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VIRUSES IN RENOVATED WATERS

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SUMMARY

To renovate may be defined as to make new again, to repair or restore to good condition. If we stop to consider this definition, it becomes increasingly obvious that, at the present time, many if not most of our water supplies fall under this definition as renovated waters.

This paper attempts to assess the present and future needs for such waters and the virus risk involved in their usage. The available knowledge of the efficiency of natural purification processes in virus removal, by water purification techniques treating possibly polluted water resources and by the direct treatment of waste water, is examined, as is the virus risk involved in the discharge of insufficiently treated wastewater into the environment.

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There have been many excellent publications dealing with viruses in renovated waters including comprehensive reports by the Committee on Environmental Quality Management and by the World Health Organization[1-6]. In these reports the pathogenic viruses which may be transmitted by water have been examined. Viral Hepatitus A is the only viral disease for which there is substantial evidence of waterborne transmission[7,8]. It seems possible, however, that other enteric viral pathogens such as recently isolated by Bishop et al.[9], Paver et al.[10] and Kapikian[11] may also be transmissible by water. The infective dose for virus in relation to the magnitude of the health risk of its presence in water has also been reviewed[3,4]. This present paper outlines certain other facts and philosophies, and presents them from a different viewpoint.

At the present time the greatest need in discussing any problem dealing with viruses in water is a clear definition as to which types of waters should be classified as renovated waters. To renovate may be defined as to make new again, to repair or to restore to good condition.

In the past, man settled in particular areas simply because of the availability of water. Uncontaminated water sources, however, are mostly located in inaccessible areas which do not favour community living and economic growth and development. Community development, therefore, generally takes place away from the actual water source, further downstream where agriculture is possible with its consequent commercial and trade expansion. Used water from such expansion is often returned to the original water resource and may, in some instances, be responsible for keeping the available resources in the area constant. If this is so, the control of pollution by dilution may no longer be possible. Reliance must then be placed on the natural biological and physical purification processes in rivers, reservoirs and the sea to renovate such waters.

From the turn of the century it was obvious that due to population waste increases, assistance in the form of water treatment would be necessary to augment this natural renovation of water. Today the waste loading of water resources is increasing to the extent that even currently used, man-devised treatment processes may not effectively repair such waters to the condition necessary to prevent the transmission of waterborne viral diseases. It is, therefore, imperative that we consider all waters which must undergo any purification process for the removal of contamination as being renovated waters. The virus reduction efficiencies of each treatment process involved in the restoration of each type of water should be critically examined in relation to the usage risk of the finally renovated product. Where a restoration process fails in efficiency, the available technology must be examined in order to determine means to augment the renovation process.

Removal of virus during sewage treatment

There is no doubt that virus pollution of the water environment begins with sewage waste disposal. The effectiveness of conventional sewage treatment practices in the removal of virus is well documented. Primary clarification does not significantly reduce virus in time periods up to three hours, and biological filtration has been shown to remove less than one log unit of virus[1]. A three year study on a sewage treatment plant[12], consisting of primary settling, biological filtration and secondary settling, showed only a one to two log virus reduction through the plant. In this study the incoming virus load was often as high as 400 000 $TClD_{50}$ per litre and, therefore, considerable quantities of viruses (2 000 $TClD_{50}$ per litre) may be discharged into the receiving waters. Even activated sludge processes, which have shown more constant efficiencies, only accomplish a two to three log reduction in viruses[1], and their effluents may still contain up to 200 $TClD_{50}$ virus per litre.

Tertiary treatment in maturation pond systems can produce a further three log reduction in virus loading, but virus is often still recoverable from one litre sample of pond effluents[12]. Disinfection by chlorination of these high chlorine demand effluents is difficult to control. Reported laboratory and field studies indicate that chlorination of wastewater plant effluents as is presently practised with low chlorine residuals, will not yield virus free effluents[1]. Complete inactivation of virus can only be obtained under operating conditions where the turbidity and free residual chlorine conditions for disinfection are strictly observed.

The above data indicate the possible virus contamination resulting from the disposal of insufficiently treated wastes into water resources. These viruses must be removed during renovation processes.

Renovation by natural biological and physical processes

The largest demand for water for domestic use may still be from naturally renovated sources. In vast areas of the developing nations, tap water is still unavailable and, as often as not, sewage wastes are untreated. In many areas endemic typhoid can be directly related to the water use pattern, showing that a reliance on natural purification processes is not possible. In these days of rapid transport, such foci of waterborne diseases should be viewed with some concern[13].

Even in areas where sewage is treated prior to discharge into natural resources, viruses appear to survive for long periods and can still be recovered from these waters[1,3]. The processes involved in their removal or inactivation are supposedly ultraviolet irradiation, temperature, adsorption onto organic and inorganic suspended solids with eventual sedimentation and attack by bacterial enzymes or other organisms[4,13].

Little work has been done to substantiate the efficiencies and mechanisms involved in the virus reduction during natural restoration processes. From the literature[14,15,16] dealing with waterborne virus epidemics it is evident that the renovation process is all too frequently incomplete and that further treatment is essential.

Renovation by physical-chemical treatment

It has been calculated[17] that if a viral concentration in sewage is 10 $TClD_{50}$ per mℓ and this amount is reduced by two logs during sewage treatment, another three logs by dilution in a river and two to three logs in a water treatment plant, a total of seven to eight log reduction in virus results. This leaves a water containing perhaps one $TCID_{50}$ of virus per 1 000 litres. Shuval[17] suggests that this is not an unimportant amount. On the basis of these calculations drinking waters may contain considerably higher numbers of viruses since counts of more than 100 $TCID_{50}$ virus per mℓ have been recorded for sewage[12].

The two to three log virus reduction has presumably been calculated for conventional water treatment plants in which coagulation with aluminium sulphate or ferric chloride, rapid sand filtration and nominal chlorine dosages are applied. In such a system the efficiency of chlorination would depend entirely on the chlorine demand, the pH level and the turbidity of the water.

During the routine testing of ten litre samples of natural water resources in Southern Africa, virus was recovered from five out of 52 weekly samples taken from a natural reservoir situated close to a city. This reservoir is used for recreational purposes and also as the water source of a conventional water treatment plant. Virus has been recovered from five out of 100 weekly ten litre samples taken of this conventionally treated drinking water.

The treatment technology is available to radically improve these reduction figures. Research on direct wastewater reclamation has done much to broaden our knowledge on the optimal efficiencies of treatment processes for the removal or inactivation of viruses. Pilot plant and field studies[12] on the various physical-chemical processes which may be used for the renovation of even highly polluted waters, are summarized as follows:

> Flocculation of colloidal and suspended material by excess lime treatment with the addition of flocculant aids to pH values of 11.2 to 11.5 concurrently inactivated four to five log units of an attenuated poliovirus reference strain. At a pH of 11.5 virus could no longer be recovered from the resultant sludge.
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> When this process was followed by carbon contacting stabilization, a further five log reduction was achieved. The treated water at this stage had a turbidity of less than 0.5 JTU. Sand

filtration further reduced the turbidity to the low levels required for efficient disinfection. Nitrogen removing processes were incorporated to reduce the chlorine demand in order to facilitate economic disinfection. Chlorination to breakpoint with a free residual chlorine of 0.5 mg per litre as HOCl and a contact time of 60 min inactivated the seven log units of the reference virus used.

A combination of the above discussed treatment processes can thus give a 16 log reduction in virus and on the basis of the previously mentioned calculations of Shuval[17] a renovated water with a virus count of less than one $TClD_{50}$ per 10^{15} litres can be expected. This advanced physical-chemical treatment of water is expensive and will not find favour unless the water demand is critical or the risk involved in the use of less expensive methods is fully justified.

The assessment of the need for renovated waters

Under prevailing socio-economic conditions, man's need for water for industry, agriculture and domestic use must increase. The fixed quantity of the total available water has already made water reuse inevitable. All such reused waters must, therefore, be renovated for the specific purpose required, and this renovation process must ensure that minimal risks are involved in their ultimate usage.

The assessment of the virus risk in renovated waters

That there is a risk involved in the reliance on natural biological purification to remove virus in water bodies is well substantiated. This risk is directly dependent on the pollution load and on the ultimate use for which the water is destined. A report[1] concludes that 'The record of waterborne infectious hapatitis gives assurance that current recommended water sanitation practice and available treatment technology, when rigorously applied, provide protection that is adequate for all practical purposes. Good water sanitation practice means that the source of water supply should not be so contaminated as to place a heavy load on the treatment process, since any lapse of treatment efficiency may then permit infective viruses to reach the finished water'. I suggest that, in many areas of the world today, the pollution of the available water sources can no longer guarantee 'good water sanitation', and that many current water plants are unable to renovate such waters satisfactorily. In the United States, it was reported in 1970 that 20 - 30 per cent of drinking water supplies could not comply with existing standards[18]. An increased risk of virus transmission by the water route is portended if present day water and wastewater treatment practices do not anticipate and stay in advance of changing world environmental conditions.

Available technology

There are two obvious lines of defence against an increasing risk of waterborne viral diseases. Water treatment processes can be upgraded to adequately remove or inactivate the increasing virus load in water resources, or radical improvements can be made in sewage purification treatment. The latter would stop pollution at source, and solve many of the present outstanding uncertainties regarding the safety of spray irrigation, dual water supply systems and recreational waters. Both possibilities are within the reach of modern technology. This is illustrated by advances in the experimental reclamation of wastewaters, where the virus load of the intake water is known and the various treatment processes built into reclamation systems form safety barriers which can be controlled to ensure the inactivation of virus to a high degree.

Standards for renovated waters

The WHO European standard lays down that there should be no detectable virus in 10 litres of drinking water[19]. This standard should apply to all renovated waters destined for any type of use. Unfortunately, little data is available as to how many conventionally treated drinking waters comply with this standard. When such information is collected, it may well be that this standard must be reviewed, especially when better methods for the virus testing of larger volumes of water are available.

Recommendations for future research

The search for better methods of virus detection in water must be continuous, thus enabling widespread monitoring of the environment for viruses. The results of such monitoring in conjunction with epidemiological studies should contribute much in assessing the risk of the low level transmission of viral diseases.

The simple removal of viruses from one water source, resulting in the possible transference of the removed virus as a pollutant to another source, is not sufficient. More data are required on the quantity and survival of viruses in river sediments and treatment wastes in order to determine the necessity for the absolute inactivation of viruses by the complete tertiary treatment of waste waters.

Inactivation studies will have to be done in greater depth. The kinetics of the inactivation processes must be supported by investigations into the actual mechanisms involved in the destruction of the environment itself. Research must, therefore, move into the field of molecular biology, while the electron microscope and biochemical studies may also prove useful tools in this connection.

Such research, together with established knowledge, will in part answer many of the questions relating to the risk involved in the use of various renovated waters. There is still, however, the missing link. It is vital that the search for laboratory techniques for the isolation of the infectious hepatitis A virus be intensified so that the outstanding questions relating to the danger of the transmission of this proven waterborne viral disease may be resolved.

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