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Effect of Human Viruses on Public Health Associated with the Use of Wastewater and Sewage Sludge in Agriculture and Aquaculture

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Note: The Author has considered references up to July 1992, when the preparation of the French version of the document has been completed.

Terms of Reference for Preparation of Background Document

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1. INTRODUCTION

The "Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture (TRS 778) published by WHO in 1989, provides guideline values for health protection in terms of intestinal nematodes and faecal coliforms. Intestinal nematodes were introduced based on the available epidemiological information supporting the conclusion that helminths present the highest risks of wastewater related disease transmission due to long latency periods with soil stage required for transmission, long persistence in the environment, low infective dose, without practical host immunity, and limited possibility of concurrent infection in the home.

The model of descending order of risks proposed that enteric viruses seem to be the least probable in terms of risk mainly because of the immunity they provide after infections contracted in the first years of life through concurrent routes of transmission at home where poor hygiene conditions prevail.

Since the publication of the document "Human Viruses in Water, Wastewater and Soil" (TRS 639) by WHO in 1979, a large amount of investigation has been made allowing for a better understanding of health problems and environmental risks related to enteric viruses. Several approaches are now available to assess the risks associated with exposure to low numbers of enteric viruses in the environment.

The large amount of information now available would constitute an important asset to review the effects of viruses on waste water reuse schemes, mainly with respect to the assessment of viral contaminants in industrialized countries where concurrent routes of infection are not significant, and high standards of hygiene are prevalent.

2. OBJECTIVES

To prepare a draft document on the subject of virus contamination associated with the use of waste water excreta and sludge in agriculture. The document is to be discussed and revised by a group of international experts, and will serve as basis for a scientific group meeting on the subject.

3. CONTENTS OF THE DOCUMENT

The document has to be written in English or French and should have a format similar to the Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture (TRS 778, WHO, 1989) and should be based on the most recent technical and scientific information available.

The document should concentrate on domestic wastewater, excreta and sludges originated from biological wastewater treatment plants and should address the following items:

- Occurrence and survival of viruses in water, soil and crops
- Environmental risks from wastewater, excreta and sludge on: surface water, groundwater, sea water, soil and crops
- Removal of viruses by wastewater treatment processes
- Health risks to wastewater treatment plant workers, field workers, crop handlers, consumers and people living near irrigated/fertilized fields.
- Techniques for detection
- Recommendations for monitoring
- Evaluation of the relevance of guideline value (viral concentration in wastewater, sludge and excreta) for restricted and unrestricted irrigation

- Health safeguards
- Recommendations for irrigation practices including operation and maintenance
- Research needed

Executive Summary

Over 140 types of pathogenic viruses can be transmitted to humans from the aquatic environment. These viruses are all enteric viruses eliminated in the stools of the infected person. The most common are the gastro-enteritis and hepatitis viruses. It should be pointed out that for a certain number of these enteric viruses (rotavirus, Norwalk virus) immunity is short-term and does not give life-long protection, and, therefore, reinfection and disease caused by these viruses can recur several times during a lifetime.

Viral contamination of the aquatic environment has been well proven, but viral density varies enormously, not only because of real differences in concentration, but also because a very wide heterogeneity can exist within any one environment.

The average viral concentration in waste water varies from 10^2 to 10^3 PFU l^{-1}, and in treated waste water can be estimated at between 10^1 and 10^2 PFU l^{-1}, depending on the type of treatment and its yield. The average viral concentration in treated sludge often reaches 10^3 PFU Kg^{1}. The concentration in surface water varies according to the intensity of faecal pollution, but can be estimated at 10^1 PFU l^{-1} in river water and between 1 and 10 PFU l^{-1} in contaminated sea water.

Viruses may be isolated in water destined for human consumption because of several reasons; a fault in the treatment or disinfection processes, because no disinfection process exists, particularly in developing countries, or due to accidental contamination of the drinking water supply.

When seafood has been bred in contaminated sea water it becomes a virus carrier.

In addition, little is known about viral contamination of the aquatic environment in developing countries because facilities for water analysis do not exist.

The epidemiology of water-borne viral diseases should be considered from three points of view: direct transmission by drinking contaminated water, transmission as a result of the use of waste water or treated sludge in agriculture, and indirect transmission from shellfish.

Where transmission by drinking water is concerned, many epidemiological examples exist, particularly of gastro-enteritis and hepatitis. It should be pointed out that few statistics exist for developing countries although the latter frequently have problems with the sanitary quality of their drinking water.

If viral infections are in fact transmitted by recreational water, their occurance is rare, and therefore the risk of transmission from this source would appear to be slight.

Where irrigation with waste water or the use of sludge in agriculture is concerned, epidemiological surveys have evaluated the risks for farmers, agricultural workers, and populations living close to land irrigated by spraying with waste water. When spraying occurs, aerosols containing enteric viruses are formed and have been found more than 700 metres downwind from irrigated land. The conclusions of the different studies have tended to show that spray irrigation using treated but non-disinfected waste water does not present a significant viral risk for the surrounding population, except during epidemics when the water has a particularly high viral particle content.

Little is known about the effects of consuming market garden produce irrigated with waste water.

The following recommendations should be made: when waste water is used for irrigation, it should undergo a simple, preliminary treatment to eliminate the maximum amount of suspended matter which is the normal viral substrate, and workers manipulating sludge or spraying equipment should, without fail, follow normal hygiene regulations.

The consumption of shellfish is a major transmission channel for enteric viruses. Many epidemics have been described and the most common causes are the gastro-enteritis and hepatitis viruses and are found in all kinds of shellfish, normally eaten raw or insufficiently cooked. The shellfish comes either from areas which are contaminated or which have been temporarily polluted, or the shellfish itself has not been sufficiently cleaned.

The transmission to man of enteric viruses through eating seafood could be reduced by the following steps; the bacteriological analysis, which at the present time, is the only check carried out on seafood sold on the open market, is followed by a virological check, if seafood-producing coastal areas were closely supervised, and if treatment systems were optimised, standardised and controlled with respect to their true efficiency in reducing viruses.

Furthermore, the "wild" harvesting of shellfish by non-professionals or tourists in polluted areas should be systematically controlled.

The survival of enteric viruses in water depends on the virus serotypes, the type of water, and in particular its organic matter and settlable solids content, and numerous other parameters, the most important being temperature. It is difficult to give precise figures for the survival of enteric viruses in the different categories of water; however it can be estimated that if the temperature of waste water is between 18° and 25° C the T99[*1] is about 20 to 30 days, in river and sea water it is about 10 days, while in drinking water the T99 is around 60 days. All these survival times increase considerably as the water temperature decreases.

The efficiency of waste water treatment systems can be estimated, in terms of reduction in log units (1 log unit = 90% reduction), at between 0 and 1 unit for primary settling and biological filters, and 2 units for stabilisation tanks (20 days, 4 tanks).

When talking about the efficiency of disinfectants in waste water, it is important to remember that if effluent is rich in organic and suspended solids, disinfectants produce uncertain results. This is because the organic matter not only protects the micro-organisms in waste water, but, even more importantly, the added chlorine combines very rapidly and primarily with the organic matter, and in particular with the ammonium ions and the organic amines, to produce chloramines which have a low capacity for destroying viruses.

Finally, during the disinfection process, toxic chlorinated by-products are released in the effluent.

It would therefore appear to be of prime importance that all suspended solids be systematically eliminated before any disinfection treatment. This would mean that a large proportion of the viruses would be transferred to the sludge and the disinfection process could then be carried out under the proper conditions.

It should also be pointed out that the reactions of viruses to disinfectants vary considerably, depending on the type of virus.

It is also true that faecal contamination indicators such as faecal coliforms and streptococci are much more sensitive to oxidants than human pathogenic viruses, which is why the disinfection of waste water can give a false sense of security because, although the indicator bacteria have been destroyed, viruses can still survive in the treated effluent.

It should be pointed out that it is difficult to apply chlorinating techniques correctly, particularly to waste water which has a variable composition. Investment and running costs for these systems are also high.

The chlorination of untreated waste water containing suspended solids should be prohibited because it is not a true guarantee of safety. However, waste water could be disinfected on condition that it first undergoes primary treatment to eliminate at least 90% of the settleable solids.

If one compares the survival of enteric viruses with that of bacteria or parasites in water and during water treatment, the following list can be drawn up, in increasing order of survivability: bacteria (vegetative forms) - enteric viruses - protozoan cysts - spores - helminth eggs.

Treated sludge contains a considerable quantity of viruses and since it can be used as an agricultural fertiliser there is the risk that the soil or crops will be contaminated. Various treatment processes can be applied to sludge lower its viral content. Viruses are totally eliminated by dehydration (high temperature drying), pasteurisation at 70° C and lime treatment, on condition that the quantity of lime used is sufficient to produce a pH of 12 or more.

The use of sludge which has been treated according to these methods therefore presents no health risk. This is not the case for primary sludge or biological sludge, which has a very high enteric virus content, nor, to a lesser extent, for digested sludge, which has a variable virus content.

Virus survivability in soil is very variable (from 11 to 180 days) and depends mainly on the type of soil, the degree of humidity, and temperature. Enteric viruses present in soil as a result of spraying or irrigation migrate to the deeper strata of the soil as a result of successive adsorption-desorption phenomena. These are dependant on the types of virus present, the soil characteristics, and rainfall. This downward migration of enteric viruses can cause ground water contamination, which occurs mainly when the viral content of the sprays is too high.

The survivability of viruses on market-garden produce varies from 2 to 23 days and depends on the type of vegetable, the viral contamination level of the irrigation water, and temperature. When the outside temperature is high, viral inactivation is proportionately greater and more rapid. On the other hand, when contaminated produce is stored at + 4° C, viral inactivation slows down and the survivability of viruses increases.

Bearing in mind the above information, one can estimate that the spraying of market-garden produce with waste water should stop three weeks before harvesting. Under these conditions the viral mortality rate due to desiccation, temperature, and exposure to sunshine should lower the viral content by a factor of 6 log.

Shellfish bred in sea water polluted with enteric viruses, ingest and concentrate these viruses not only in its digestive tract but also in its tissues.

The life span of these viruses in immersed shellfish varies according to the microbiological quality and temperature of the water, but can be more than 60 days. Storing contaminated shellfish in refrigerators or freezers does not greatly reduce its viral content.

Decontamination techniques, based on the immersion of bivalves for between 24 and 72 hours either in good quality sea water, or sea water that has been disinfected, give good results from a bacteriological point of view, if used correctly. However, results are not satisfactory where viral content is concerned. Indeed, conventional depuration, as currently practised, does not always provide adequate protection against the transmission of viral diseases.

Shellfish do not eliminate bacteria and viruses at the same rate, which is why viral diseases can occur as a result of eating depurated oysters which have satisfied bacterial sanitary criteria.

It is therefore recommended that seafood be depurated only when it has a low viral contamination level. Depuration should be carried out by immersion in water of good microbiological quality, which has preferably been disinfected for a minimum period of 72 hours, without interruption.

When shellfish has been heavily contaminated it should be immersed for a long period in non-polluted sea water before being considered for treatment.

It would appear that only the seafood bred in shellfish breeding areas free from microbial pollution is totally risk-free for the consumer. It is therefore essential to protect shellfish breeding areas by prohibiting the disposal of untreated or incorrectly treated waste water in these zones.

For the isolation of viruses, the basic technique is still the isolation on cell cultures, because it is the only technique which reveals the infectious nature of the virus. However, very special attention should be paid to the molecular biology technique, Polymerase Chain Reaction (PCR). This technique is extremely sensitive and well suited to the analysis of large series of samples, and can be carried out on non-concentrated, raw samples. It is based on the search for nucleic acids and applies to all enteric viruses. It should eventually enable structured analyses of the aquatic environment to be carried out in developing countries, thereby obtaining data, at present unobtainable, on viral contamination levels of water in these countries. However, present knowledge of the practical aspects of this technique, the exact extent of the positive benefits to public health, and of the hazards and epidemiology involved, is too incomplete for this technique to become a basic methodology at the present time.

In order to be able to fully evaluate the risks involved in using waste water and treated sludge in agriculture and aquaculture, it is essential to be in possession of epidemiological criteria, criteria concerning the sanitary quality of the environment, and to take into account the concepts of minimum infectious dose, infection and disease.

At the present time, sanitary checks on the quality of waste water, the water in shellfish and seafood producing areas and the water used for market garden produce are based solely on bacterial contamination indicators (except in the State of Arizona, USA).

These bacterial indicators (faecal coliforms and streptococci) are unsatisfactory indicators of both viral content and the efficiency of disinfection treatments in eliminating enteric viruses. A large amount of research is being carried out to try and find a reliable indicator, which could be one or several bacteriophages, of viral contamination in aquatic environments. It would appear that the specific F-RNA bacteriophages and the *Bacteroides fragilis* phages could be suitable indicators but further research needs to be carried out, particularly into ecological aspects, before any final conclusion can be reached.

It is now accepted that the minimum infectious dose for enteric viruses is low and is certainly below 50 infectious particles.

It is of fundamental importance to evaluate the risks linked to virus content in water used for irrigation, market garden produce, and seafood.

Since 1988 work has been carried out to evaluate the viral risks linked to the consumption of drinking water, and the viral risks to the reuse of waste water. Some figures have emerged from this work concerning the viral concentration of water and the uses to which water is put. It has been shown that the viral risk is higher when a golf course is watered than when market garden produce is irrigated.

Practical conclusions can be drawn from this evaluation work, for example, the need for a latency period between the irrigation and harvesting of market garden produce. The duration of this latency period could be calculated according to the viral concentration of the water, spraying methods, weather conditions (temperature, sunshine and rainfall), and acceptable levels of risk.

This evaluation work needs to be developed further in order to be able to establish norms and make recommendations concerning the viral content of waste water, based on objective criteria.

At the present time, not enough is known about the viral content of waste water to be able to establish norms, or make recommendations concerning standards.

Section 5 of this document contains recommendations and suggested avenues for research based on the various elements mentioned above.