Research on the health implications of the use of recycled water in South Africa

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Summary

South Africa has an inadequate and unreliable supply of water. It is expected that water resources will be a limiting factor to development by the year 2020. Reclamation and re-use of sewage effluent is one possible method of supplementing existing supplies. Windhoek has had direct supplementation of its water supply for over a decade. Guidelines for using recycled sewage as a source of potable water are given and South African studies on chemical, microbiological and virological aspects of reclaimed water are reviewed. Epidemiological studies, retrospective in Windhoek and prospective for Cape Town, are discussed.

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The RSA suffers from an inadequate and unreliable supply of water. Kriel[1] summarised as follows: 'Not only is a large portion of the country relatively dry, but the rainfall and the resulting river flows are erratic with long periods of drought that substantially reduce the proportion of the total run-off, which could be made available as a reliable source of water supply.' The recent drought, experienced by a large part of the country, seems to be the most severe on record, but there is no reason to believe that more severe droughts may not occur in the future. At the same time, the RSA is experiencing a rapid growth in its population which exerts an ever greater demand for potable water. Based on present trends, it is estimated[2] that water supply and demand in South Africa as a whole will coincide at about the year 2020.

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The demand[3] for water (domestic, industrial and agricultural) may vary from about 200 m^3/capita/d to as much as 2 300 m^3/capita/d, although the amount consumed for potable use[4] is no more than 2 l/capita/d. The Science Committee of the President's Council suggested, in their 1983 report on the demographic tendencies in South Africa, that if a figure of around 350 m^3/capita/d is accepted, then it is a simple matter to arrive at a minimum figure of 90 million people that can be sustained on the known water resources of the RSA.[5]

However, if the uncertainty of water supply, the uneven distribution of water over the country and the fact that certain areas already experience water shortages are considered, then it would be more prudent to plan on a total population of between 68 and 80 million people.

The Science Committee concluded in their report that water was the most important restraining element in the development of the RSA and that several industrial regions would suffer a water shortage before a total population of 70 million was reached.

Water is used by man to convey his waste products and may therefore be considered to be a conveyor belt. It is also known that 60 - 70% of the water used for industrial and domestic purposes eventually becomes sewage.[6] The removal of the waste products by sewage treatment (biological oxidation) and chemical treatment, render this water fit for re-use. This renovated water is a dependable and readily available water source and can be used to augment other water supplies. This implies that, within certain limits, water can be used over and over again. The question is, if this water is re-used as a *potable water*, what are the health implications? Some of the research carried out in the RSA in order to answer this question is described.

Reclamation of water for potable use in South Africa

Reclamation of water for potable use can proceed directly or indirectly. In other words, the reclaimed water can be mixed directly with the potable water prepared from the other sources and distributed or it can be used indirectly. Indirect re-use is practised in many areas, such as in the Pretoria-Witwatersrand-Vereeniging region, where treated effluents are discharged to the Vaal River from whence water is then withdrawn for treatment and distribution. This system is used in many overseas countries too, the city of London and The Netherlands being notable examples.

A second mode of indirect re-use is to infiltrate the treated effluents to an underground aquifer from whence it is re-used via boreholes and wells. A good example of this system is in use at Whittier Narrows in Los Angeles County and Water Factory 21 in Orange County in California — a state which is plagued by water shortages.

The best known sample of direct re-use of tertiary treated sewage effluents as a potable source, is Windhoek, SWA/Namibia. The augmentation of Windhoek's potable water supply has been in practice since 1969 and was supported by an extensive research programme to watch over the quality of the water produced and to maintain an epidemiological survey of the population.

The water supply of Cape Town will fall short around the turn of the century.[2] Therefore the Water Research Commission (WRC) of the Department of Water Affairs contracted the Municipality of Cape Town to build and operate a demonstration and research pilot plant at the Cape Flats sewage works to study the feasibility of reclamation in that region and to develop the necessary expertise.

Guidelines for using recycled sewage as a source of potable water

The Department of National Health and Population Development will be responsible for the final approval of direct recycling and re-use of sewage effluent, and therefore released its guidelines for the use of reclaimed water during 1982.[7] Briefly summarised, these guidelines are:

1. There must be convincing evidence that no alternative economically feasible conventional water supply of acceptable quality is available.

2. The treated effluent must be of domestic origin and should contain the minimum of industrial effluent, which should be of a known volume and composition. An effective catchment quality control system to monitor the composition of such industrial effluents is recommended.

3. Strict design and operating criteria are to be specified for the reclamation plant. It is essential to include more than one process for the removal or inactivation of hazardous substances and pathogenic organisms — these will serve as multiple safety barriers. In addition, the training qualifications and experience of plant personnel will be stipulated.

4. Provision must be made for adequate storage capacity to prevent reticulation of any reclaimed water during the estimated time it would take for a break-down of any process and its detection to occur. Normally this would be about 48 hours.

5. The reclaimed water should be blended thoroughly with conventionally treated water and the final mix supplied to users should not contain more than 20% reclaimed water. This is an additional safety measure that would decrease the concentration of any potentially hazardous substance. Since the concentration of total dissolved and other organic compounds may be different in the reclaimed water supply compared with the conventional water supply, this may cause a change in the observed taste of the water.

6. The percentage of reclaimed water present in the domestic supply should be kept as constant as possible. Again, this is to prevent undue variations in the taste of the water.

7. Epidemiological surveys must, where possible, be conducted in the area concerned before and after the introduction of the reclaimed water.

8. The introduction of reclaimed water as a domestic water source must be preceded by an intensive information and publicity campaign to inform the public about the necessity for using reclaimed water and its safety.

South African studies on the health aspects of recycled water

The direct use of water reclaimed from treated sewage effluents in southern Africa began in 1969 with the commissioning of the reclamation plant in Windhoek. Since then the following bodies have been active in funding research into the quality of the reclaimed water and into the health aspects of drinking water generally: (*i*) the Department of National Health and Population Development; (*ii*) the South African Council for Scientific and Industrial Research (CSIR) through the National Institute for Water Research (NIWR); and (*iii*) the WRC.

Chemical, microbiological and virological quality of drinking-water

An extensive research programme on aspects such as the development of analytical techniques (both microbiological and chemical), quality criteria for drinking-water, quality of drinking-water derived from various sources, and the efficacy of various process units in removing pollutants is being carried out by the NIWR.[8] This programme is supported by the Department of National Health and Population Development.

The following is a brief summary of the studies carried out by the NIWR to determine the quality of the reclaimed water and, for comparative purposes, also that of conventional drinking-water supplies.

The effect of the chemical, organic carbon, concentrated from water by the activated carbon process in the experimental Stander reclamation plant in Pretoria was studied in rats. The organic carbon was reclaimed by chemical solvents and injected into rats subcutaneously. The rats were then examined to ascertain if the organic carbon had carcinogenic effects. The results of the tests were negative.[9]

In a follow-up study humus tank effluent, reclaimed water, tap-water and distilled water was given to different groups of rats as their sole source of water. Spent and virgin active carbon were also mixed into feed. The experiment lasted over 30 months and humus tank effluent was the only liquid causing adverse effects.[10]

The development of continuous automatic biological surveillance systems based on fish respiratory and behavioural responses to intoxication was reported.[11-13] Fish are more sensitive than man to several toxicants and therefore provide an early warning of the possible presence of toxicants.

The Ames *Salmonella*/mammalian microsome mutagenicity assay[14] is now well established as a means of detecting mutagens in water. This test was applied to study the ability of the reclamation process to reduce mutagenic activity. No mutagens were detected in the final chlorinated reclaimed water from the Stander plant.[15,16] This observation was in contrast with the presence of mutagenic activity in certain drinking-water supplies after conventional treatment of river waters.[17,18] No evidence has been obtained, however, that even this observed mutagenic activity constituted a health hazard. It now appears that the Ames test might be over-sensitive.[19]

Sensitive cell culture techniques were also used for the detection of toxicants and potential carcinogens in reclaimed drinking-water from both the Stander plant in Pretoria and the Windhoek plant.[20-22] Although some transformation activity was detected in the final water, it was still of the same order as found in conventionally treated drinking-waters.

The presence of enteric viruses in the raw water supplied to the Windhoek and Stander reclamation plants and their removal by the different treatment stages during reclamation have also been extensively studied.[23-27] The results of these studies led to a proposal for the disinfection of water to prevent the transmission of microbial diseases.[28] This proposal centered around a specification for the turbidity of the water to be disinfected, the achievement of break-point chlorination, the maintenance of a contact time of at least 30 minutes with the chlorine, and, lastly, the insistence that the pH value must be about 7,0.

The use of coliphages as indicators of the virological quality of polluted water (Apies River, Pretoria) was also investigated.[26] It was found that the coliphage count did not always correlate with that of the enteric viruses, but that this test, in combination with the standard plate count and that of acid-fast bacteria,[18] offered a practical and reliable indicator system for evaluating the virological safety of treated drinking-water supplies — even if this water was directly reclaimed from waste water.

Epidemiological studies

The WRC entered into a contract with the South African Institute for Medical Research for the performance of two studies in Windhoek. One was a surveillance of the microbiological quality of the drinking-water supplied to Windhoek and the other was an epidemiological study of the population exposed to reclaimed water. These studies were carried out over a decade and were reported by Isaäcson *et al.*[29] and Isaäcson and Sayed.[30]

These investigations emphasised the fact that the drinking-water in Windhoek did not contribute to the occurrence of the acute effects of diarrhoeal diseases and viral hepatitis. In fact it was concluded that, from a microbiological point of view, the reclaimed water was safe to drink. Data were also collected on general mortality rates. At this stage no clear-cut answer can be given about possible long-term effects. Data collected to date, however, show that there is no reason to suspect a chronic effect. Unfortunately, it was not possible to begin epidemiological studies before the introduction of reclaimed water into the drinking-water supply in Windhoek because of the urgency of replenishing the water resources of that city. However, the epidemiological study is being continued to obtain more information on chronic effects, if any.

The above results are largely supported by the findings of the comprehensive epidemiological study of Whittier Narrows, California, where reclaimed water has been used for many years.[31,32]

The Cape Peninsula might be the first area in the RSA to consider the use of reclaimed water, since once all the existing known sources of potable water have been exploited sources such as desalination of sea water and the reclamation of treated sewage effluents will have to be considered. Therefore the WRC entered into the following contracts:

1. The Department of Community Health, University of Cape Town, was to establish and operate a databank of the prevailing disease pattern of Cape Town and its environs. This database would be used to supply health data for the study of the effects of any change in the quality of the drinking-water supplied in the area, whether it was reclaimed water or not. This databank[33] consists primarily of information on mortality rates, morbidity as seen by general practitioners[34] and birth defects.[35]

2. The above contract was extended to include the development of the necessary expertise in order to establish epidemiological databanks in other areas of the country when and where the need arose. The emphasis of this study is the establishment of a databank to record information on birth defects and the usefulness of mortality data for a study of trends in chronic diseases.

3. The Department of Clinical Virology, University of Cape Town, was to study the virological quality of the final water produced by the Cape Flats experimental reclamation plant operated by the Cape Town Municipality. This study confirmed that reclaimed water conforms to all known microbiological criteria for potable water.[36]

Discussion

The re-use of water, whether it is direct, indirect, planned or unplanned, raises the question whether existing drinking-water supplies are safe. This is particularly important as the environment is subject to an ever-increasing rate of pollution and so man is exposed to an ever-increasing load and variety of pollutants. Water is but one of three major routes of entry into the body — air and food being the others. Therefore to assess the safety of drinking-water in isolation might result in unnecessary restrictions on the use and re-use of water. It would be unwise to insist on the total elimination of a chemical compound from water, while the intake of the same compound via air and food is not considered.

The cost of reducing or eliminating a chemical compound might be prohibitive and therefore the risk associated with its intake should also be considered. A prime example of the use of calculated risk is blood transfusion. It is known that a blood transfusion is not entirely risk-free, yet it may be argued that so many lives are saved through its use that the associated risk is not unreasonable. Is this same argument not also true for water?

Water is a known route of transmission of disease whether caused by micro-organisms or by chemical compounds. There is ample proof that well-disinfected water does not transmit microbiological diseases. The role of chemical compounds is not entirely clear and has become more complicated since the start of the use and production of synthetic compounds not normally present in the environment, such as pesticides. These compounds fulfil a vital role in man's existence and their use is important for survival. It is also known that nature itself produces carcinogenic compounds, of which the mycotoxins are a good example. Therefore man has never lived in an environment free from chemical compounds affecting his health. The solution lies in improving the technology of removing or reducing the levels of exposure to as low levels as possible within limits of economic feasibility.

The modern-day analytical chemist is able to analyse substances to find minute quantities of chemical compounds, often in the ng/l range, and the question to be answered is: how important is this concentration when man is exposed to it over a lifespan of say 70 years? The Environmental Protection Agency of the USA[37] has carried out such calculations and suggests that a value of 38 ng/l of *bis*-(chloro-methyl) ether would cause 1 case of cancer in a population of 10 million. Three further questions arise: (*i*) can a concentration of 38 ng/l of this ether be reduced in water at reasonable cost? (*ii*) is it realistic to call for such a low risk? and (*iii*) can an increase of 1 case in the incidence of a carcinoma in 10 million people be detected epidemiologically?

The above questions are put to show the dilemma of the water scientist. It is believed that the medical profession will have to join hands with the water scientists to obtain answers to these questions and to set realistic goals for the quality of drinking-water. Only in this way will we be able to ensure that the health of man is not subjected to undue risks and that he can look forward to a future not unnecessarily complicated by his environment.

This article was based on the research carried out by many South African researchers in this field. Their contributions to our knowledge of the quality of reclaimed water and its possible effects on the health of the user are gratefully acknowledged.

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