

SUITABILITY OF LOW TEMPERATURE VACUUM PAN EVAPORATOR CONDENSATE FOR PLANT USES

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SUMMARY

A preliminary study to investigate the possibility of utilizing condensates and tailwater from the low temperature vacuum pan evaporation of skim milk for evaporating plant uses was made. The results indicated that the utilization of these condensates and tailwaters for various plant purposes is possible and should provide a readily available, safe and sanitary water source if adequate steps such as quality monitoring and treatment are taken to insure that the highest quality of water is retained and used. The use of tailwater as a heat exchange medium on a single pass basis should require only quality control monitoring. However, condensate or tailwater which is to be used for other purposes should be aerated and may need additional treatment to prevent the development of tastes, odors, growths, corrosion, and scale formation.

During the concentration of skim milk by vacuum pan evaporation, a significant volume of water is driven off in the form of vapor. For example, the condensation of 100 lb. of skim milk from 9% solids to 38% solids results in the production of 76 lb. or 9 gal of water. Because of the quantity of condensate produced in the average evaporation plant, it would be desirable to utilize this water in various ways in the plant if it were of suitable quality. Several skim milk evaporating and drying plants in Michigan are presently using or desire to use the mixture of this condensate and cooling water which is called tailwater in plate heat exchangers to recover heat from the evaporation process. In addition, in some areas of the State, the existing ground water supplies have a high mineral content which makes them difficult to use without expensive pretreatment. The use of evaporator condensate for boiler feed make-up water and plant clean-up water in place of the available ground water is being given serious consideration in these areas because of its low mineral content. Although evaporator condensate was presumed to be of high quality and bacteriologically safe, little information was available regarding its physical, chemical, and bacteriological quality.

In order to obtain information relative to the suitability of vacuum pan evaporator condensate for plant usage, a cooperative study was conducted by the Michigan Department of Agriculture and the Region V office of the Division of Environmental Engineering and Food Protection of the Public Health Service. The primary objectives of the study

were: (a) to obtain information regarding the chemical, physical, and bacteriological quality of low temperature vacuum pan evaporator condensates, (b) to propose a system for monitoring the quality of the condensate and selecting that of the highest quality for use, and (c) to determine whether the quality of the condensate would have to be improved before it would be suitable for use and which treatment processes would be suitable for this purpose.

The condensates worked with during the study were the condensed vapors given off during the condensation of skim milk in double effect vacuum pan evaporators having a first effect temperature between 155 and 165 F and a second effect temperature between 115 and 130 F during operation. The condensate is designated as being first effect or second effect depending on the effect at which it is driven off; a mixture of condensate from one or more effects with condensing water is called tailwater. The tailwater temperature varies between 100 F and 120 F depending upon the respective temperatures and the relative volume of the condensate(s) and the cooling water usually from a well supply.

PLANT WATER SUPPLY QUALITY REQUIREMENTS

The Public Health Service Recommended Milk Ordinance (1) under Section 7, Item 7p, states that:

"Water for milk plant purposes shall be from a supply properly protected and operated and shall be easily accessible, adequate, and of a safe, sanitary quality."

Satisfactory compliance with these requirements includes approval as safe by the State Health Authority, and, in the case of individual water systems, complies with at least the specifications of Appendix D, Standards for Water Sources, and Appendix G, Chemical and Bacteriological Tests of the Suggested Milk Ordinance. Samples for bacteriological testing of individual plant water supplies are to be taken upon the initial approval of the physical structure, semi-annually thereafter, and when any repair or alteration of the water supply system has been made.

For the purpose of this study, the physical, chemical, and bacteriological quality of the condensate was compared with the requirements of the Public Health Service Drinking Water Standards (2) and the suggested standards for industrial waters (3) to determine the acceptability of this source of water for plant uses.

In this preliminary study, only quality requirements have been given consideration and no attempt has been made to determine the accessibility of adequate quantities of water of suitable quality from this source for the desired uses.

SAMPLING

Three factors considered in the determination of water quality are the bacteriological, the physical, and the chemical characteristics of the water. Ideally, a comprehensive testing program which includes the collection of samples from a number of evaporating plants over an extended period is necessary to accurately estimate variations in the parameters of quality and the average values of these parameters for a substance with broad variations in quality such as vacuum pan evaporator condensate. However, for the purpose of stimulating interest in the possibility of utilizing this source of water, the study was limited in its extent and the results serve only as a rough estimate of the characteristics of such condensates.

Samples were collected from three evaporating and drying plants during the course of the study which was July 9-20, 1963. At two of these plants, samples were collected for bacteriological and physical examination only, including samples collected and examined in the plant laboratory by plant personnel at one of the plants. At the third plant, grab samples were collected for chemical analysis and composite sampling was conducted to detect the presence of organics in the condensate in addition to the samples collected for bacteriological examination.

Quantitative tests to evaluate the physical characteristics of evaporator condensate, other than temperature measurements, were not made during the sampling program. The determination of taste and odor is difficult to conduct and requires carefully controlled conditions to be meaningful. Tests for turbidity determinations while highly desirable were not made because the necessary equipment for this test was not readily available. However, qualitative tests were made at the time of sampling to detect the presence of visible sediment or cloudiness in the sample and any objectionable odors.

SAMPLING RESULTS

All bacteriological samples collected were examined using the test for the presence of members of the coliform group by the membrane filter technique (4) and the procedures for total count using the membrane filter technique (5) using M-enrichment broth except for those samples examined in the plant laboratory. These samples were examined for the presence of members of the coliform group using the multiple fermentation tube technique (4) and using the standard plate count (4) at 35 C. The results of the bacteriological sampling are presented in Table 1.

These results indicate that vacuum pan evaporator condensates can satisfy the requirements of the Drinking Water Standards (2) with a coliform density of less than one/100 ml and are bacteriologically potable. The results also indicate that the condensate can be classified as "passable" (a water having a total bacterial count up to 500/ml) for use as dairy plant washing and rinsing purposes. There is the possibility, however, that the bacterial content of the condensates includes a significant density of thermophiles and/or anaerobic organisms as well as other

TABLE 1. BACTERIOLOGICAL QUALITY OF VACUUM PAN EVAPORATOR CONDENSATES

Source	No. of samples	Coliforms		Plate counts	
		Average /100	Range /100 ml	Average /ml	Range /ml
1st effect condensate	6	<1	none	100	5 to 280
2nd effect condensate	4	<1	none to 1	170	8 to 320
Condensing water	3	<1	none to 2	430	35 to 650
Tailwater	15	<1	none to 1	68	2 to 620

types which were not detected by the plant count procedures used.

The results of observations and measurements made of the physical characteristics of evaporator condensates are summarized in Table 2. The first effect condensates usually contained more visible solids and were normally cloudier than second effect condensates although both appeared clear at times. Quantitative turbidity measurements are required to determine the average characteristics of the condensates at a given plant and at any given time because of turbidity variations during operation. The cloudiness can be attributed to suspended milk solids which are occasionally carried over with the water vapor during the evaporation process.

Table 3 provides an indication of the chemical quality of low temperature vacuum pan evaporator condensates when skim milk is being condensed and is based on tests conducted by the Michigan Department of Health Laboratory. As is expected, the low total solids in the condensates indicates that only a negligible amount of inorganic chemicals are present because of the nature of the evaporation process. It is desirable that water used for washing and rinsing purposes in dairy plants have an organic matter content of less than 12 mg/liter as measured by the COD or permanganate consumed test (3). These results indicate that the condensates contain much higher concentrations of organic matter than is desirable for a milk plant water supply.

The organic content of condensates was anticipated and in an attempt to analyze the quantity and character of this organic material in more detail, a carbon filter adsorption test (6) was conducted on the combined first and second effect condensates from a low temperature vacuum pan evaporator. The following estimates of concentrations of organic matter capable of being absorbed on carbon were obtained from this test: carbon chloroform extractables, 1412 ppb; carbon alcohol extractables, 278 ppb.

TABLE 2. PHYSICAL QUALITY OF VACUUM PAN EVAPORATOR CONDENSATES

Source	No. of samples	Temperature		pH		Turbidity odor	
		Average	Range	Average	Range		
1st effect condensate	5	140	138 to 142	7.2	6.9 to 7.3	Clear to Cloudy	none
2nd effect condensate	5	97	76 to 121	7.3	6.0 to 8.1	Clear to Cloudy	sweet

TABLE 3. CHEMICAL QUALITY OF VACUUM PAN EVAPORATOR CONDENSATES

Source	No. of samples	Total solids (mg/l)		COD (mg/l)		Chlorides (mg/l)	Nitrates (mg/l)	Nitrites (mg/l)
		Avg	Range	Avg	Range	Avg	Avg	Avg
1st effect condensate	4	53	28 to 80	83	63 to 96	0	0.0	0.00
2nd effect condensate	3	57	32 to 82	73	45 to 90	0	0.0	0.00

As a basis of comparison, the recommended limit for the chloroform extractables for drinking water is 200 ppb (2) and the chloroform extractable concentration of surface waters is normally about 100 ppb (3).

The infra-red spectrophograph of the carbon chloroform extract (without solubility separation) indicated the presence of a carboxylic acid type compound. As the odor of the extract was unmistakably that of butyric acid, it is reasonable to assume that the extract was predominantly butyric acid or butyrates. The chloroform extractables are a measure of those organic constituents of a water usually associated with tastes and odors and a water with a CCE concentration which exceeds 200 ppb is usually of poor quality from a taste and odor standpoint. Therefore, it is anticipated that taste and odor problems would result if vacuum pan evaporator condensates were used as a plant water source without proper treatment.

DISCUSSION

The evaporator condensates from the low temperature vacuum pan condensation of skim milk contain very little inorganic matter and bacteriologically are of potable water quality. However, they may contain relatively high concentrations of organic matter at times and may have some slime-forming organisms and other similar undesirable organisms. The organic matter in the condensates varies from relatively simple carboxylic acid type compounds to the more complex milk solids. The carboxylic acid type compounds are probably derived from fats re-

maining in the skim milk some of which are broken down and volatilized during the evaporation process. There is also the possibility that part of the butyric acid identified in the carbon chloroform extract may be a product of bacteriological action resulting from the seeding of the carbon bed with bacteria and the degradation of more complex deposited organic matter. It is anticipated that the identity of the carboxylic acid type compounds will vary considerably with the evaporation process and with the characteristics of the incoming skim milk. The more complex milk solids result from the entrainment of these solids in the water vapor and their carry-over to the condensers. The amount of these substances in the condensates and the frequency with which their carry-over occurs will vary with the evaporation process and the construction of the evaporation equipment.

SUITABILITY OF CONDENSATES FOR USE

It is anticipated that most of the organic compounds in the condensates particularly the entrained milk solids are only slightly soluble or insoluble and consequently, the condensate with the lowest organic matter content will be the clearest. This is important because the suitability of the condensates or tailwater for use in the plant will depend on the selection by some monitoring procedure of the water with the lowest organic content. The suitability of tailwater will also depend on the original quality of the condensing water.

Properly monitored tailwater will probably be acceptable without additional treatment for use as a

single use heat transfer medium without being detrimental to the heat exchange system or the product being preheated. However, a number of operational problems may develop from the organic matter remaining in the monitored water and undesirable non-coliform organisms when present if tailwater or condensates are used in a recycled cooling system, as boiler feed make-up water, as plant clean-up water, or for similar purposes without additional treatment. The organic matter in the condensates could create corrosion problems in cooling systems and boilers, deteriorate timber (delignification) in cooling towers, leave harmful or taste causing residues on plant equipment when the water is used for rinsing and cleaning, or develop undesirable tastes and odors in the plant. The presence of certain organisms in the condensates could lead to the development of slimes, algae, aquatic plants and other growths with accompanying tastes and odors as a result of their use without prior treatment.

MONITORING AND TREATMENT

Because of the organic matter content of condensate is quite variable and can change rapidly during the evaporation process, some method of continuous monitoring in the condensate or tailwater line will be the most practical way to minimize the organic content in these waters. The method used should measure a readily detectable parameter such as turbidity or conductivity which has previously been correlated with the COD or organic matter content of the water. Condensate or tailwater of acceptable quality could be retained in the piping system for use or treatment and unsatisfactory water could be diverted to waste automatically by flow diversion valve coupled with the monitoring device. It is recommended that condensate or tailwater having a standard turbidity greater than five units be discharged to waste because of the anticipated correlation between insoluble milk solids and turbidity.

Monitoring methods suitable for screening condensates or tailwater include the direct measurement of turbidity based on optical transmittance using a photoelectric cell and the measurement of conductivity using a conductivity bridge. Whichever method is used, the diversion setting will have to be correlated with the standard turbidity and the COD or organic matter content, and checked periodically to insure that all condensate or tailwater of unsuitable quality is diverted.

The use of tailwater with a turbidity of less than five standard units in a plate heat exchanger on a single pass basis should not result in a solids build-up in the system or product contamination. Because of variations in the ratio of condensate volume to

condensing water volume, the conductivity of tailwater is highly variable and an optical method of turbidity measurement would seem to be more suitable for monitoring tailwater.

Condensates and tailwater should be aerated following the monitoring step to remove as many of the volatile organics as possible. This can be accomplished effectively through the use of a conventional cooling tower or aerator. It may also be necessary to add a corrosion-suppressing compound or in the case of some tailwaters a compound to prevent scale formation. Because of the nature of the organic matter in the condensates and the possible presence of undesirable organisms, it may be necessary to add a chemical such as chlorine with a suitable detention period to suppress the development of growths and prevent the development of tastes and odors. Whatever treatment is given to the water, it must not add substances that will prove deleterious to its use or contribute to product contamination. If the condensates or tailwater is to be used for plant clean-up water or similar purposes, it is suggested that adequate storage be provided to meet the water requirements for at least one day's operation. This would allow for diversion of water which does not meet the suggested quality requirements.

It is advisable that preliminary tests be conducted on the condensates or tailwater before it is decided to utilize this source of water in the plant. Such a testing program should be designed to: (a) estimate the quality of the available condensates or tailwater, (b) estimate the volumes of water available from these sources of suitable quality for use, and (c) determine whether treatment is required for the intended uses and if so what type of treatment would be necessary. Suggested tests to determine condensate quality include standard turbidity, COD, pH, and total solids. Additional hardness and mineral analyses would also be desirable when tailwater is being analyzed. Samples should be collected hourly during evaporator operation and composited into a single sample. The examination of the daily composite sample each day over a two week operation period should be adequate to obtain the desired information. In addition, hourly turbidity determinations should provide valuable information regarding the frequency of carry-over and the average turbidity of the condensates or tailwater. When chlorination is being considered as a possible method of treatment, an estimate of the chlorine demand of the daily composite would also be helpful.

The conduct of additional bacteriological studies is also recommended. It is suggested that samples be examined daily for a two week period for evidence of coliform contamination and total plate count and weekly thereafter. It may also be desirable to con-

duct examinations to detect the presence of thermophilic and anaerobic bacteria in the condensates.

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AMENDMENT TO 3-A SANITARY STANDARDS FOR PUMPS FOR MILK AND MILK PRODUCTS, REVISED

Serial #0204

Formulated by

International Association of Milk, Food and Environmental Sanitarians

United State Public Health Service

The Dairy Industry Committee

The "3-A Sanitary Standards for Pumps for Milk and Milk Products, Revised, Serial #0203" are hereby amended by adding the following paragraphs:

A. (5) Pump impellers or rotors, and cases or stators, which operate in conjunction with a metallic counterpart, may be made of or covered with plastic materials. Plastic materials used for pump impellers or rotors, and cases or stators, shall be of such composition as to retain their surface and conformation characteristics under conditions encountered in normal use and cleaning operations.

A. (6) Plastic materials, when used for specified applications shall meet the applicable provisions of the "3-A Sanitary Standards for Multiple-Use Plastic Materials Used as Product Contact Surfaces for Dairy Equipment, Serial #2000".

B. 10) The surface of plastic pump impellers or rotors, and cases or stators, shall comply with the applicable provisions of the "3-A Sanitary Standards for Multiple-Use Plastic Materials Used as Product

Contact Surfaces for Dairy Equipment, Serial #2000".

B. (11) The plastic coating of pump impellers or rotors and cases or stators (if covered) shall be bonded in such a manner that the bond is continuous and mechanically sound so that in normal service the plastic material does not separate from the base metal. The final bond shall conform in all respects to the criteria established in paragraph A. (6).

B. (12) The finish of the product contact surface at the interface juncture of the plastic and metal shall conform with the requirements of paragraphs A. (1) a. and B. (10).

This amendment shall become effective May 24, 1966.