HOME R/O SYSTEM FOR DRINKING WATER IN KOREA

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1. Introduction

Industrialization has given humanity many benefits, such as material abundance and conveniences. However, it has also caused detrimental side effects to the environment which are becoming a global problem. During the 1960's, the national economic scale in Korea was expanded and personal lifestyles rapidly improved. These improvements also caused environmental problems such as water contamination.

Water contamination caused by old, worn water pipes, harmful materials and deposits from the water purification processes decreased the tap water quality, causing unpleasant odors and tastes. Due to poor maintenance of the reservoir facilities of tap water quality, citizens lost their faith in the water quality. In the long term, it made us worry about the health of our nation's citizens (6,16).

During the late 1980's, a research announcement was made regarding tap water and water resource contamination. At this time, the use of spring water, bottled water, individual wells and water purification devices appeared as self-help methods for dealing with the health threat. Because of the possible pollution of spring water and ground water, the use of purification devices rapidly increased at this time.

In the 1980's, the use of water purifiers was confusing because they did not function well and there were no quality standards(10). This caused confusion in the distribution. When it came to the 1990's, the faucet direct and reverse osmosis (R/O) systems emerged. For now, the R/O system is used in more than 80% of the home water purification market. Faucet direct purifiers vary in their methods of purification. The four methods are: microfiltration (MF) which is using ceramicfilter, ultrafiltration (UF), ion-exchange resin and softener(10).

From the simple filter methods, we are recently choosing the R/O method which can collectively reduce the heavy metal and bacteria. The R/O method comes mostly from America(15).

In this report, we want to realistically cover the water contamination that we are facing, the attitudes of consumers about it, the changes in what we use for drinking water, the home water purifier market share, and the direction of the development of the market.

2. Contamination of municipal water resource.

Classifying water resources, river and stream makes up 59%, reservoir 31.6%, ground water 9.4%. Mostly, we are relying on surface water. Since surface water is very susceptible to cotamination, the problem of contaminated water is becoming serious(14)(Fig. 1).

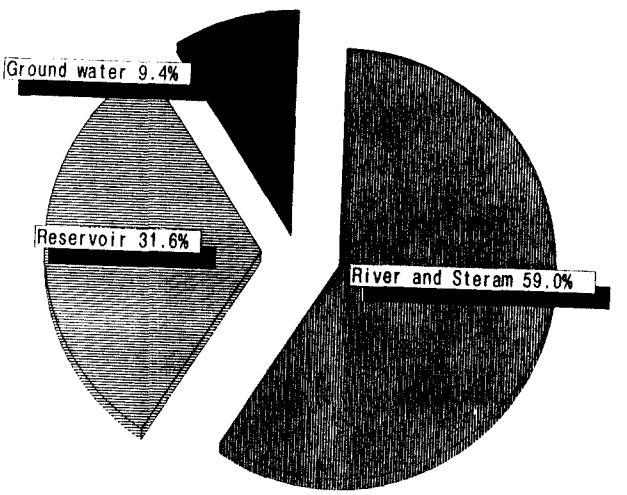


Fig. 1. Distribution of Water Resources in Korea.

Seeings the changes in the annual BOD in the major rivers of Korea, the Han River has improved since 1987. But there have been no big changes in the Naktong River and the Kum River. The Yongsan River has become worse. None of the rivers' water quality is meeting Level I or Level II standards, which are necessary to supply safe water by the existing methods of purification(12)(Fig. 2).

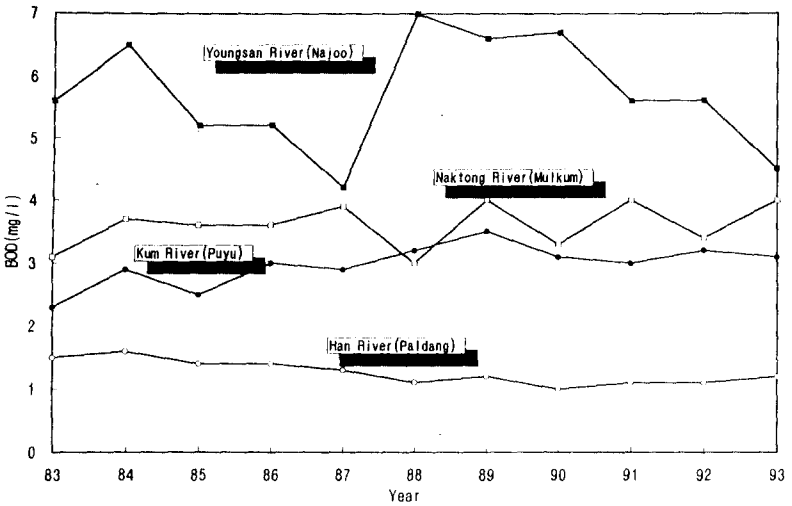


Fig. 2. Change of BOD in the Major Rivers of Korea.

According to the water quality standards in 1992, the results show that there was 33.5% of Level I 57.6% of Level II, 8.4% of Level III, and 0.5% of any ohter level(Fig. 3).

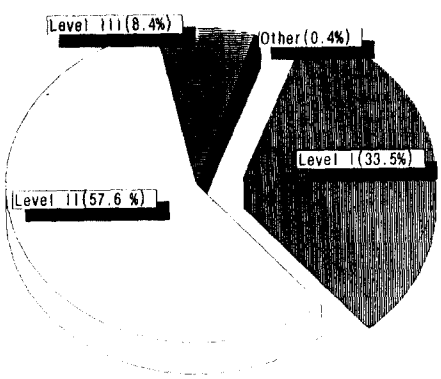


Fig. 3. Distribution of Water Quality Levels in Korea.

Seeing the changes in BOD in the water collecting places on the Han River, rarely do any of the places meet a BOD of 1 mg/ℓ, which is the standard for Level I water(Fig. 4). When we judge the quality of the lake water which is occupying almost 45% of our water resources by the Trophic state, if the current rate of contamination continues, unless we have a special way of handling N and P, most of the water will be in the Eutrophicfication. This can cause an increase in Algae, resulting in a bad odors and taste(9).

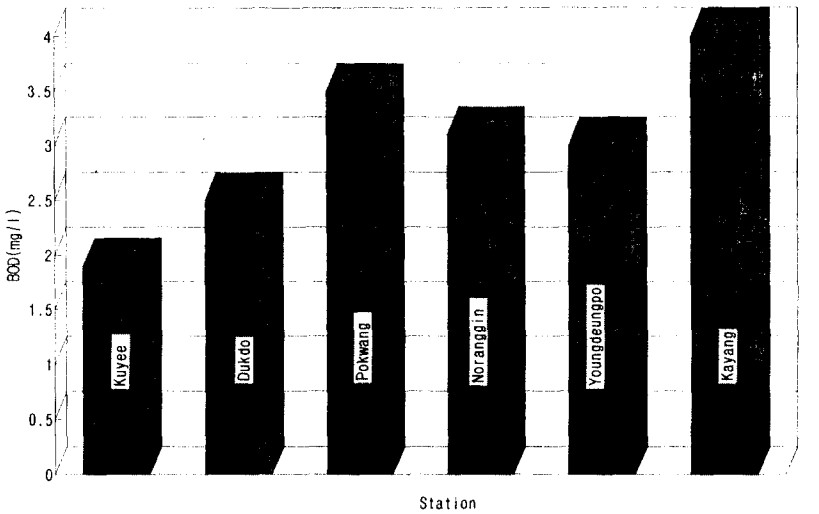


Fig. 4. Comparison of BOD in the Reservoirs on the Han river.

We can say that there were no big changes in the quality aspect compared to the changes of quantity in the supply of tap water in this country. As population has increased, industry has developed, water quality is getting worse, and the number of harmful materials have increased. Therefore, it is hard to completely handle the problem with the exitsting water purification processes(13).

We became concerned about the safety of tap water because increased levels of contaminating materials such as iron, cadmium, phenol, and neutral detergent were found in quantities over the standard in ten treatment works in Pusan, Taegu, Mokpo and some other cities in august 1989. We checked over 46 treatment works, and in 9 reserviors (20%), the bacteria, coliform bacteria and toxic materials like amonium nitrogen were found in quantities over the standard. It was then announced that we could not use that water as a drinking water source.

In March 1991, D Electronics, which is located in Kumi City, drained 30 tons of phenol. This phenol made its way into the Dasa Reservor, which supplies 70% of the drinking water for Taegu City. A tap water germicide, chlorine, chemically reacted wtih the phenol to create chlorophenol, which is harmful to humans. This created 300-500 times the odor that phenol itself creates. People who drank this chlorophenol contaminated water experienced vomiting, diarrhea, stomach aches, stinging around the mouth and neck, body rashes, moist tetter and itching. Pregnant women also experienced melena and miscarriage. In January 1994, there was a drinking water problem caused by ammonium nitrogen(NH_4-N) in the Pusan and Kyongnam areas. The tap water had terrible odors like those of disinfectants and ammonium nitrogen(NH_4-N). The Naktong River was their main source of drinking water. The Minister of the Environmental Department announced that they had found benzene and toluene, two possible cancer causing agents, in the Naktong River water. The drinking water problem then became a major issue in Korea(18,3).

3. Contamination Caused by Outworn Water Pipes

The water coming from a water resource has many opportunities for deterioration of water quality while it is being transported to homes through the distribution system. The distribution system consists of a settling tank, a high-speed sand filtration system, and chlorination. The water is then piped to the individual users. The sourecs of contamination are odors, taste, organic matter, sediments, and poor maintenance of the water treatment facility and pipes(Table 1).

Table 1. Tap Water Contaminating Materials and Sources Before, During and After the Process.

1. Before Treatment
   - ■ Naturally existing materials.
     - Substances like iron,manganese and sulfur which, in excess, can cause poor taste or odors.
   - ■ Chemical materials.
   - ■ Many kinds of chemical materials are made by industrial activities.
     - Chemicals containing harmful materials.
     - Leakage from a wastewater treatment, landfill and storage places.
     - Discharge from factories and sewage treatment plants
     - Drainage of pesticides.
     - Decrepit pipe erosion and sediment.
     - Illegal disposal.
2. During Treatment
   - ■ Chemicals added during the water purification process: coagulants, disinfectants, chemicals for water softening.
   - ■ Harmful materials which can be produced in the purifying process: Byproducts of disinfectant like THMs
3. After Treatment
   - ■ Chemicals added in the process of distrubiton: Chlorine(remained), anticorrosives.
   - ■ Corrosion of distribution pipes or reservoir.
   - ■ Microbal contamination due to leaked pipes..

SOURCE: Lee(1995)

The material used for making water pipes in Seoul is mostly iron(Table 2).Water pipes corrode chemically. As a result of that, when water flows through the pipes, it collects corrosive materials, thereby causing the redwater(Fe) problem. Galvanized pipes, which are also often used as water pipes, cause the blackwater(Mn) problem in the same manner that iron pipes cause the redwater problem(6,16,17).

The water released from a reservior is stored in a water tank before being supplied to houses through water pipes. Because the water remains in the tank for a considerably long time before arriving at the house, the quality of the water can decrease. The poor quality of the water can also be caused by the material or structure of the water tank. Alien substances produced by corrosion of the water pipes can cause sediment at the bottom of the tank(11). This sediment stays in the tank and further contaminates the tap water. When the current of the water is strong enough, sediment can be mixed in the tap water and cause people to question the quality of the tap water.

Table 2. Materials used for making water pipes in Seoul.

Item	Transmission	Distribution	water supply
IRON COATING	92.7%	1.8%	
IRON	7.3%		
ZINC COATING		98.2%	50.0%
COPPER			10.6%
PVC			13.5%

SOURCE: Statistical Yearbook(Seoul, 1995)

4. Contamination of Ground Water

Now, the quality of a lot of ground water in this country is bad enough that it cannot be used for drinking water. In urban areas, this can be blamed on insufficient water treatment facilities. In rural areas, pesticides and animal waste can work as the direct and indirect reasons for ground water contamination(11).

According to research(1993) conducted under the supervision of the Environmental Department on the contaminated state of the ground water all over this country, 260 wells (20% of the number of the wells checked) were found to exceed standard allowed in drinking water(Table 3). The phenomenon of ammonium/nitrate nitrogen contamination is obvious in the ground water in urban and rural areas. In areas near industrial factories, small amounts of special harmful substances like trichloroethylene, which has something to do with detergents, were found(11). As we can see from the above, it is obvious how serious the ground water contamination is in this country.

Table 3. The results of water quality investigation of ground water

	Item	Sandards (mg/ℓ)	Site	
			Below	Over
Specified Hazardous materials	Cd	0.01	1,536	10
	Pb	0.1	1,536	10
	Cr^{+6}	0.05	1,545	1
	Trichloroethylene	0.01	472	48
	Tetrachloroehylene	0.03	511	9
General Hazardous materials	pH	5.6-8.5	1,504	42
	NH_4-N	10	1,375	171
	ABS	0.05	1,546	0

SOURCE : Environ. Dept.(1993)

5. The States of Drinking Water use

The states of domestic water use, according to the study conducted by Hyundai Research(1994) boiled tap water makes up 43.1%, bottled water 21.2%, spring water and ground water 21.9%, and purified water 13.8%. In the research conducted on the daily use of drinking water by Chungyong(1995) *et. al.*, we normally use 53.4% boiled tap water, 18.3% bottledwater, 16.5% spring water, and 7.8% purified tap water.

Therefore, drinking unprocessed tap water accounts for only 2.1% of our daily use of water. According to the results of the research which was done by Oricom Company(1995), boiled tap water makes up 53.4%, bottled water 22.9%, spring water 17.2%, and purified tap water 10.7%. Since the ratio of each survey is almost the same, they reflect our society's distrust of tap water(Fig. 5).

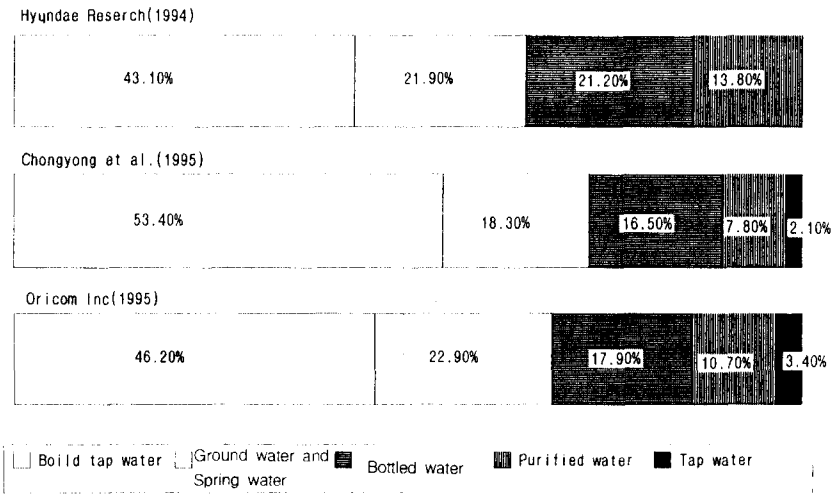


Fig. 5. Sources of Drinking Water by Percent of Households.

The biggest reason cited for tap water distrust is heavy metal, which accounts for 48.7%. Iron and rust account for 15.0%, bacteria and microorganisms for 13.5% and turbidity for 10.3%(3). Our distrust of tap water caused us to concern for other methods of obtaining drinking water, such as bottled water, spring water, boiled tap water and purified water(Fig. 6).

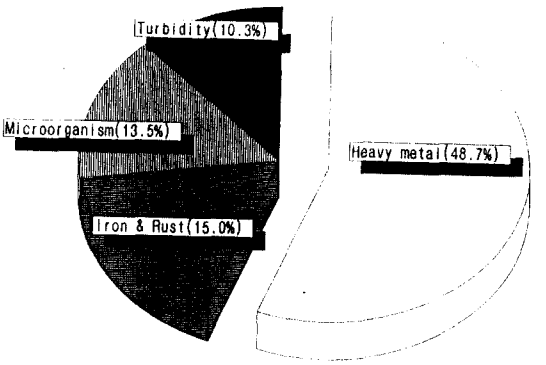


Fig. 6. Main Factor of Distrust of Tap Water.

6. Domestic Water Purifier Market

The demand for water purifiers started increasing around 1988 due to dissatisfaction and distrust of the tap water. In the middle to late 80's, ceramic filters or systems using elvan were common. This kind of natural filtration system was the mainstream product. Even though this natural filtration system was making a sensation in the domestic market during '88 and '89, it almost disappeared after that due to consumer's distrust. During the 90's, New domestic models using electrolysis method, ion-exchange resin, or ultrafiltration method appeared(9).

The history of domestic purifiers goes back about 10 years. The companies which started early, booming after 1985, went bankrupt and disappeared year following 1990. In 1990, there were 169 companies; in 1991 there were 87 companies; in 1992 there were 70 companies; and after 1993 there were only about 40 companies still in business. The domestic market scale for home water purifiers increased from 63 million dollar in '88 to 125 million dollar '89, but in '90 decreased to 45 million dollar In '91, due to consumer's distrust, difference in product quality and influence of the media, the market scale decreased to 38 million dollar. In 1992, it decreased to 31 million dollar. However, the demand for purifiers abruptly aroused again due to the Naktong River contamination incident and several other pollution incidents which

increased the interest regarding drinking water. In 1993, the market scale went up to 125 million dollar and in 1994, it again increased to 250 million dollar(10). At the end of 1995, it is expected to be about 375 million dollar(Fig 7).

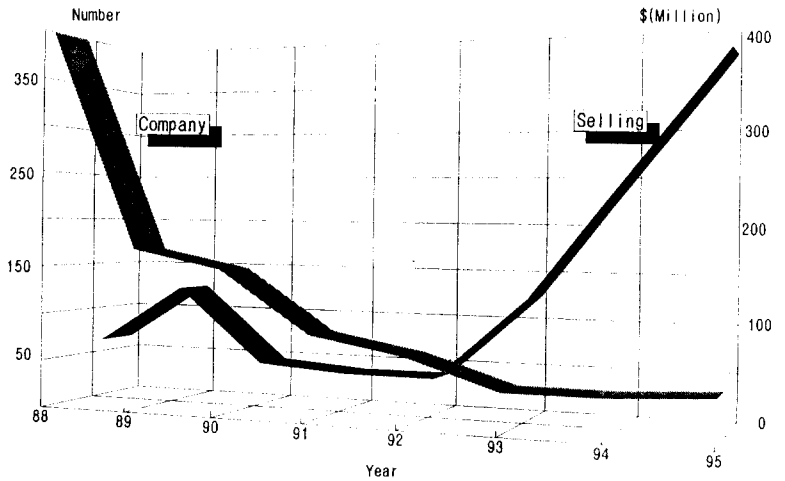


Fig. 7. Changes in the Number of Companies and Yearly Selling.

In the beginning, the purifier manufacturing companies were small businesses or "household factories." But recently, big comapnies have entered the market. The structure of the domestic purifier business in the country is 20% manufacturing and 80% selling, but 20% of selling is the handling of imported goods(9)(Fig. 8).

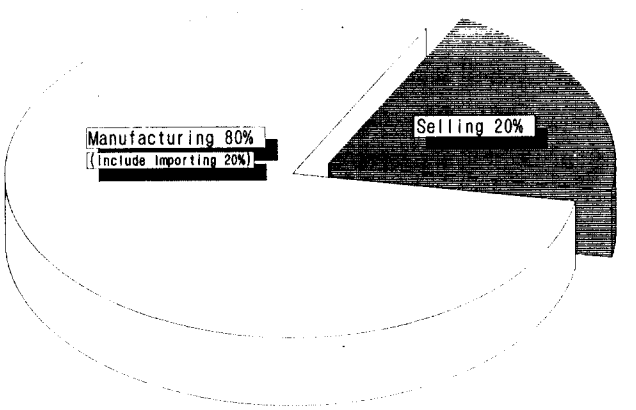


Fig. 8. Distribution of Water Purifier Company by the Type of Business.

At the general changes in the structure of domestic purifiers, they are changing form the natural filtration method (water containing style) to a faucet direct method (faucet connecting style). The natural filtration method has many problems, such as the troublesome in water supply and not being able to make much purified water quickly since it works with gravity and propagation of microorganisms in the water tank. It is also being substituted from an undersink type unit to a countertop model. In the case of the undersink type, it has some merit of efficiency in being able to save space since it is installed under the sink. But It also has the shortcoming of inconvenience due to the difficulty of afterservice and the complex installation work. A pressure tank is also needed. Countertop type purifiers, which are installed on the sink and connect directly to the faucet, are preferred by users.

In the aspect of its function, although the natural filtration method accounted for more than 90% of the purifiers in the late 80's, after 1990, the natural filtration method disappeared due to consumer's demand for a better quality product. The faucet direct style (MF, UF) and reverse osmosis style (R/O) purifiers started to be distributed. Before 1990, the natural filtration method acounted for 22.7%, reverse osmosis 4.5%, and the faucet direct method 54.5%. But after 1993, R/O went up to 73.5%, faucet direct (MF, UF) went down to 17.6%, and the natural filtration method dropped to 4.4%. Gradually, reverse osmosis is becoming the major form of water purification(9)(Fig 9).

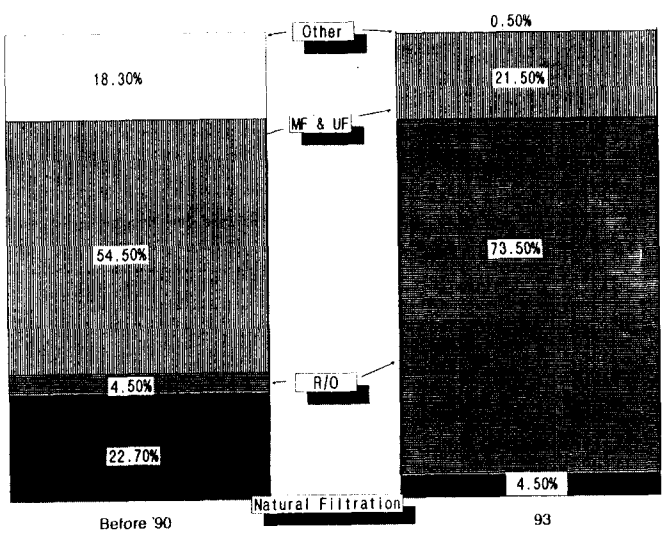
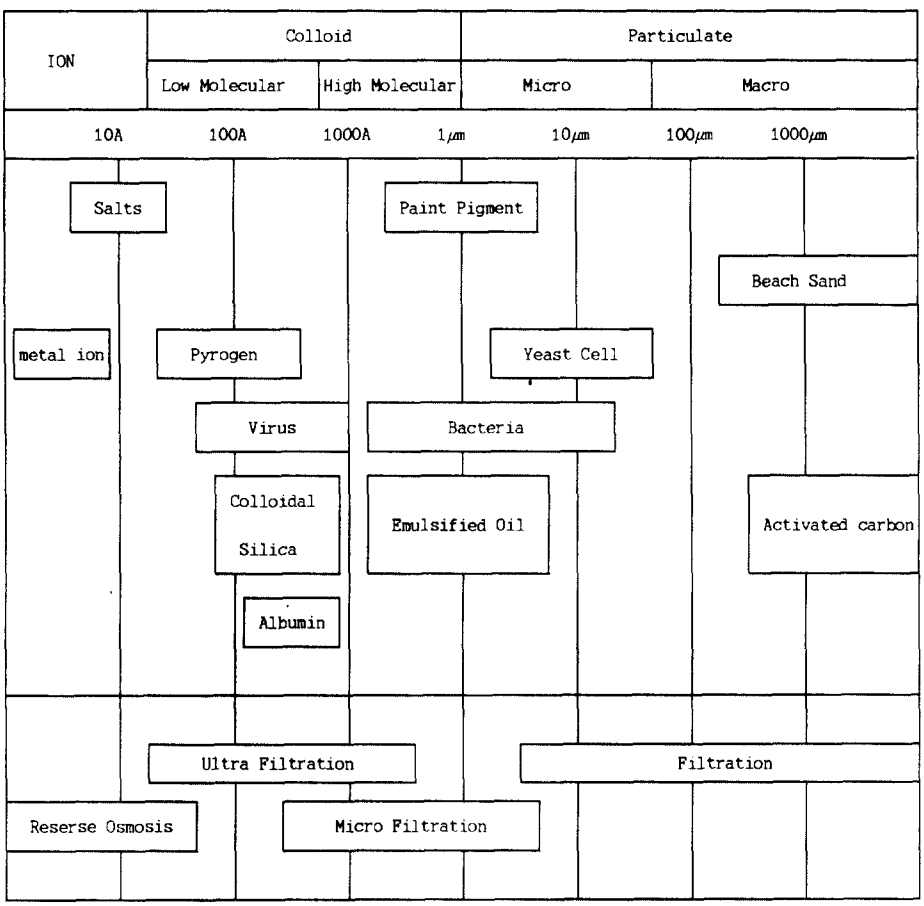


Fig. 9. Distribution of Water Purification Type of Korea (before '90 and '93).

The majority of water purifiers now in use are adopting a mixed method of purification to allow for each method's shortcomings. The major purifying methods can be divided into ceramic filter method for faucet direct connection, ultrafiltration and reverse osmosis.

In the case of the ceramic filter method, it can hardly reduce the very small contamination like viruses and chemical contaminats, even though it can filter the rust or solids which is suspended in the water. Ultrafiltration methods can reduce most of the microorganisms and organic substances, but not the ion substances (heavy metals and chemicals). But reverse osmosis has a high percentage of elimination of all harmful contaminats(heavy metals, organic and inorganic contaminants, bacteria and viruses) (1.18)(Table 4).

Table 4. Particle size removal range by MF, UF, and R/O.



SOURCE: WQA(1993)

Reverse osmosis, which are normally used in home purifiers, use a spiral type membrane. This typical membrane reduces contaminants and leaves them on the surface of the filter, thus eliminating much of the chance for the filter to become clogged. The original material preferred for these filters was CTA(cellulose triacetate), but now TFC(thin film composite) is preferred because it can be increase the volume of permeate. This way, the volume of water moving through the membrane with less water pressure without problems(5,19)(Fig. 10).

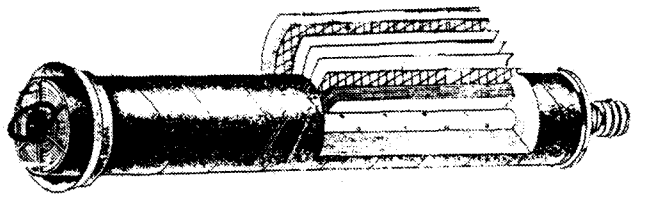


Fig. 10. R/O Membrane Type(Spiral Wound).

Purifiers using the reverse osmosis method are popular in this country. The reason that the R/O method has recently obtained a large ratio is because people want purifiers which can remove not just the chemical contaminants, but also heavy metals. The use of reverse osmosis in household purifiers caused an increased interest in their function in the other fields of the industries. Not like the hollow fiber purifier which has a simple shape for faucet connection, and being used by activated charcoal filter and simple polyester felt pretreatment, reverse osmosis purifiers use activiated charcoal to protect the membranes to improve the water taste, and to minimize the contamination of the membrane by contaminants(15)(Fig. 11).

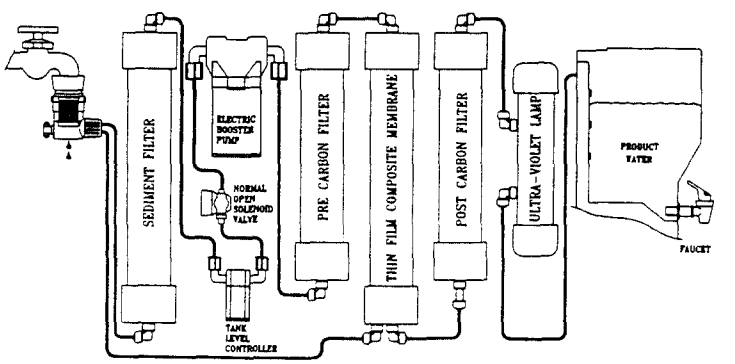


Fig. 11. Typical Schematic Diagram of Home R/O System.

In order to prove the quality of water purifiers in an atmosphere of consumer distrust and to stabilize the expansion of the market, a quality approval system was initiated on October 1, 1987. Korea Chemistry Inspecting and Testing Institue, which was managed by the Industrial Promotion Department, classified the issue as "Industrial Goods." Thereafter, the quality was assured by a "Q mark."

When the purifier market was in despair, consumer distrust had to be removed in order to activate the market. To that end, a quality approval system was sought. The "C" mark system of the Korea Water Works Institute and the "Jung" mark system of the Korea Water Purifier Industrial Cooperative were introduced in 1994, and they were important part in the market. As the results of the concerning about these mark systems, the authorities(Minstry of Environment) revised and approved the"Jung" mark to the "Mul" mark in 1995. The improved the "Mul" mark system divided the water purifier function checklist into basic obligation items and option items(Table 5).

Table 5. Classification of the water quality test items for "Mul" mark.

	Numbers	Item
Obligation items	5	Odor, Taste, Color, Turbidity, Heterotrophic bacteria
Option items	36	Group 1 : THMs, 1.1.1-trichloromethane, Trichloromethane, Tetrachloroethylene, Benzne, Dichloromethane, Ethylbenzene, Toluene, Xylene, Residual Chloride (10 items) Group 2 : Diazinon, Marathion, Parathion, Phenol, Fenitrothion, Carbaryl, Detergents (7 items) Group 3 : Mercury, Lead, Chrome(6+), Arsenic, Cadmium, Iron, Aluminium, Zinc, Copper, Ammonium Nitrogen, Selenium, Manganese (13 items) Group 4 : Cyanide, Fluoride, Nitrate Nitrogen (3 items) Group 5 : Chloride ion (1 item) Group 6 : Sulfate ion (1 item) Group 7 : Hardness (1 item) Group 8 : Total Coliforms (1item)
Total 41 items		

After a purifier passed the basic obligation items, the manufacturing company itself is responsible for self-testing of the option items. These items depend on the consumer's requirements and the water quality itself. So there were then many ways for a purifier to become approved, unlike the previous test system which had thirty-eight requirements, all which had to be passed. At that time, only R/O or a few other methods were able to get approval. Hence, the domestic purifier market may activate not only R/O systems but also MF or UF systems.

At first, most of the business were small scale businesses. They did simply importation and sales. But now, big companies like Samsung, Dongyang-Magic and expert purifier companies such as Woong-Jin Coway have entered the business. Through their technical development efforts, the shortcomings of purifier will be cured, one by one.

But the membrane technology in Korea is still behind when compared with that of developed countries. In Korea, it still remains at the experimental level in learned circles and laboratories. In order to reach the state of being of practical use, much effort and investment by purifier business circles is absolutely necessary.

First, we need to study the seasonal and regional water quality characteristics. Then we can move ahead with the development of membrane which can adequately handle the water quality. Finally, we should strive to make a purifier of Korean style. It is a task which should be undertaken through the closer cooperation of the industry circles, the learned circles and the laboratory circles.

7. Conclusion

1) Due to industrialization, serious water contamination problems have shown up. Domestic water resource quality decreased and from the 1980's heavy metals, THMs and phenol caused tap water contamination issues. The pipes also let out alien contamination into the water. All of these things made people lose their trust in tap water and in the safety of tap water use.

2) In daily life, we drink boiled tap water most of the time and bottled water, natural spring water, and purified tap water, in that order. We harldy drink tap water without any treatment and the major reason for distrust about tap water is heavy metals, containing iron, rust, bacteria, and turbidity, in that order. Therefore, it reflects our society's distrust about tap water.

3) From around 1988, the demand for purifiers rapidly increased due to distrust and dissatisfaction about tap water. After that, because of the distrust regarding purifiers, it went down to 31 million dollar in '92. But after that, due to many water contamination incidents, we started to have an interest in drinking water. At the end of 1995, the scale is expected to reach about 375 million dollar.

4) Home purifiers normally use the reverse osmosis method. The type of membrane is spiral wound, the material is TFC(thin film composite) and there is a tendency to want counter top units rather than under sink units.

5) The early purifier factories were small, "household factories," which imported and distributed purifiers. Recently, since big companies have entered the market, the technology and development of the existing companies, the industry has stabilized. Later, we expect the purifier market to expand.

6) After a purifier passed the basic obligation items, the manufacturing company itself is responsible for self-testing of the option elements. These items depend on the consumer's requirements and the water quality itself. At that time, only R/O or a few other methods were able to get approval. Hence, the domestic purifier market may activate not only R/O systems but also MF or UF systems.

7) Domestic membrane manufacturing technology is still in early stage when compared to developed countries. It is still in the experimental stage in learned circles and laboratories. So our task seems to be to produce a Korean purifier by developing a membrane which is adequate for domestic water quality through the closer cooperation of the industry circles, learned circles and laboratory circles.

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