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Variation of Inorganic Compounds in Home Bath Water

Jun Kobayashi[1]*, Keiichi Ikeda[2] and Hideo Sugiyama[3]

[1]*Faculty of Veterinary Medicine, Nippon Veterinary and Life Science University, Tokyo, Japan*
[2]*Faculty of Pharmaceutical Sciences, Hokuriku University, Ishikawa, Japan*
[3]*Graduate School of Health Sciences, Matsumoto University, Nagano, Japan*

Abstract

Bath water is heated to warm the body, and in Japan it is used to remove cleaning agents from the skin before entering the bathtub. Usually this water does not enter the body, but there have been cases where people have caught infectious diseases through inhalation of aerosols. In this study, we examined the change in hygiene and chemical composition of the bathtub water in various conditions as a model of circulating bath. To investigate the potential for bacterial growth in home bath water in Japan, changes in the concentrations of metal and non-metal inorganic compounds were studied as the number of days the water was re-used. With re-use of bath water within 1 week, the concentrations of most of the compounds increased, but the phosphorus decreased. Increasing concentrations could be attributed to sweat secreted from skin of the bather, compounds eluted from the water heater, as the bath water was re-heated, and addition of bath salts. Consumption of inorganic compounds by bacteria and precipitation of metal hydroxides could be thought to the decreasing concentrations. Common bacteria and coliform bacteria were also measured simultaneously, and only the coliform bacteria increased in the water on the second day the water was used for bathing. It seems bacteria probably grew in the pipes between the water heater and the bathtub.

Keywords: Inorganic compound; Bathing; Coliform bacteria

Introduction

Bath water is heated to warm the body, and in Japan it is used to remove cleaning agents from the skin before entering the bathtub. It is assumed that the water does not enter the body during bathing. However, in a shower, water can be unintentionally inhaled as an aerosol. Water could also enter the body through wounds in the skin. In public baths, used water may not be replaced with fresh water for several days, and this could result in spread of infectious diseases. Bacteria can grow in water heaters if they are not cleaned properly, and the addition of inorganic compounds to the bath water from the water source or the skin of bathers can be thought to promote bacterial growth. Many bacteria can grow in soil [1,2], and in a bathroom, bacteria in the bath water will circulate throughout the water heater where they could adhere and grow. Consequently, filtration of water before it enters the water heater is a requirement at large public baths in Japan [3]. However, many home bathrooms in Japan are equipped with small cyclical type boilers that re-heat bath water without filtration, and bacteria could multiply in these systems [4,5]. It is a Japanese custom to soak in a bathtub after cleaning the body outside of the bathtub, and the water is re-used for subsequent baths. If you wash the body in the home bathtub, dirt adheres to the pipe between the water heater and bathtub. So this pipe is difficult to wash, bring the risk of contaminating the dirt at the time of the next bathing. As a result, other than the part of the unit bath, it is not possible to wash the body in the bathtub.

This custom may increase the risk for contracting such illnesses compared with in other countries. Sekine et al. showed that bacteria such as *Legionella*, require inorganic compounds for growth [2,6]. She added trace elements to the agar medium, and checked the increase and decrease of bacteria. It is thought that this demand nature is naturally maintained also in the bathroom, the inorganic compounds may be required for growth of bacteria in bath water. This is considered to lead to prevention of infectious diseases. In order to prevent bacteria infection, daily water quality testing is important. In this study, as a model case of circulating bath, we examined the change in hygiene and chemical composition of the bathtub water in various conditions. Changes in the concentrations of inorganic compounds home bath water in Japan were investigated as the number of days the water was re-used for bathing increased. The relevance of these results to growth of bacteria was considered.

Methods

Instruments and reagents

The target analytes were inorganic elements (Li, B, Na, Mg, Si, P, K, Ca, Sc, Ti, V, Mn, Fe, Cu, Zn, Ge, Se, Rb, Sr, Mo, Ba, W, Tl, Pb, Th, U), inorganic anions (Cl^-, NO_3^-, SO_4^{2-}), coliform bacteria, common bacteria, residual chlorine, chemical oxygen demand (COD) and pH. In these, the inorganic element was selected based on the report of Sekine.

The inorganic elements were analyzed at ppm levels by inductively coupled plasma emission spectrometry (ICP-AES, Optima 4300 DV; PerkinElmer, Waltham, MA), and at ppb levels by inductively coupled plasma mass spectrometry (ICP-MS, Elan 6100 DRC, PerkinElmer). The reference solution (XSTC-13; Spex Certiprep, Metuchen, NJ) was used for the inorganic element analyses by ICP-AES and ICP-MS. Anion chromatography was conducted using a AI 450 (Dionex, Sunnyvale, CA). A negative-ion mixed reference solution IV (Kanto Kagaku, Tokyo, Japan) was used as the standard for anion chromatography. Levels of coliform bacteria and common bacteria were measured using experimental paper (Sibata Scientific Technology Ltd., Soka, Japan) according to the manufacturer's instructions. Packtests including *N*,*N*-diethyl-1,4-phenylenediamine and alkali permanganic acid (Kyoritsu Chemical-Check Lab, Tokyo, Japan) were used for measurement of

***Corresponding author:** Jun Kobayashi, Faculty of Veterinary Medicine, Nippon Veterinary and Life Science University, Tokyo, Japan, Tel: +81-422-31-4151; E-mail: junkoba@nvlu.ac.jp

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residual chlorine and COD, respectively. The pH was measured with a pH meter (F-22; Horiba, Kyoto, Japan). High purity nitric acid (TamaPure AA-100, Tama Chemicals, Kawasaki, Japan) was used in the experiments. A membrane filter (MILLEX HA, Millipore, Billerica MA; pore size 0.45 μm) was used for filtration of the samples. Purified water (>18 MΩ cm, Elix 3/Element A10, Millipore) was used for reagent preparation. All other reagents were of special grade and available commercially.

Sampling and pretreatment

Samples of home bath water were obtained from one residence in Chiba, Japan, from June to July 2008. The gas heater (FR-250, Hitachi Housetec, Ibaraki, Japan) at this residence was equipped with a hot-water supply, a system for re-heating the water, and controls for the volume and temperature of water entering the bath.

Bath water samples were collected before bathing every day for 1 week in each of the condition. For each day of the week, the same water was used for bathing and not exchanged for fresh water until the next week. The bathtub (Kiramic RPU-0042, Otaki Gas, Chiba, Japan) was cleaned on the first day of each week, and then water (42°C, 200 L) was added. A sample of this water was collected from the bath before bathing, and a sample of tap water was collected from the bath faucet. Measurements for common bacteria, coliform bacteria, and residual chlorine were conducted. Another sample of the bath water was taken after the water had been re-heated for bathing on subsequent days, and the same measurements as above were conducted. Experiments were conducted for 8 weeks (conditions), and each week was used to investigate different bathing conditions, including addition of bath water to maintain the water at the same level as the day before, addition of bath salts or a chlorine disinfectant, and cleaning of the water heater. The chlorine disinfectant is possible to perform cleaning of the pipe between the bath and the heater by being circulated. However, it is not always possible to add a physical force, only sterilization and protein denaturation are carried out. A list of all of the experimental conditions are shown in Table 1.

COD and pH measurements were conducted on all the bath water samples. Samples were filtered before anion chromatography, and acidified with concentrated nitric acid after filtration for ICP-AES/MS. The prepared samples were kept in a refrigerator before use.

Exp. Series	Water level control*1	Bathing	Additive*2	Tub cleaning*3	Boiler cleaning*4	Disinfectant*5
I		✓		✓		
II	✓	✓	✓	✓		
III	✓	✓		✓		
IV				✓		
V		✓*6		✓		
VI		✓		✓	✓	
VII		✓	✓	✓	✓	
VIII		✓		✓		✓

Table 1: Experimental conditions investigated during bathing every one week (I–VIII). *1Hot water was added to adjust the level of the bath water to the same as that the day before, and the water in the tub was heated again before bathing. *2Bath salts were added at 2 day intervals over the week. *3Before starting the weekly experiment, the bathtub was cleaned using detergent and a brush. *4The water heater was cleaned with a commercial detergent by circulating the bath water. *5A chlorine disinfectant was added each day after bathing. *6Before bathing, the bather did not rinse soap from their body.

For pre-bathing, test water of the first day in each condition was considered to reflect the between-day variation of tap water components, and little affected passing through the water heater. Component variations of test water from the second day, are affected by re-heated, bathing and standing. In particular, continuous rising and falling of the component concentration is thought to indicate that the same phenomenon is continuous.

Results and Discussion

Inorganic components

The concentrations of Na, K, Ca, Cu, Zn, Rb, Ba, Cl^- and SO_4^{2-} increased over each week (Figure 1). By contrast, the concentration of P decreased (Figure 2), and the concentrations of Mn and Ti showed both increases and decreases (Figure 3). The concentrations of Li, B, Mg, Si, Sc, V, Fe, Ge, Sr, Mo, W, Th and NO_3^- did not change. ICP-MS measurements were performed for Se, Tl, Pb and U. However, the measured values were close to the limit of detection, and the results cannot be considered as reliable. The bathtub, water heater, bather, and bath salts, were all considered as potential sources of the inorganic elements. The concentrations of Cu and Ba increased in all experimental conditions (I–VIII), and the bathtub and the water heater were likely

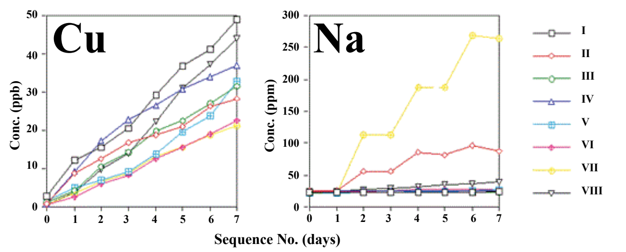

Figure 1: Changes in the concentrations (increasing concentrations) of inorganic compounds within the 7 days. The same bath water was used in each of the eight experiments (I–VIII). The experimental conditions are shown in Table 1. K, Ca, Zn, Rb and Ba were varied in the same trend as Cu. Sulfate was varied in the same trend as Na.

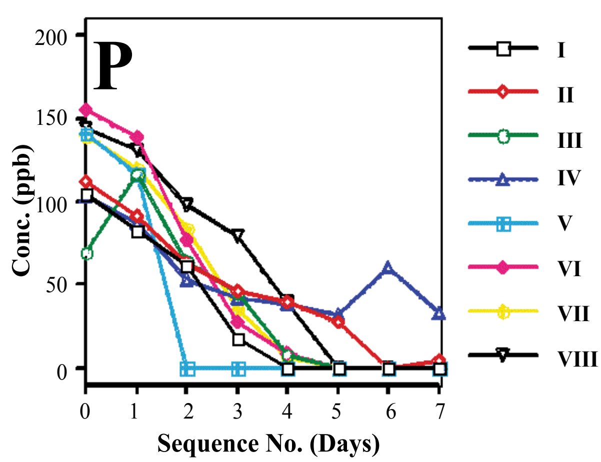

Figure 2: Changes in the concentrations (decreasing concentrations) of inorganic compounds within the 7 days. The same bath water was used in each of the eight experiments (I–VIII). The experimental conditions are shown in Table 1.

sources for these elements. To support this, the water heater was known to contain Cu. The concentrations of K, Ca, Zn, Rb, and Cl^- increased under all conditions, except for IV. Therefore, these elements are likely secreted by the bather Sweat is known to contain Na, K, Ca and Cl^- [7,8], and a small amount of Zn [9]. Rb is thought to behave like Na and K because it is an alkaline metal. When bath salts were added to the bath, the concentrations of Na, Ti, Cl^- and SO_4^{2-} increased dramatically. The ingredients label of the bath salts confirmed it contained Na and SO_4^{2-}, and Ti is also a known ingredient of bath salts. The Ti concentration decreased in some conditions and the P concentration decreased in all the conditions. Bacteria in the water could have consumed these elements. The changes in the concentration of P could be attributed to the source water as with the COD. In condition IV, where bathing did not occur, the decrease in the P concentration was slow. This is because bacteria that would have entered the bath water from the bather were not present to consume P. By contrast, Ti can be consumed rapidly by only a few bacteria, and may have a catalytic function. Furthermore, the possibility that Mn was oxidized to oxyanions was investigated. Sekine et al. reported that Mn and Se are co-factors of *Legionella* growth [2,6]. In the present study, the Mn concentration did not decrease, and the bather did not develop Legionnaires' disease. To support this, the concentration of Fe, which is required for *Legionella* growth [10,11], did not change.

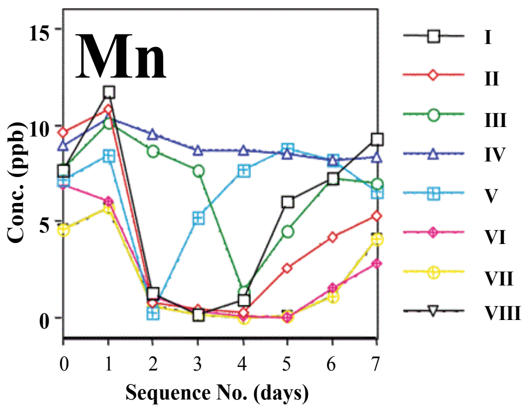

Figure 3: Changes in the concentrations (no consistent trend) of inorganic compounds within the 7 days. The same bath water was used in each of the eight experiments (I–VIII). The experimental conditions are shown in Table 1. Ti was varied in the same trend as Mn.

COD, residual chlorine and pH

In the water sample taken before bathing, the COD was not 0 mg/dL. This was attributed to the tap water source, which was swamp water. Increases in the COD during the experiments (Figure 4) could be cause by sweat and dirt from the bather. Consumption of organic matter by bacteria was thought to causes the decreases observed in the COD. Additionally, the pipes and water storage area could have affected the COD. Compared with the other experimental conditions, V and VIII had higher COD values. These results could be attributable to soap and the chlorine disinfectant in the water. The residual chlorine

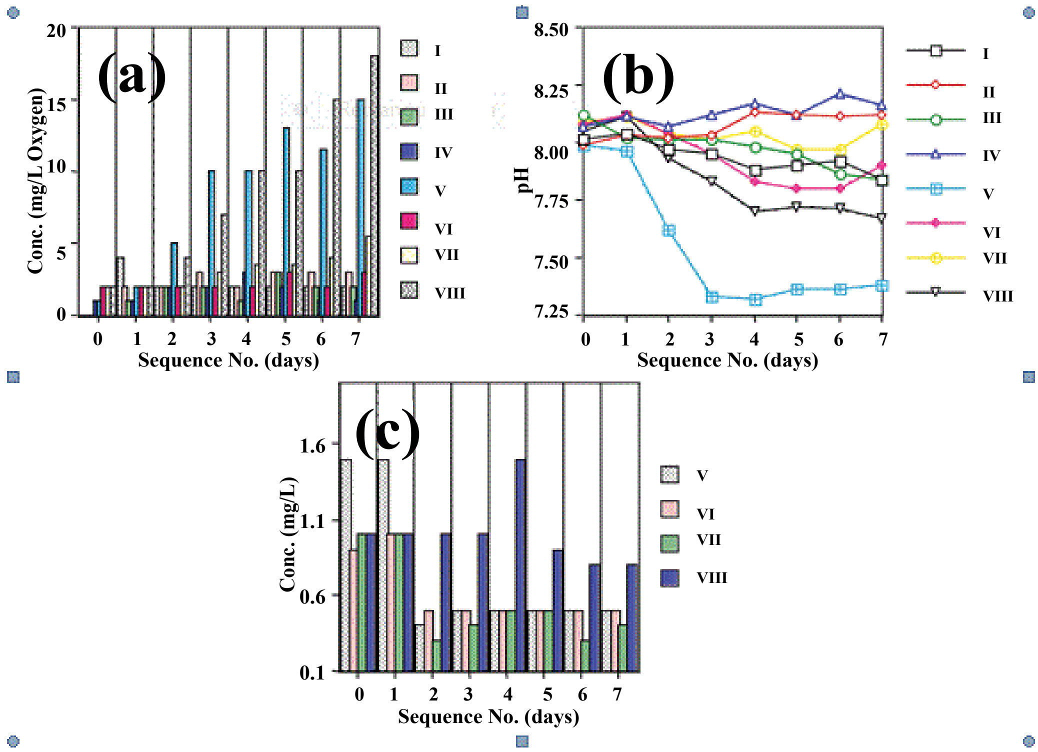

Figure 4: Changes in the COD (a), pH (b) and residual chlorine (c) within the 7 days. The same bath water was used in each of the eight experiments (I–VIII). The experimental conditions are shown in Table 1.

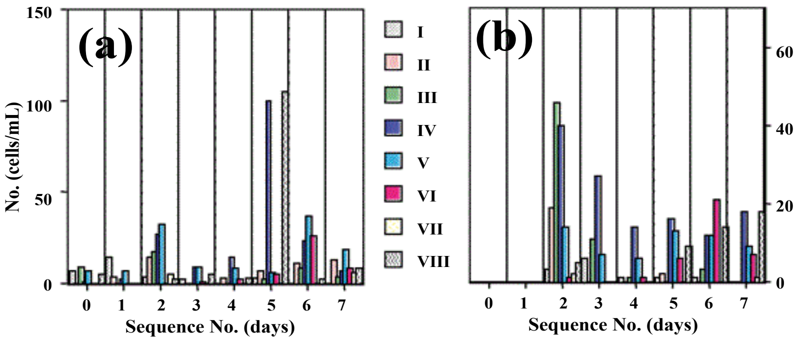

Figure 5: Changes in the number of viable bacteria (a) and coliform bacteria (b) within the 7 days. The same bath water was used in each of the eight experiments (I–VIII). The experimental conditions are shown in Table 1.

concentration was highest on the first day of each week, and then decreased gradually as there was no further addition of chlorine disinfectant during the week. This decrease was probably caused by volatilization of the chlorine with heating of the water. However, even with these decreases, a free chlorine concentration of 0.1 mg/L was obtained on the seventh day. Because other results showed that bacterial growth occurred, these chlorine measurements were not useful for determining if disinfection of the water occurred [12,13]. Measurement of residual chlorine is recommended at public baths and hot springs in Japan. In the present study, the Packtest was used for the measurement. However, this kit can react to substances other than chlorine [14]. Therefore, the chlorine concentration should be measured by other methods [15]. Over the week, the pH decreased gradually under all experimental conditions. The decrease under the conditions in experiment V was particularly remarkable, and this could be attributed to sweat remaining on the skin of the bather [16].

Common bacteria and coliform bacteria

Bacteria were detected in the water sample from the faucet. In each of the eight weeklong experiments, the number of bacteria decreased initially and then increased again (Figure 5). All bacterial levels were less than 100 cells/mL, which is the upper limit for domestic water supply in Japan [17]. Coliform bacteria were not detected in the water samples on the first day, but they were detected on the second day, which was the first day the water was heated for re-use after bathing. The levels of coliform bacteria then decreased and increased at different points after the second day. Increases in the viable cell counts show that bacteria were present on the body of the bather or in the bathroom. Changes in the coliform levels were probably affected by circulation of the bath water through the water heater, piping, and bathtub. Because cleaning the bathtub before each experiment was sufficient to remove any bacterial growth, there were very few places that bacteria could adhere and grow within the bathtub. Therefore, bacteria must have grown inside the water heater or pipes between the bathtub and heater [18]. Some bacteria are protected from detergent by formation of a biomembrane, and cannot be easily removed [1,12]. Mold growth can occur at the faucet and enter the bath water when the bath is filled [19]. Bacteria were detected in the bath water immediately after the water heater was cleaned, which indicates that the bactericidal effect of chlorine in the bath water was not maintained for a long time.

Conclusion

As a result of taking a bath for relaxation and health promotion, it is putting the cart before the horse if it suffered from infection. The direct detection procedure of the legionella bacteria which is the typical infection over bath water takes time very much, and needs a special culture condition. Therefore, it is not suitable for a routine test. There are some commercial kits for measurement of standard bacteria or residual chlorine, and anyone can perform it simple. If these are strongly related from infection, it can prevent and monitor indirectly. To clarify the potential for bacterial growth in home bath water, we investigated changes in the concentrations of metal and non-metal inorganic compounds as the water was re-used. Then the concentrations of most of the compounds increased. However, the concentration of P decreased, and the concentrations of Ti and Mn showed both increases and decreases. These are considered to have been consumed by growth of a microbe.

In future, an investigation of the inorganic compounds present in bath water in a public bath would be useful. Measurement of residual chlorine by other methods should also be investigated. These results could be used to clarify if bath water is a suitable environment for the growth of pathogenic bacteria, and if bathing enhances or decreases bacterial growth. In cases where bacteria could enter the water from soil, such as in a hot spring, chlorination can be used to prevent bacterial growth. However, addition of chlorine could lower the quality of the water for bathing by affecting its color and/or smell. In situations where it is difficult to perform chlorination, other methods for stopping bacterial growth should be investigated.

References

1. Ishikawa A, Okada J, Kondo H, Takayama Y, Sunagawa K, et al. (2004) [Legionella pneumonia which occurred in a private whirlpool bath user]. Kansenshogaku Zasshi 78: 898-904.
2. Sekine M (2005) [Development of simple detection method of legionella bacteria]. Juntendo Med J 51: 425.
3. Karasudani T, Kuroki T, Otani K, Yamaguchi S, Sasaki M, et al. (2009) [Legionella contamination risk factors in non-circulating hot spring water]. Kansenshogaku Zasshi 83: 36-44.
4. Bollin GE, Plouffe JF, Para MF, Hackman B (1985) [Aerosols containing Legionella pneumophila generated by shower heads and hot-water faucets]. Appl Environ Microbiol 50: 1128-1131.
5. (2000) Infectious Disease surveilence center(2000) topic for this month 21:188-199.
6. Sekine M (2006) [Development of simple and rapid detection method of legionella bacteria – For the practical use of the disease prevention]. Juntendo Med J 52: 491.
7. Duboc P, Schill N, Menoud L, van Gulik W, von Stockar U (1995) [Measurements

of sulfur, phosphorus and other ions in microbial biomass: influence on correct determination of elemental composition and degree of reduction]. J Biotechnol 43: 145-158.

8. Gros JB, Poughon L, Lasseur C, Tikhomirov AA (2003) [Recycling efficiencies of C, H, O, N, S, and P elements in a Biological Life Support System based on microorganisms and higher plants]. Adv Space Res 31: 195-199.

9. Hoshi A, Watanabe H, Kobayashi M, Chiba M, Inaba Y, et al. (2001) Concentrations of trace elements in sweat during sauna bathing. Tohoku J Exp Med 195: 163-169.

10. Matsumoto N, Sasaki T, Nakao H, Katoh T, Fukuda, et al. (2008) An outbreak of Legionnaires' disease associated with a circulating bathwater system at a public bathhouse II -Radiological findings of pneumonia. J Infect Chemother 14: 123-129.

11. Hindré T, Brüggemann H, Buchrieser C, Héchard Y (2008) Transcriptional profiling of Legionella pneumophila biofilm cells and the influence of iron on biofilm formation. Microbiology 154: 30-41.

12. Miyamoto M, Yamaguchi Y, Sasatsu M (2000) Disinfectant effects of hot water, ultraviolet light, silver ions and chlorine on strains of Legionella and nontuberculous mycobacteria. Microbios 101: 7-13.

13. Fujimura S, Oka T, Tooi O, Meguro M, Chiba M, et al. (2006) Detection of legionella pneumophila serogroup 7 strain from bathwater samples in a Japanese hospital. J Infect Chemother 12:105-108.

14. Shimizu S, Uemura H, Itoh S (2004) On measuring residual chlorine in water -Comparison between diethyl–p-phenylenediamine (DPD) method and o-tolidine (OT) method. Bull Kanagawa Ins of Public Health 34.

15. Sakamoto R, Horiguchi D, Ikegami T, Ishiyama M, Shiga M, et al. (2003) A new water-soluble chromogenic indicator: an application to the determination of chlorine in aqueous solutions. Anal Sci 19: 1445-1447.

16. Sugase, S, Tsuda T (2002) Determination of lactic acid, uric acid, xanthine and tyrosine in human sweat by HPLC, and the concentration variation of lactic acid in it after the intake of wine. Bunseki Kagaku 51: 429-435.

17. Water Supply Administration, the Ministry of Health, Labour and Welfare (2013) Water quality standards items and values.

18. Yabuuchi E, Agata K (2004) [An outbreak of legionellosis in a new facility of hot spring bath in Hiuga City]. Kansenshogaku Zasshi 78: 90-98.

19. Benouis K, Benabderrahmane M, Harrache-Chettouh D, Benabdeli K (2008) [Is Turkish bath water potable?: The baths of Sidi-Bel-Abbes]. Sante 18: 63-66.