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Water and Wastes Management in Carrot Processing

by

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A Thesis

Submitted to the Faculty of Graduate Studies
in partial fulfillment of the requirements for the
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ABSTRACT

Powdered activated carbon treatment was shown to be feasible in a batch process to regulate the quality control factors in carrot processing effluents enabling possible reuse of such effluents within the process.

"Aqua Nuchar" powdered activated carbon was chosen after evaluation of several commercially available carbons. An activated carbon dosage of 0.1% (w/v) applied at every fifth reuse of the carrot rinse water was able to control the aesthetic factors such as odor, foam, color, turbidity, enzyme activity and microbial growth.

Adsorption isotherms were developed for amino acids and sugars, major chemical constituents in carrots, which could become possible components of carrot processing effluents.

A schematic for an improved carrot dehydration processing line is included in the report. A possible saving of at least 60% in the wastewater treatment cost could be achieved using activated carbon treatment and in-plant reuse of effluents, as compared to the standard secondary biological treatment.

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NOMENCLATURE

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Terms	Explanation
MGD	million gallons per day
TSS	total suspended solids
g	gram
g/l	grams per litre
rpm	revolutions per minute
ppm	parts per million
nX	successive reuses of rinse water without treatment, where n = number of rinses
gpd	gallons per day

I. INTRODUCTION

1.1 Effluent Controls Relating to the Food Industry in Canada

Since Canada's food industry -- the largest industry in Canada -- has been characterized as one which discharges highly polluting effluents to the environment, it has been selected by the Environmental Protection Service of Environment Canada, for the development of effluent controls. Higgins (1974)(1) suggested in-plant controls through minimizing water use, water re-use, by-product recovery and process modification in the development of effluent regulations and guidelines for the food industry. The intent of the controls, issued under the Fisheries Act, is to protect the fish and marine organisms across Canada from the discharge of harmful substances. The aim of the regulations and guidelines is to ensure that the food processing plants operating in Canada employ "best practicable process and treatment technology" in their plants. Installation of "best practicable process technology" will ensure that "end-of-pipe" loadings are minimized as well as affording greater opportunities for by-product recovery. Regulations are immediately effective for new plants, while guidelines are indications of a future course of action for the existing food processing plants.

The food processing industries for which effluent guidelines have been developed are fish, potato and meat processing. Future development of effluent controls within the next few years would include the dairy industry and the canned and frozen foods industry.

In summary, Canada's food industry is following a similar pattern to that initiated by the U. S. Environmental Protection Agency, in the development of regulations and guidelines for the U. S. food industry.

1.2 Water Pollution Control in the United States

According to the U. S. Environmental Protection Agency under the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), effluent limitations guidelines for industrial discharges to municipal systems were set forth, for the degree of effluent reduction attainable through the application of "Best Practicable Control Technology Currently Available" (BPCTA) and "Best Available Technology Economically Available" (BATEA). The reductions must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively, with the aim of zero discharge by 1985. The "Standards of Performance for New Sources" set forth the degree of effluent reduction which is achievable through the application of the best achievable demonstrated control technology, process, or other alternatives (2).

1.2.1 U. S. Food Processing Industry

In 1970, a national program was established by the Environmental Protection Agency and the U. S. Food Processing Industry in dealing with the guidelines listed in section 1.2. The First National Symposium on Food Processing Wastes (3) reported on existing projects of the Research and Demonstration Grant Program of the Federal Water Quality Administration. The objectives were to represent a cooperative, coordinated program between industry and government in mutually solving troublesome water pollution problems and reviewing some of the latest efforts to reduce water pollution from the food processing industry. The First Symposium (3) suggested that goals include the refinement of conventional methods of treatment; the development of processes capable of higher degrees of treatment or completely closed loop systems; improvement of processing methods to reduce the quantity of water required per ton of product and development of profitable by-products from the recovered processing "wastes".

In 1971, the Second National Symposium (4) was expanded to include air pollution and solid wastes.

The total systems approach was suggested by Dr. R. A. Gallop at the Fourth Symposium (1973)(5) to be the most ideal solution to water and waste management in the food processing industry in which the entire plant is viewed as a "total system" with the waste element being considered as important as the intended commercial products. The process water could be recycled with in-plant treatment such as activated carbon adsorption. Solid wastes produced at the plant could be converted into activated carbon for on site use (6). A pilot plant in Southern California (7) was reported to have converted sewage solids to activated carbon which was then used to treat the incoming wastewater, which resulted in virtual elimination of sewage solids, removal of heavy metals contained in the sewage and elimination of odors. The "spent" activated carbon could be recycled back with the solid wastes and reactivated. Some carbon and ash were the only residues in the system and the gases generated from the solid wastes could be used as a source of power.

The total system approach is now being successfully demonstrated by the Hawaii's Sugar Cane industry (8) and the pulp and paper industry (9).

SCOPE OF INVESTIGATION

This study deals with the use of activated carbon as a possible method of purification for reuse as part of the "total systems" concept approach to the carrot processing industry.

"Aqua Nuchar" powdered activated carbon was the carbon chosen for use in this study, after evaluation of six available commercial powdered activated carbons. The evaluation was based on the (x/m)Co value (maximum theoretical amount of impurities adsorbed by a unit weight of carbon).

Adsorption isotherms were developed for simulated carrot wastes and organic compounds which could be possible components of carrot processing effluents.

Instrumental measurement of oxygen demand of simulated carrot wastes using the "Aquarator" was investigated.

Recommendations are made for an improved carrot dehydration processing line which handles solid and liquid wastes as part of the "total systems" concept. Costing of incorporating a carbon treatment with reuse is compared to conventional secondary biological treatment.

II. LITERATURE REVIEW

2.1 Fundamental Processes of the Carrot Processing Industry

The individual processing steps have been described by U. S. E. P. A. (1975)(2), Copley and van Arsdel (10) and von Loescke (11).

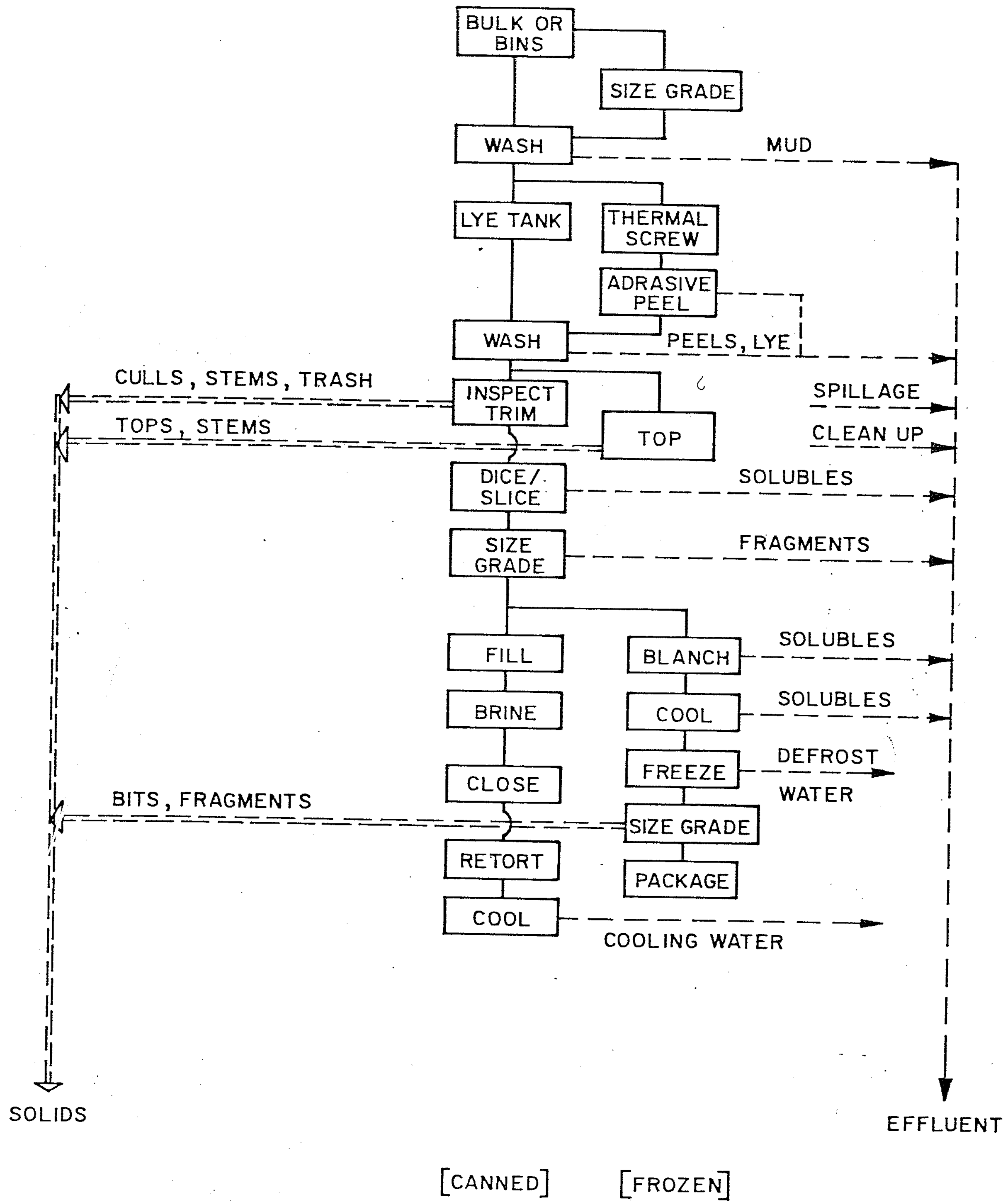
A flow diagram for a typical carrot process is shown in fig. 1.

2.2 Water Use in Carrot Processing

A considerable volume of information concerning water use for fruit and vegetable processing is available. Most of this information applies to canning and freezing operations.

Information on waste volumes from vegetable processing has been available in reference texts such as Mercer (12) of the National Canners Association. Although this data has traditionally been accepted, its reliability has recently been questioned. Soderquist (13) observed that information cited by Mercer and other accepted textbook sources is derived from studies conducted 20 - 30 years ago and based on "grab" samples gathered over sampling periods as short as a few hours or days. However, food processing effluents are subject to wide short-term and seasonal variations. Soderquist (14) has attempted to provide more meaningful data by establishing a mobile laboratory unit which has continuously monitored the processing effluents of several Oregon fruit and vegetable

Fig. 1 TYPICAL CARROT PROCESS FLOW DIAGRAM (2)



processors throughout entire processing seasons.

Total water use information for carrot processing is summarized in table (1) and water requirements for unit operations are given in table (2).

2.3 Waste Characteristics of the Carrot Processing Industry

The largest water usage is needed for cooling, plant cleanup, and product washing. Peel removal waters and blancher effluents are the main contributors to both biochemical oxygen demand (BOD) and suspended solids levels. Initial washing operations were observed to generate both large volumes of wastewater and high settleable solids levels as evidenced from the amount of mud in the effluent.

Wastewater strengths can vary considerably depending on the processing methods, conditions, and plant activities at the time of sampling. The high pH values result from the use of caustics such as lye in peeling.

Slicing and dicing operations can also contribute organics to the waste stream by generating juices and vegetable particles. The rate of leaching of the organics is initially high and decreases exponentially with time and with the number of washes (21). In-plant flumes can be recirculated and reused provided that the water is controlled and properly chlorinated.

The waste flows and loads summary of seven carrot processing plants are shown in table (3), while the waste characteristics of three unit operations from the carrot

TABLE (1) TOTAL WATER USE FOR CARROT PROCESSING

PROCESS	FRESH WATER	EFFLUENT	TOTAL WATER USE: IMPERIAL GALLONS /TON RAW PRODUCT		IMPERIAL GALLONS /CASE*		REFERENCE
			RANGE	AVERAGE	RANGE	AVERAGE	
CANNING		X		4163		60.4	15
CANNING		X				19.0	12
CANNING		X	1249**	3081			16
CANNING & FREEZING		X		3081			17
CANNING	X				33-46		18
CANNING (U.K.)		X		1250			19
CANNING (FRANCE)		X		1350			19
CANNING (U.S.)		X		5000			19
DEHYDRATED		X		4000			19
CANNING & FREEZING		X		3300			20

* 24 #303 cans unless specified
** standard deviation
X-data obtained for either fresh water or effluent

PROCESS EFFLUENT	UNIT WATER USE IMPERIAL GALLONS /TON RAW PRODUCT RANGE	 AVERAGE	IMPERIAL GALLONS /CASE* RANGE	 AVERAGE	% OF TOTAL	REFERENCE
CLEAN					12-30	17
PEEL					30-40	17
CUT					20-28	17
BLANCH					0-5	17
FILL, SEAL, COOK					15-20	17
WASH-FLUME		79		1.1	1.9	15
BLANCH-TUMBLE PEEL		2057		29.9	49.4	15
ABRASION PEEL		1440		20.9	34.6	15
WHOLE GRADER		233		3.4	5.6	15
SLIVER SCREEN		212		3.1	5.1	15
SLICED GRADER		142		2.1	3.4	15
FILLER						15
TOTAL		4163		60.4		

* 24 #303 cans unless specified

TABLE (2) UNIT WATER USE FOR CARROT PROCESSING

TABLE (3) COMMODITY SURVEY - GROUP B - RAW WASTE FLOWS AND LOADS SUMMARY* (23)

ACTIVITY	NO. OF PLANTS	FLOW		BOD		TSS	
		MGD	GAL/TON	mg/L	LB/TON	mg/L	LB/TON
Carrots	7	0.310	2762	1260	29.0	762.0	17.6

* from industry survey and EPA data.

TABLE (4) WASTE CHARACTERISTICS OF UNIT OPERATIONS FROM A CARROT PROCESSING LINE (21)

TYPES OF PROCESS	VOL. OF WATER (GAL/TON)	BOD		SUSPENDED SOLIDS	
		(mg/L)	(LB/TON)	(mg/L)	(LB/TON)
WASHING	600	243	1.4	4120	24.7
	1600	78	1.2	2190	35.0
CANNING	1250	1400	17.5	2000	25.0
	1350	1100	14.8	1830	24.7
DEHYDRATION	4000	1220	48.8	703	28.1
		(860)	(34.4)	(157)	(6.3)

Values in parenthesis relate to settled waste waters.

processing line are listed in table (4).

2.4 Amino Acids and Sugars of Carrots

The study of the amino acids and sugars composition of carrots is important because they are leached or destroyed to some degrees during washing and blanching, consequently generating high pollutional loads.

Amino acids in hot water extracts of carrots which were detected and identified were glutamic acid, valine, leucine, aspartic acid, lysine and serine (22). Carbohydrates present included sucrose, maltose and glucose. The constitution of a simulated carrot soup is shown in table (5).

2.5.1 The Quality Control Criteria in the Purification Systems of Carrot Wastewater

Quality control factors such as physical, physico-chemical, biochemical and biological (fig. 2) must be regulated in order to enhance the feasibility of recycling process wastewater as part of the "total system" concept approach (section 1.2.1.) to the food industry (24).

In the case of water purification in the carrot processing lines, the physical factors refer to factors such as solids, color and turbidity; the physico-chemical factors refer to levels of harmless or potentially troublesome dissolved organics; the biochemical factors refer to the presence of enzymes which might cause alteration of appearance, off-flavor, and reduction in nutritive value; and the biological factors refer to the number of

TABLE (5) CONSTITUTION OF SIMULATED CARROT SOUP (22)

SUBSTANCE	mg/100ml
ASPARTIC ACID	3.15
THREONINE	75.90
SERINE	140.00
GLUTAMIC ACID	60.50
PROLINE	1.86
GLYCINE	2.00
ALANINE	55.40
CYSTINE	trace
VALINE	143.60
METHIONINE	1.69
ISOLEUCINE	5.28
LEUCINE	3.28
TYROSINE	3.74
PHENYLALANINE	3.53
TRYPTOPHANE	1.60
LYSINE	1.22
HISTIDINE	1.35
ARGININE	2.73
TAURINE	20.30
GLUCOSE	75.75
MALTOSE	415.90
SUCROSE	482.98
SUCCINIC ACID	14.10

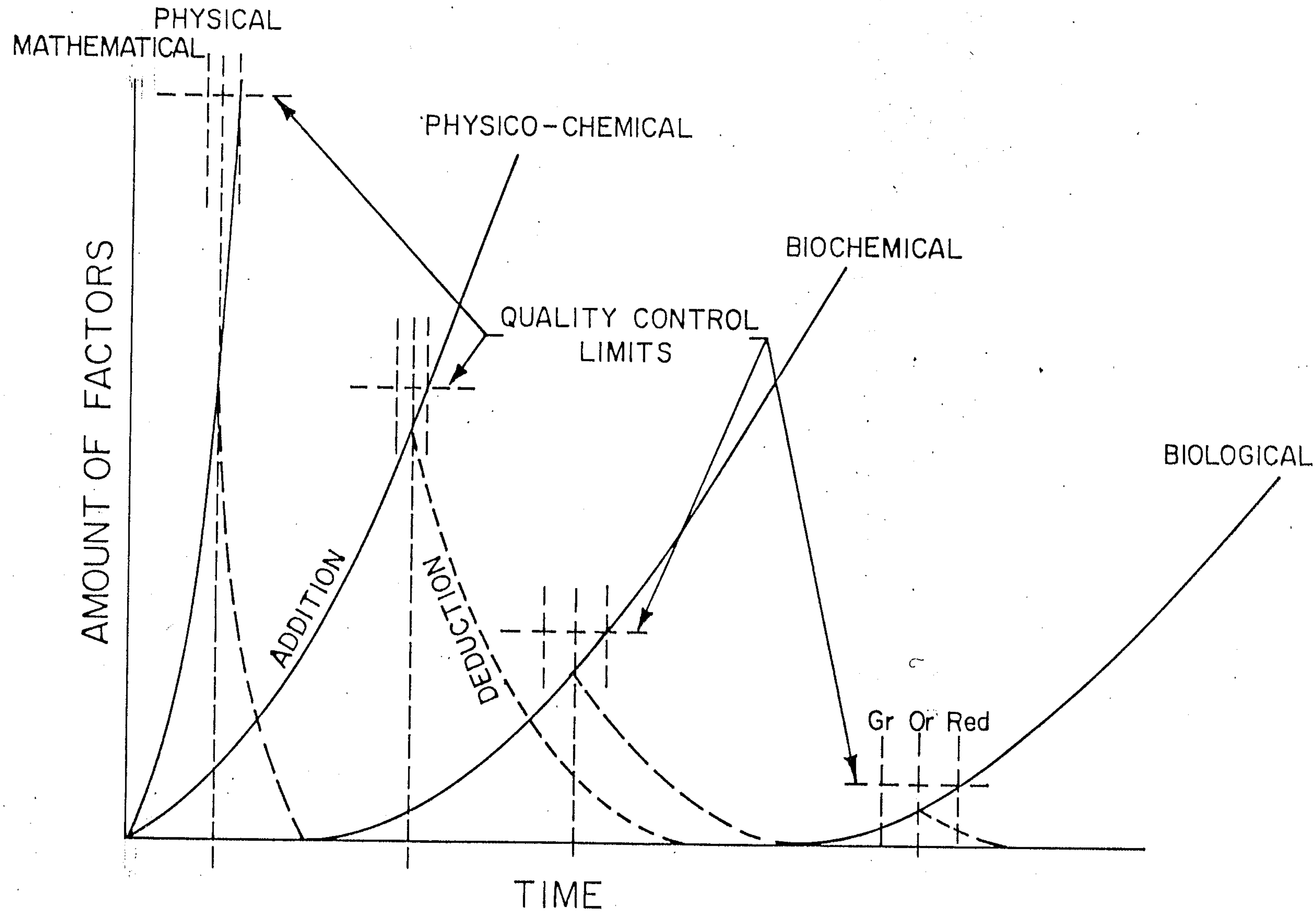


Fig. 2 Growth Rates of Types of Problems, when Recycling Process Waters (24)

potentially objectionable, and possibly dangerous organisms, viruses and bacteria.

The primary objective in wastewater purification systems is to remove the potential build-up of the physical and physico-chemical problems at rates equal to or greater than their rates of increase. The biochemical and biological problems, subsequently can be effectively controlled due to their long induction time.

2.5.2 Enzyme Activity Relating to Carrot Processing

Carrots have been reported to possess polyphenolic compounds and phenolase activity (25). Carrot browning has been a serious problem to Manitoba carrot producers. In Manitoba, unwashed carrots are placed in cold storage immediately after harvest, where they remain until premarket washing. It is suspected that abrasion by mechanical washing damages the skin surface, thereby exposing the internal tissue to oxidation. Chubey and Nylund (1969)(26) suggested that oxidative browning of carrots was caused by the oxidation of phenolic compounds. However, no direct relationships were found between potential browning and total or oxidizable phenols (27).

Water used in carrot processing will leach from the surface of the carrot tissues color-forming compounds such enzymes and enzyme substrates. The colored process water may be undesirable from an aesthetic viewpoint and it also may contain appreciable foam, microbial populations. If recirculated upon freshly exposed food tissue, it may also promote further development of browning. Browning reactions are important for quality control in terms of the alteration of appearance, flavor, nutritive value and possible toxicology (28).

2.5.3 Microbiology of Carrot Processing Effluent

An over-all standard of water quality for the food industries is not practical because so many specialized requirements prevail (29). Traditionally, water for use in food processing operations must usually meet certain required standards of quality, usually equal to those for drinking water, especially the bacteriological standard (30).

The biological characteristics of water are distinguishable by the following effects that are significant from a water quality control viewpoint (31) :

(1) bacterial, viral, protozoal, and helminthic organisms capable of transmitting infections and diseases by the water route,

(2) planktonic algae, actinomycetes, fungi, and other organisms capable of producing objectionable odors, tastes, color, and turbidity,

(3) organisms capable of producing toxic effects by the release of extracellular, metabolic end-products,

(4) nuisance organisms which interfere with water treatment processes and operations.

These four types of effects may be caused by primary or corollary pollutants.