NSF

SPECIAL REPORT

PRELIMINARY STUDY

on

Comparative Leaching Characteristics of Plastics, Copper, and Galvanized Steel Piping Systems Components

Prepared by

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Ann Arbor, Michigan 48106

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BACKGROUND

Results of a three year study of plastic pipe and fittings for potable water applications was published by the National Sanitation Foundation (NSF) in 1955 (1). The study was designed to demonstrate whether or not substances with known health effects would be extracted by an aggressive potable water passing through the pipe and fittings and taste, odor, or appearance of the water would be affected by the pipe and/or fittings. Twenty-two samples, including plastics which were then commonly used with potable water as well as some examples of plastics not intended for potable water applications, were included in the study. After testing the effects of contact with several different aggressive waters, a relatively soft water with pH adjusted with carbon dioxide to 5.0 was selected for the study.

The objective in selecting an exposure water was to simulate a typical "worst case" extractant. Durfor and Becker (2) reported that the pH of treated water in the 100 largest US cities ranges from pH 5.0 to 10.5. Ann Arbor tap water adjusted to pH5.0 was used in the special study and by NSF for subsequent testing of plastics until 1973. To assure reproducibility of testing and to permit other laboratories to undertake equivalent testing, a "standard" extractant water was adopted. This water contains 100 mg/l hardness as calcium carbonate ($CaCO_3$) and 0.5 mg/l chlorine; pH is adjusted to 5.0 ± 0.2 with carbon dioxide. In addition, a "standard" water at pH 11.0 has been formulated to demonstrate extractant levels at the other extreme to which plastics could be exposed in potable water end use applications. Both of these waters were used in the preliminary study on metals piping system components. The formulae for these waters are shown in Tables I and II.

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TABLE I. STANDARD pH 5.0 EXTRACTANT WATER

Distilled Water (ℓ)	Stock Solutions (ml)		
	Buffer[1]	Hardness[2]	Chlorine[3]
to 1.0	25	25	0.5

CO_2 bubbled to pH 5.0 ± 0.2.

[1]3.36 g $NaHCO_3$ dissolved in distilled water and made to 1 liter; prepared fresh daily.

[2]4.44 g $CaCl_2$ dissolved in distilled water and made to 1 liter; prepared fresh daily.

[3]7.3 ml NaOCl (5.5 percent) added to 200 ml distilled water; prepared fresh weekly.

TABLE II. STANDARD pH 11.0 EXTRACTANT WATER

Distilled Water (ℓ)	Na_2CO_3 0.05M (ml)	NaOH 0.1M (ml)
to 1.0	500	250

As a final test of possible health effects in the early study of plastics pipe and fittings, for a period of 18 months, colonies of Wistar strain white rats were given water exposed to the plastics. No significant effects between test and control populations were observed. *Note: A copy of the complete study report was transmitted to Tom Johnson, California Department of Housing and Community Development by Tom Gable, NSF, on February 5, 1980. Additional copies of the study report as well as all other documents referenced in this report are available upon request.*

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Standard 14 (3) was adopted by the NSF Board of Trustees in October 1965; a testing program to assure conformance with the Standard was initiated subsequently in 1965. Following the initial study but prior to 1965, evaluation and listing of plastics piping system components was conducted under contract with each participating manufacturer. The contracts provided for testing and regulation of all parameters subsequently included in Standard 14.

Products which meet the requirements of Standard 14 are authorized to bear the appropriate NSF markings, and are identified in listings, published annually. 1,368 items - pipe, fittings, materials, appurtenances, and joining materials - are included in the 1980 Listing Book (4). Samples of items which bear the NSF marks have been obtained from the production facilities by NSF regional personnel during unannounced visits, and tested in Ann Arbor. *No plumbing system components alternative to plastics are so thoroughly tested.*

The physical and chemical paramters monitored in extraction testing of all plastics products listed by NSF for potable water applications are shown in Table III. Failure experiences for metals extractions from 1977 through July 31, 1980 are summarized in Table IV. Enforcement procedures for failed products are detailed in the Standard and related written Administrative Policies (5). They range from re-sampling by NSF personnel to delisting with notification to relevant state regulatory agencies.

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TABLE III. PHYSICAL AND CHEMICAL PARAMETERS MONITORED IN EXTRACTION TESTING OF PLASTICS FOR POTABLE WATER END USE

Parameter	MCL mg/l (ppm)
Antimony	0.05
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
pH	
Phenolic Substances	0.05
RVCM	10.*
Selenium	0.01
Solids Dissolved (Total)	70.
Tin	0.05

Comments: *In the finished product.

TABLE IV. FAILURE EXPERIENCES IN METALS EXTRACTED DURING TESTING OF PLASTICS

Year	Number Samples	Failures	
		Number	Percent
1977	194	4	2.1
1978	132	0	0
1979	220	1	0.4
1980 (thru July 31)	103	1	1.0

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OBJECTIVE

The objective of the preliminary study of metals piping system components was to demonstrate the comparative leaching characteristics of these products and plastics listed by NSF for similar (i.e., potable water) end use applications.

RATIONALE

Wong and Berrang (6) reported that copper plumbing systems constructed with 50/50 tin/lead solders are potential sources of unacceptably high levels of lead in tap water. Copper pipe with 50/50 soldered joints is commonly used for household plumbing. Samples from infrequently used taps contained lead up to 0.410 mg/l in the first 125 ml flowing from the system after 24 hours of residence time. More than 600 ml of flow was required before the level of lead contamination dropped below the current MCL of 0.05 mg/l. In samples from a tap which had not been used for six months, levels as high as 3.0 mg/l were measured in the first flows, and the MCL was reached after approximately two liters of flow.

To confirm these data, Wong used a simulated new household copper plumbing system constructed with 50 feet of 1/2-inch pipe and 20 joints held in place with 50/50 solder. Between 12,000 and 25,000 liters (3,170 and 6,607 gallons, respectively) of water was flushed through this system before the level of lead was less than the established maximum contaminant level of 0.05 mg/l. "After our simulated system for 50/50 solder was flushed with 150,000 ℓ of water, equivalent to the normal water usage of about one year, the average dissolution rate was found to be 0.4 µg Pb/solder joint/hr., for water stagnant for one hour, and 0.1 µg Pb/joint/hr. for water stagnant for 24 hours. Tests on the real system of a one year old house yielded a dissolution rate of 0.4 µg Pb/joint/hr. *The implication is that water stagnant in a one year old household plumbing system (about 2 ℓ) could exceed the Canadian federal limit of 50 ppb after 4-20 hours, assuming a dissolution rate of 0.1 to 0.5* µg Pb/solder joint/hr.

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NOTE: The MCL for lead established in the US regulations (EPA National Primary Drinking Water Regulations) is also 50 ppb (equivalent to 50 µg/l; equivalent to 0.05 mg/l). (7)

As a result of these studies, the authors recommend that new household copper plumbing systems be flushed with water equivalent to one year of normal usage, and that the first two liters drawn from any system not be consumed if water has been stagnant in the system for 24 hours.

In addition to exposure to high levels of lead, a known cumulative toxin, there is concern about ingestion of high levels of copper in water transmitted through copper household piping systems. The MCL for copper expressed in the EPA National Secondary Drinking Water Regulations is 1.0 mg/l. Moffitt (9) reported, "Doctors claim that corroding copper water pipes have been poisoning office-staffs in new and renovated complexes in Newcastle, NSW - with similar illnesses found in other Australian cities." High serum copper levels were measured in the exposed population, and "analyses of water samples from the buildings have disclosed levels of copper in the water that are many times the accepted standard of 1.0 milligrams per liter. ... Three tests of the water on one day showed that it contained 12.96, 8.14, and 13.08 milligrams of copper per liter, with a reading of 18.32 at 8am the following day. This compared with the maximum allowable concentration of copper set at 0.30 milligrams per liter in treated water for Australian capital cities, and 1.00 for untreated water supplies. Other readings in Newcastle have reached 200 milligrams per liter - 200 times the accepted safe level."

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The Oregon Deparment of Human Resources has reported to the American Medical Association (AMA) that residents who complain of disagreeable tastes and odors in their drinking water and have suffered apparently related mild diarrheal symptoms may have been affected by contamination from galvanized pipe used in household plumbing service lines. The AMA responded with a resolution (10) adopted by its House of Delegates, which states ... "Whereas, Currently existing standards for galvanized steel pipe for potable water plumbing do not address preventing the introduction of potentially harmful chemicals into drinking water passing through the pipe; therefore, be it

RESOLVED, That the American Medical Association encourage national agencies directly involved in standard setting activities such as the National Sanitation Foundation and the US Public Health Service (Communicable Disease Center and Food and Drug Administration) to develop standards for galvanized steel pipe used for plumbing purposes that would include health aspects as well as physical and chemical properties."

NSF has indicated to AMA a willingness to be responsive to the expressed need.

These reports and the AMA communique provide rationale for the preliminary study undertaken by NSF.

PROTOCOL

Samples

Three samples of copper and galvanized pipe and fittings were purchased separately as random "off-the-shelf" orders, two each (copper and galvanized) from a local wholesale and retail plumbing supply outlet, and one from a local hardware store. Two samples of tin stabilized polyvinyl chloride (PVC) pipe and fittings were

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selected randomly from samples received for testing by NSF.

The copper pipe samples were cut and reamed (inside bevel) using standard plumbing procedures. Joints (couplings) were made using a flux cleaner and 50/50 (50 percent tin and 50 percent lead) solder.

Galvanized pipe samples were cut, threaded, and reamed using standard plumbing procedures. Couplings were sealed with Galaxy Stainless Plumbing Putty (ingredients not available).

Plastic pipe was cut with a band saw. Joints were primed with a primer containing THF, cyclohexanone, DMF, and MEK. The solvent cement used contained THF, cyclohexanone, and MEK.

All materials were rinsed with distilled water before exposure.

Each type of product was tested as pipe only and an equivalent length of pipe plus fitting. Fittings in the copper and galvanized tests were couplings; a 90-degree PVC elbow was used in the plastic pipe tests. All samples were 1-inch I.D.

Test Procedures

Two different protocols were used in this study: conventional static NSF multiple cold exposures with all extractants tested, and a procedure used in Great Britain to simulate the dynamics of flow through a system (11).

NSF Procedure

The standard ratio-surface area of exposure to volume of water exposed - was used with all samples tested (i.e., 1.0 liter standard pH 5.0 or 11.0 extractant water to 250 square inches - 1,612.9 square centimeters-of sample). Pipe samples were cut by sawing into 5-inch (127.0 mm) sections and burrs removed. They were placed in Pyrex beakers and the entire sample surface covered

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with the appropriate volume of extractant water. Beakers were covered and held at 37 ± 0.5°C for 24 ± 1 hours. Water was decanted and tested as "first extractant." Beakers were refilled and the samples exposed at 37 ± 0.5°C for 24 ± 1 hours. Water was decanted and tested as "second extractant." Beakers were refilled and exposed at 37 ± 0.5°C for 72 ± 4 hours for "third extractant" testing.

British Procedure

One hundred milliliters (100 ml) of standard pH 5.0 or 11.0 extractant water was poured into eight-inch lengths of copper, galvanized, and PVC pipe and pipe with joined fittings. The ends were sealed with rubber stoppers coated with plastic wrap previously tested to assure that no detectable metals would extract from the wrap. Samples were attached to a motor driven rod to rotate at 30 rpm. (See Figure 1.) After one hour, the water was removed and tested. Sample was refilled (100 ml) and rotated for six hours; then, the water was removed and tested. Samples were refilled (100 ml) and the water tested after 24 hours of rotation.

At 100 ml of water per eight-inch length of one-inch pipe (or pipe and fitting), the ratio of surface area of sample to volume of extractant water exposed is 3.25 square centimeters per ml, or approximately two times the area to volume ratio used in the conventional NSF extraction procedure. Other differences include the simulated flow in the British method, exposure of cut and external surfaces in the NSF method, and varying periods of exposure (24, 24, and 72 hours, NSF; and 1, 6, and 24 hours, British).

Analyses

Exposed extractant water was poured through course filter paper (White, Crepe, VWR Grade No. 615) into borosilicate bottles, high purity nitric acid (HNO_3) added (0.2 percent for pH 5.0 exposures and 0.5 percent for pH 11.0 exposures), and the samples refrigerated. Analyses were performed using atomic absorption

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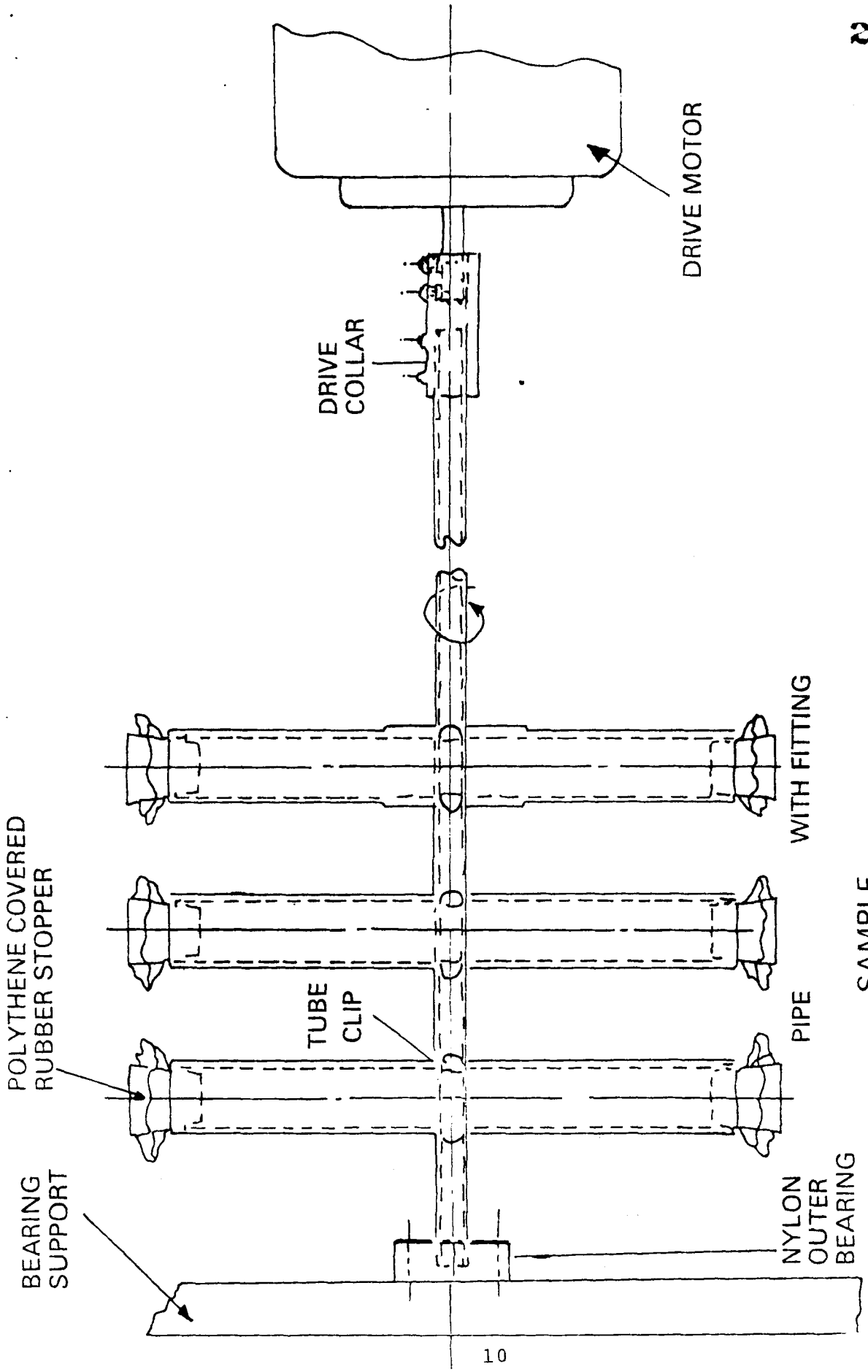

FIG. 1 APPARATUS USED IN BRITISH EXTRACTION PROCEDURE

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spectrophotometry following procedures described in Standard 14 (3). When necessary to overcome matrix interferences common to the pH 11 extractant medium, slight modifications were made in furnace times or temperature settings. Quality assurance practices were followed in accordance with Standard 14 and standard NSF laboratory practices.

RESULTS

All samples - copper, galvanized, and plastic pipe using the NSF procedure, and pipe and joined fittings using the British procedure - were within the established maximum contaminant levels (MCL's) for antimony (NSF MCL=0.05 mg/l); arsenic (EPA Primary Regulations MCL=0.05 mg/l); barium (EPA Primary Regulations MCL=1.0 mg/l); and cadmium (EPA Primary Regulations MCL=0.01 mg/l). Levels of copper, lead, iron, selenium, tin, and zinc exceeded NSF or EPA MCL'S in one or more samples tested. These data are presented in Table V.

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TABLE V. RESULTS

Parameter	MCL (mg/l)	Sample	Procedure	Extract (mg/l) pH 5.0			pH 11.0		
				1	2	3	1	2	3
Copper	1.0[1]	Copper pipe A	NSF	0.8	0.6	2.1	0.23	0.13	0.13
		Copper pipe B	British	0.49	0.29	19.50	1.58	1.86	0.52
		Copper pipe B + fitting	British	2.83	2.27	2.65	1.26	2.10	1.16
		Copper pipe C	British	0.57	1.26	22.50	1.36	2.08	0.42
		Copper pipe C + fitting	British	3.08	2.16	1.50	1.34	1.72	0.58
		Galvanized pipe A, B, C	NSF and British	All samples <MCL					
		Galvanized pipe B, C, & fittings							
		Plastic pipe A, B							
		Plastic pipe A, B, & fittings							
Lead	0.05[2]	Copper pipe A	NSF	0.014	<0.005	0.005	<0.005	<0.005	0.013
		Copper pipe B	British	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01
		Copper pipe B + fitting	British	3.2	3.6	1.4	0.30	0.40	0.70
		Copper pipe C	British	<0.005	<0.005	<0.005	0.01	0.01	<0.01
		Copper pipe C + fitting	British	3.4	4.4	1.6	0.50	0.08	0.90

[1]EPA National Secondary Drinking Water Regulations

[2]EPA National Primary Drinking Water Regulations

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CONTINUATION TABLE V. RESULTS

Parameter	MCL (mg/l)	Sample	Procedure	Extraction (mg/l) pH 5.0 1	pH 5.0 2	pH 5.0 3	pH 11.0 1	pH 11.0 2	pH 11.0 3
Lead (con't)		Galvanized pipe A	NSF	0.110	0.162	0.038	1.6	1.4	1.7
		Galvanized pipe B	British	<0.005	<0.005	0.011	0.06	0.16	0.16
		Galvanized pipe B + fitting	British	<0.005	0.025	<0.005	0.01	0.44	0.99
		Galvanized pipe C	British	0.117	0.120	0.099	0.900	1.5	1.8
		Galvanized pipe C + fitting	British	0.066	0.084	0.038	0.500	0.70	1.2
		Plastic pipe A, B	NSF and British	All samples <MCL					
		Plastic pipe A, B, + fittings							
Iron	0.3[1]	Galvanized pipe B + fitting	British	2.01	4.15	0.86	0.01	0.01	0.03
		Copper pipe A, B, C	NSF and British	All samples <MCL					
		Copper pipe B, C + fittings							
		Galvanized pipe A, C							
		Galvanized pipe C + fitting							
		Plastic pipe A, B							
		Plastic pipe B + fitting							

[1]EPA National Secondary Drinking Water Regulations

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CONTINUATION TABLE V. RESULTS

Parameter	MCL (mg/l)	Sample	Procedure	Extraction (mg/l) pH 5.0 1	pH 5.0 2	pH 5.0 3	pH 11.0 1	pH 11.0 2	pH 11.0 3
Selenium	0.01[2]	Galvanized pipe A	NSF	0.022	0.022	0.022	<0.01	<0.01	<0.01
		Galvanized pipe B	British	0.006	0.008	0.007	<0.01	<0.01	<0.01
		Galvanized pipe B + fitting	British	0.008	0.015	0.005	<0.01	<0.01	<0.015
		Galvanized pipe C	British	0.010	0.013	0.007	<0.01	<0.01	<0.01
		Galvanized pipe C + fitting	British	0.005	0.017	0.007	<0.01	<0.01	<0.01
		Copper pipe A, B, C	NSF and British	All samples <MCL					
		Copper pipe B, C + fittings							
		Plastic pipe A, B							
		Plastic pipe A, B + fittings							
Tin	0.05[3]	Copper pipe A	NSF	<0.002	0.002	<0.002	0.23	0.13	0.13
		Copper pipe B	British	<0.005	0.009	<0.005	<0.01	<0.01	<0.01
		Copper pipe B + fitting	British	<0.005	0.043	0.098	0.80	0.60	0.10
		Copper pipe C	British	<0.005	<0.005	<0.005	0.01	<0.01	<0.01
		Copper pipe C + fitting	British	<0.005	0.079	0.090	0.50	1.0	0.30

[2]EPA National Primary Drinking Water Regulations

[3]NSF

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CONTINUATION TABLE V. RESULTS

Parameter	MCL (mg/l)	Sample	Procedure	Extraction (mg/l) pH 5.0 1	pH 5.0 2	pH 5.0 3	pH 11.0 1	pH 11.0 2	pH 11.0 3
Tin (con't)		G anized pipe A	NSF	<0.002	<0.002	<0.002	<0.01	<0.01	<0.01
		G anized pipe B	British	<0.005	<0.005	<0.005	0.08	<0.01	0.01
		G anized pipe B + fitting							
		G anized pipe C							
		G anized pipe C + fitting	British			All samples <MCL			
		P tic pipe A, B							
		P tic pipe A, B fitting							
Zinc	5.0[1]	C er pipe A	NSF	0.05	0.03	0.02	<0.01	<0.01	7.4
		G anized pipe A	NSF	95.	65.	85.	1.6	1.6	10.
		G anized pipe B	British	13.7	43.5	63.0	0.46	0.75	0.98
		G anized pipe B + fitting	British	11.5	40.5	47.5	1.18	1.73	4.16
		G anized pipe C	British	50.	90.	44.	0.93	1.15	2.11
		G anized pipe C + fitting	British	44.	96.	48.	1.30	1.42	3.84
		C er pipe B, C							
		C er pipe B, C fittings	British			All samples <MCL			
		I stic pipe A, B							
		I stic pipe A, B fittings							

[1]EPA National Secondary Drinking Water Regulations

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CONCLUSIONS AND RECOMMENDATIONS

Results of this study appear to support data in the referenced literature for levels of lead and copper extracted from simulated and in-service copper service lines.

Data for leaching characteristics of plastics piping system components are available as a result of the comprehensive special study, published in 1955; NSF Standard 14; and the subsequent voluntary program for testing and listing plastics for conformance with the Standard. No types of plumbing system components alternative to plastics have been extensively tested by a third party certifier; no product standards similar to NSF Standard 14 for thermoplastics are known to exist for the commonly used metals, copper and galvanized steel.

This study is preliminary because of the limited numbers of samples examined to date. However, using waters at low and high pH values simulating the range reported for finished waters in the 100 largest US cities, no levels of metals extracted from PVC samples - pipe, and pipe and fittings - included in the study exceeded established maximum contaminant levels for any of the parameters tested. Excessive levels of copper, lead, tin, and zinc were extracted from samples of copper and/or galvanized components purchased as off-the-shelf items from local vendors.

The data cited from the literature and obtained from this preliminary study indicate clearly the need for further testing of copper and galvanized pipe and fittings intended for transport and delivery of potable water.

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Thrombocytopenia Associated with Swan-Ganz Catheterization in Patients

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Flow-directed, balloon-tipped pulmonary-artery catheters (Swan-Ganz catheters) induce thrombocytopenia as a result of increased consumption of platelets in dogs.[1] In the present study, we examined the effects of Swan-Ganz catheters upon platelet counts in adult patients undergoing coronary-artery bypass graft operations.

MATERIALS AND METHODS

Thirteen patients who underwent coronary-artery bypass grafting for coronary-artery disease were studied. The studies were approved by the University of Pennsylvania Committee on Studies Involving Man. In seven patients, Swan-Ganz catheters,§ and in six patients, central venous catheters,¶ were employed for monitoring hemodynamic performance. Six of seven patients in the Swan-Ganz catheter group and five of six in the central venous catheter group were male. Mean ages, body weights and body surface areas (±SE) were 53 ± 3.4 years, 81.8 ± 4.9 kg, and 1.95 ± 0.06 m^2, respectively, in the Swan-Ganz catheter group, and 57 ± 4.5 years, 83.8 ± 2.7 kg, and 1.93 ± 0.05 m^2, respectively in the central venous catheter group, not statistically significantly different. In both groups the catheters were introduced through right internal or external jugular veins and remained *in situ* for 24 hours.

Extents of disease, premedications, anesthetic methods (halothane, nitrous oxide, oxygen) and medications before, during and after anesthesia were similar in the two groups. None of the patients had postoperative complications or received platelet infusion during the period of study. The durations of cardiopulmonary bypass and the amounts of blood transfused between sampling times in the two groups were compared.

Peripheral blood platelet counts were performed in triplicate by phase-contrast microscopy[2] of blood drawn into ethylenediamine tetraacetic acid (EDTA) from a radial artery or an antecubital vein (24 hours after the removal of the catheter) and diluted in a standard fashion.** Blood samples for platelet counts and hematocrits were obtained before catheterization, an hour after catheter insertion but before surgical incision, and six, 24 and 48 hours after catheter insertion. The catheters were removed 24 hours after insertion.

Rectal temperatures were recorded at the times of blood sampling.

Statistically significant differences between platelet counts of the two patient groups at the 95 per cent confidence level were confirmed by analysis of variance. Differences between platelet counts at specific time intervals was confirmed by Tukey's test for unconfounded means.

RESULTS

Mean (±SE) peripheral blood platelet counts (number of platelets/mm^3 blood) for the two groups are shown in figure 1. An initial decrease (six hours) in both groups corresponds to the period of cardiopulmonary bypass. Platelet counts in the Swan-Ganz catheter group, but not the central venous group, continued catheter to decline such that at 24 hours the mean platelet count was 83,000 fewer ($P < 0.05$) than that in the latter group at the same time interval (and 117,000 [$P < 0.05$] less than the initial Swan-Ganz catheter control value at time 0). After removal of the Swan-Ganz catheter at 24 hours, platelet count began to rise, although platelet counts in the Swan-Ganz catheter group continue to remain significantly depressed at 48 hours.

Mean durations of cardiopulmonary bypass (±SE) were 83.6 ± 8.7 min in Swan-Ganz catheter group and 81.7 ± 10.0 min in the central venous catheter group, not significantly different.

The numbers of units of blood transfused (mean

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Address reprint requests to Dr. Richman.

Key words: Blood: platelets. Equipment: catheters, Swan-Ganz.

§ Edwards Laboratories, Santa Ana, California.

¶ 16-gauge, 8-inch polyurethane Arrow central venous catheter, Arrow International, Inc., Reading, Pennsylvania.

** Unopette®, Becton-Dickinson, Rutherford, New Jersey.

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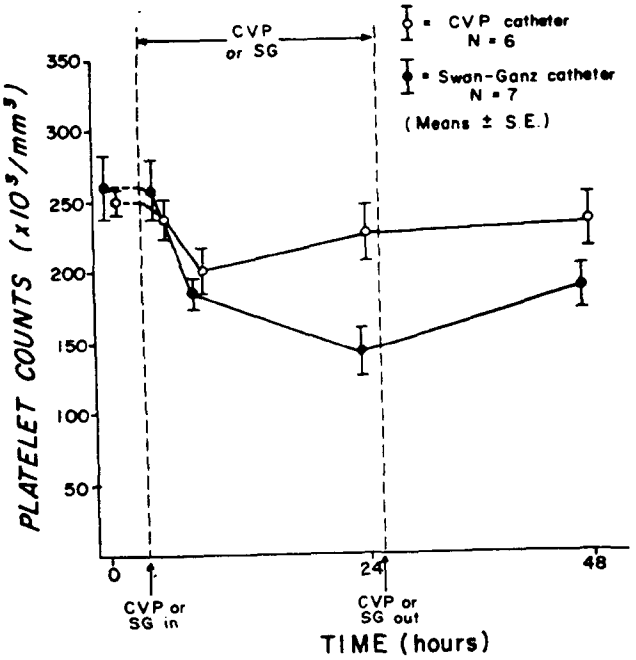

FIG. 1. Mean platelet counts (±SE) for patients with Swan-Ganz catheters (*solid circles*) and central venous catheters (*open circles*). "CV or SG in" is the time of catheter insertion; "CV or SG out" is the time of catheter removal; "0" is the time of pre-catheterization sampling.

± SE) were 2.3 ± 0.36 in the Swan-Ganz catheter group and 2.7 ± 0.33 in the central venous catheter group, and statistically the same. Hematocrits and body temperatures after different intervals of time were the same in the two groups.

DISCUSSION

We found that insertion of a pulmonary-artery catheter was associated with increased platelet consumption, and that the phenomenon reversed [illegible] removal of the catheter. Use of cardiopulmona[illegible] bypass contributed to the early decreases of platel[illegible] counts in both groups studied,[3] but the decrease [illegible] platelet counts in the Swan-Ganz catheter grou[illegible] continued throughout catheterization and afte[illegible] termination of cardiopulmonary bypass. After r[illegible] moval of the Swan-Ganz catheter, the platelet cou[illegible] began to increase.

Swan-Ganz and central venous catheters are fa[illegible] ricated from foreign materials that induce thrombu[illegible] formation.[4,5] That Swan-Ganz catheters reduce plat[illegible] let counts more than do central venous catheters ma[illegible] reflect the greater surface area of the former catheter[illegible] Thrombus formation along the surface of the cathete[illegible] has been observed by others in man and by us i[illegible] dogs.[1,4,5]

Although, in this study, clinical evidence of an[illegible] complication associated with platelet reduction wa[illegible] not observed, our findings demonstrate that pro[illegible] longed pulmonary arterial catheterization should b[illegible] included in the differential diagnosis of thrombo[illegible] cytopenia.

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