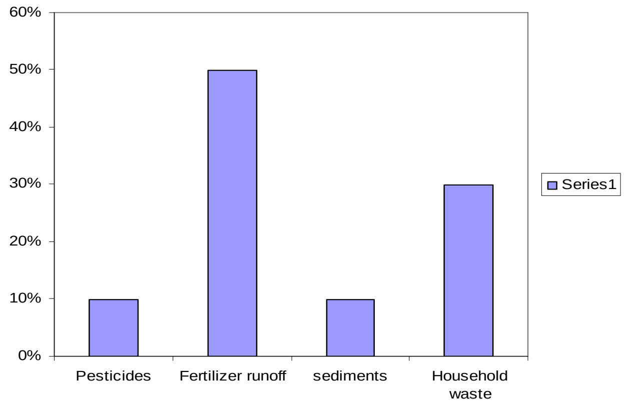

Fig. 2 Type of pollution in the area

IV. Discussion and Conclusion

Collected data indicated that the stream site 1 (up stream) and stream site 2 (down stream) are poor. It can be noted that the water is not suitable for domestic use in terms of agriculture; there is a definitive possibility of contamination of vegetables and other crops eaten raw. Without doubt, the community awareness of the dangers of using polluted water is evident, from the limited use made of the stream water. One would, however still argue for further environmental education and capacity building programmes, taking into account the generally low levels of education of residents, coupled with the fact that over 50% use the stream to water their vegetation, farming, washing of clothes and household uses.

A high percentage of the community (50%) uses the river for dumping household wastes. This however is done not out of ignorance of the possible negative environmental consequences of such action but out of necessity. Unfortunately the municipality is failing to capitalise on this awareness to put clearly, the problems associated with water pollution in the area. The Senate has passed laws to combat water pollution thus acknowledging the fact that water pollution is, indeed, a serious issue. But the government alone cannot solve the entire problem. It is ultimately up to us, to be informed, responsible and involved when it comes to the problems we face with our water. Having established the nature and approximate extent of the water pollution problems, it is now appropriate to consider what remedial actions are feasible. There are two options which is treating the water effluent at the site and preventing the water at the source.

The community must become familiar with their local water resources and learn about ways for disposing harmful household wastes so they don't end up in streams. In farms the community must determine whether additional nutrients are needed before fertilizers are applied, and look for alternatives where fertilizers might runoff into the stream. The community has to preserve existing trees and plant, new trees and shrubs to help prevent soil erosion and promote infiltration of water into the soil and streams. Around their houses, they must keep litter, pet waste, leaves, and grass clippings out of gutters and storm drains. These are just a few of the many ways in which the community, as humans, has the ability to combat water pollution.

Secondly water has to be treated before it is good for consumption. We have various methods of water treatment especially conventional methods. Conventional water treatment unit processes, are pre-treatment steps of chemical coagulation, rapid mixing and flocculation, followed by floc removal via sedimentation or flotation. Conventional treatment is quite demanding in chemical use, energy input and mechanical parts as well as skilled manpower that are often unavailable, especially in rural areas of developing countries like South Africa. This scenario calls for appropriate technologies that utilize locally available materials, skills and other resources in accessing quality, effective and less costly treatment system such as Roughing filters.

Roughing filters are simple, efficient and cheap water treatment technology compared to the conventional system. This is in terms of technical labour requirement, daily operation, maintenance costs and treatment efficiency and effectiveness [8].

Roughing filters can be considered as a major treatment process for water, since they efficiently separate fine solid particles over prolonged periods without addition of chemicals. Roughing filtration provides superior treatment to basic sedimentation methods [9] and represents an attractive alternative to more costly conventional coagulation methods. Roughing filters are primarily used to separate fine solids from the water that are only partly or not retained at all by stilling basin or sedimentation tanks. Roughing filters mainly acts as physical filters and reduce the solid mass. However, the large filter surface area available for sedimentation and relatively small filtration rates also supports absorption as well as chemical and biological processes. Therefore besides solid matter separation, roughing filters also partly improve the bacteriological water quality and, to a minor extent, change some other water quality parameters such as colour or amount of dissolved organic matter [9]. Roughing filters are classified as deep-bed filters, whereby proper filter design promotes particle removal throughout the depth of the filter bed, maximising the capacity of the filter to store removed solids. Particle removal efficiency in roughing filters is dependent on filter design, particulate, and water quality parameters [9], [10].

Roughing filtration technology is a filtration process through a coarse medium using low filtration rates. Given the high solid retention capability of roughing filtration, this process was considered likely to be an appropriate treatment for suspended solids by means of biological process [9]. We have two types of roughing filters Vertical flow roughing filters and Horizontal flow roughing filters.

A. Design Concept

With the renewed interest in roughing filter has come fresh thinking on design concepts related to plant layout, access to filter performance, monitoring and kinds of materials to use for filter media. Wegelin design can simplify construction of a filter and can make the design job easier. Now the conceptual filter theory for evaluating the efficiency of the filter is still based on the filtration theory described by [9]. When a particle in the water passes through a gravel bed filled up with gravel there is a chance to escape the particle either on the left side or on the right side or a chance to settle at the surface of the gravel. Hence the probability of chance of the success of removal and the failure is 1/3 and 2/3. According to Fick's law the filter efficiency can be expressed by the filter coefficient or,

$$\frac{dc}{dx} = -\lambda c \quad (1)$$

Where:
c = Solid concentration,
x = Filter depth,
λ = Filter coefficient or coefficient of proportionality. From the above equation it can be stated that the removal of the suspended particles is proportional to the concentration or the particles present in the water.

The total length of the filter can be described as the number of parallel plates and act as a multistage reactor so the performance of the HRF can be ascertained on the basis of the results obtained from the small filter cells. The total suspended solid concentration after a length of Δx of the filter cell can be expressed,

$$c_{outlet} = \Sigma^{C}{}_{inlet} e^{-\lambda i \Delta x} \quad (2)$$

Where:
λ_i = Filter efficiency of each filter cell,
Δx = Length of experimental filter cell
c_{inlet} and c_{outlet} = Concentration of particles in the inlet & outlet of the filter.

It is to be stated that after evaluating the filter depth (length) and the filter coefficient and the Suspended Solids concentration, the performance efficiency of the filter can be predicted.

According to [9], the effluent quantity for the n number of compartments is given by,

$$Ce = C_0 * E_1 * E2 * E3 * E4^{*}. \ldots \ldots En \quad (3)$$

Where
C_0 = Concentration of the HRF influent,
Ce = Concentration of the HRF effluent
$E_1, E_2, E_3, E_4. \ldots \ldots E_n$ = Filtration efficiency for the each compartment (1, 2, 3 respectively).

The basic expression for the above relationship is expressed by,

$$Ce = Coe^{-\ddot{e}L} \quad (4)$$

Where:
$\ddot{e}$ = Coefficient of filtration
L = Length of the filter.

The Filter efficiency is given by,

$$E = Ce/C_0 = e^{-\ddot{e}L} \quad (5)$$

$$Ce = Co * E$$

E_i = Filter efficiency for (i−1, 2, 3 . . . n) compartments.

The description of the theory above showed that solid removal by filtration can be described by exponential equation.

B. Vertical Flow Roughing Filters

Vertical flow roughing filters operate either as down flow or up flow filters. They are hence either supplied by inflowing water at the filter top or at the filter bottom. The vertical flow roughing filters incorporates a simple self cleaning mechanism and occupies minimal floor space when compared to horizontal flow roughing filters.

The filter material of vertical-flow roughing filters is completely submerged. A water volume of about 10 cm depth usually covers the gravel and other local available materials like coconut fiber and broken burnt bricks. The top should be covered by a layer of coarse stones to shade the water and thus prevent algal growth often experienced in pretreated water exposed to the sun. Drainage facilities, consisting in perforated pipes or a false filter bottom system, are installed on the floor of the filter boxes. Finally, pipes or special inlet and outlet compartments are required to convey the water through the subsequent three filter units and they are shown in Fig. 3.

C. Horizontal Flow Roughing Filters

As shown in Fig. 3, unlimited filter length and simple layout are the main advantages of horizontal roughing filters. Horizontal roughing filters have a large silt storage capacity. Solids settle on top of the filter medium surface and grow to small heaps of loose aggregates with progressive filtration time. Part of the small heaps will drift towards the filter bottom as soon as they become unstable. This drift regenerates filter efficiency at the top, and slowly silts the filter from bottom to top.

Horizontal-flow roughing filters also react less sensitively to filtration rate changes, as clusters of suspended solids will drift towards the filter bottom or be retained by the subsequent filter layers. Horizontal-flow roughing filters are thus less susceptible than vertical-flow filters to solid breakthroughs caused by flow rate changes. However, they may react more sensitively to short circuits induced by a variable raw water temperature. Roughing filters has achieved great results in Kenya, Tanzanian, Sri Lanka, and Indonesia etc.

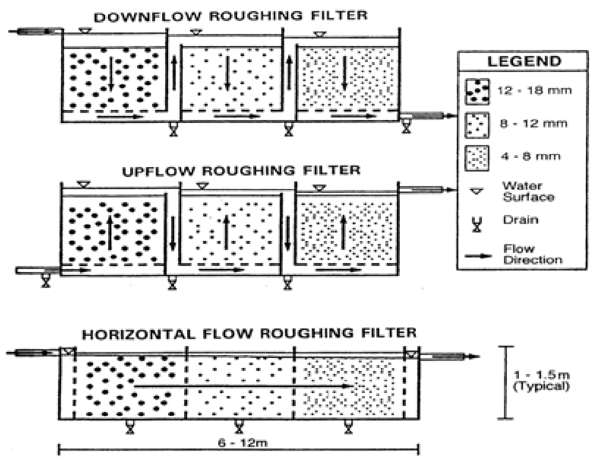

Fig. 3 Diagram of Horizontal, up flow and down flow roughing filters. Source: [9]

As we head into the 21st century, awareness and education will most assuredly continue to be the two most important ways to prevent water pollution. If these measures are not taken and water pollution continues, life on earth will suffer severely. Global environmental collapse is not inevitable. Growing demand for freshwater availability, in conjunction with the global push to meet the UN Millennium Development Goals for hunger, water, and sanitation, suggests that the target of 0% oversubscribed territory will be difficult if not impossible to meet. However, continued over-abstraction cannot be sustained indefinitely. More effective measuring, reporting, and tracking of global water quality and quantity, on a country-by-country basis, must occur in order to better inform policy making and international efforts toward meeting the Millennium Development goals. But the developed world must work with the developing world to ensure that Goals needs of new industrialized economies do not add to the world's environmental problems. Politicians must think of sustainable development rather than economic expansion. Conservation strategies have to become more widely accepted, and people must learn that energy use can be dramatically diminished without sacrificing comfort.

In short, with the technology that currently exists, the years of global environmental mistreatment can begin to be reversed. In the long run, the Tshwane municipal Council should aim at changing the nature of, and increasing the interaction between the community and their environment. In a water scares country like South Africa, developing the stream system as part of a larger conservation area will not only benefit the local community of Soshanguve, but the country at large.

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