Central American experiences with regard to disinfection using equipment to produce oxidant gases or sodium hypochlorite on site began in the late 1980s. Since then, different equipment has been evaluated and its effectiveness has been confirmed, although the disinfectant produced has not been efficiently used. This situation is due to many factors, one of which is that the health sector has the challenge to meet the most urgent needs of the countries and has thus had to relegate to a second place the actions for preservation and improvement of water quality. A summary of the main activities carried out in each country is presented, with information on the installed and used capacity of technologies for the production of disinfectant on site.

1. Introduction

Disinfection using technologies for the on-site production of sodium hypochlorite or oxidant gases began around 1987 in rural areas of Central America.

At that time, and with PAHO support, the first MOGGOD prototypes were built, as evaluated during the 1st International Seminar on Disinfection with Mixed Oxidants, held at CEPIS in 1987, and in the 2nd International Seminar conducted in Mexico with the participation of North, Central and South American countries.

After some years, and again supported by PAHO Representative Offices in the countries, the MASICA program through different projects such as PROAGUA and PROQUIM, carried out other demonstration projects emphasizing technologies for the on-site production of sodium hypochlorite.

In 1995, GTZ and PAHO agreed to carry out the Subregional Project for Training and Social Mobilization for the Prevention and Control of Cholera in Latin America and the Caribbean.
In May 1997, a Seminar on the Evaluation of Disinfection Results was held in Tegucigalpa, Honduras, with the participation of other Central American countries, to evaluate and discuss the each country’s experiences in this field.

As a result of that meeting, it was agreed to conduct a study on the use of equipment for on-site production of sodium hypochlorite as a subregional project in Central America for the prevention of cholera. A final document containing the Central American experiences was distributed and a Central American Committee was set up to maintain an exchange of information on the progress of water quality control and disinfection processes.

2. Central America, water quality and disinfection proposals

2.1 Water quality

Central American countries are a meeting point for North and South America. Water conditions for the countries of the Region are quite similar. Water coverage for urban areas ranges between 70% and 80%. However, the coverage for rural areas is significantly lower: 35% to 45%, except for Costa Rica, which has a significantly higher coverage. It should be noted that up-to-date data on coverage are not easily available.

For drinking water, sources such as springs have traditionally been used, but these have been reduced due to climate changes in the Region, aggravated by El Niño. These sources are considered to be of good quality and suitable for human consumption. However, because of the scarcity of sources, surface waters have begun to be used (rivers and lakes) which usually present a high degree of bacterial contamination and, more recently, pollution from chemicals used in agriculture. In addition, it should be mentioned that the need for land for staple food crops has played an important role in deforestation in the Region, a situation which contributes to reducing the flow of alternative water sources.

In terms of water quality, generally speaking water from springs is adequate for human consumption. On the other hand, surface waters are mostly not safe and therefore, not suitable for human consumption without prior treatment.

2.2 Disinfection actions

Actions directed toward disinfection began with the efforts carried out by PAHO jointly with the drinking water sectors of the different countries of the Region.

One of the main actions was the development of the technology for the production of disinfectant at the local level, complemented with technical support and community mobilization strategies. Demonstration projects were set in motion to promote the use
of the new technologies and their subsequent further development and implementation.

With the cholera epidemic in Central America in 1991, health authorities of all countries of the isthmus began to look for ways of counteracting its negative effects. Every country launched preventive programs of disinfection with available resources. In Panama, all rural water supply systems were chlorinated with calcium hypochlorite provided by health authorities. In Costa Rica, disinfection with sodium hypochlorite produced on site was adopted, using specialized equipment. In Honduras, Nicaragua and El Salvador, disinfection programs of water supply systems were implemented, especially in rural areas and at the household level, supported by operational personnel of the health units, equipment for on-site production of disinfectant, and the use of calcium hypochlorite. In Guatemala, a contingency plan was prepared based on the use of commercial sodium hypochlorite solutions, which were the most readily available during the crisis period.

PAHO has played an important support role in the Region, providing the different countries with equipment as shown below:

**Table 1 - Equipment donated by PAHO to Central American countries**

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of units of equipment</th>
<th>Equipment in operation</th>
<th>Brand of equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>PANAMA</td>
<td>10 (1)</td>
<td>2 (2)</td>
<td>DIPCELL – SANILEC</td>
</tr>
<tr>
<td>COSTA RICA</td>
<td>250</td>
<td>465 (3)</td>
<td>DIPCELL – SANILEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CLORID – OXI</td>
</tr>
<tr>
<td>NICARAGUA</td>
<td>86</td>
<td>86 (4)</td>
<td>DIPCELL – SANILEC</td>
</tr>
<tr>
<td>HONDURAS</td>
<td>20 (5)</td>
<td>(6)</td>
<td>DIPCELL–SANILEC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CLORID–OXI</td>
</tr>
<tr>
<td>EL SALVADOR</td>
<td>49</td>
<td>(6)</td>
<td>DIPCELL</td>
</tr>
<tr>
<td>GUATEMALA</td>
<td>23</td>
<td>6 (7)</td>
<td>DIPCELL–SANILEC</td>
</tr>
<tr>
<td>TOTAL</td>
<td>418</td>
<td>559 (8)</td>
<td></td>
</tr>
</tbody>
</table>

(1) Estimated data
(2) Estimated for end of 1997
(3) Scheduled by AyA for end of 1997
(4) PAHO/NICARAGUA report for 1996
(5) Data of the first PAHO donation
(6) Not determined
(7) Estimated for 1998
(8) Estimated using available data
3. Programs developed in Central America

The following paragraphs give a summary of the programs developed in Central America, and describe the main elements in each country.

By way of introduction, the Central American countries are in the isthmus that forms a bridge between North and South America. Table 2 gives general data on these countries:

Table 2 - Data on Central American countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Area (square kilometers)</th>
<th>Population</th>
<th>Population density (population per square kilometer)</th>
<th>Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>PANAMA</td>
<td>77,326</td>
<td>2,535,000</td>
<td>34</td>
<td>BALBOA</td>
</tr>
<tr>
<td>COSTA RICA</td>
<td>51,100</td>
<td>3,199,000</td>
<td>63</td>
<td>COLON</td>
</tr>
<tr>
<td>NICARAGUA</td>
<td>130,700</td>
<td>4,265,000</td>
<td>33</td>
<td>CORDOBA</td>
</tr>
<tr>
<td>HONDURAS</td>
<td>112,088</td>
<td>5,595,000</td>
<td>50</td>
<td>LEMPIRA</td>
</tr>
<tr>
<td>EL SALVADOR</td>
<td>21,393</td>
<td>5,517,000</td>
<td>262</td>
<td>COLON</td>
</tr>
<tr>
<td>GUATEMALA</td>
<td>108,889</td>
<td>11,234,900</td>
<td>103</td>
<td>QUETZAL</td>
</tr>
</tbody>
</table>

3.1 Panama

In the Republic of Panama, the Ministry of Health, MINSAL, is responsible for supplying water to communities with a population of under 1,500. The larger populations are served by the Instituto de Acueductos y Alcantarillados, IDAAN.

In 1992, cholera reached a mortality rate of 3% in Panama. For this reason, MINSAL gave priority to actions for the prevention of diarrhoeal diseases and cholera.

The result of these priority actions was a mass disinfection campaign using calcium hypochlorite, provided by the Ministry of Health and distributed and operated by the staff of local health centers. The impact of this strategy was to achieve a coverage of 100% in the province of Darien, one of the places worst hit by the cholera epidemic.

At the central level, a technology for on-site production of sodium hypochlorite was used. The solution was distributed in communities of the province of Darien and in the health jurisdiction of East Panama. Four communities were selected and containers of 500 milliliters were used for its distribution. Experiences have been developed with PAHO support using technologies for on-site production of sodium hypochlorite through projects such as PROQUIM and
SANEBAR. But they have been limited and need to be systematized by allocating responsibilities to the Division of Waters of the Ministry of Health. In Panama there are different brands of equipment donated by PAHO for on-site production of sodium hypochlorite, which are in the process of installation, evaluation and dissemination, after training and follow-up of both institutional personnel and direct beneficiaries.

As one the initial actions, the installation of six Regional Laboratories for Control and Monitoring of Water Quality has been planned. Workshops have also been planned to provide institutional staff and community members with training in the installation, operation, and maintenance of equipment for on-site production of sodium hypochlorite.

3.2 Costa Rica

In Costa Rica, the Instituto Costarricence de Acueductos y Alcantarillados, AyA, has been responsible for the provision, operation and maintenance of most of the country’s water supply systems since 1961.

In 1995, there were 1,261 water supply systems, representing a national coverage of 92.8% (around 2,796,281 inhabitants). In addition, 68.9% of the population was receiving disinfected water. The following table shows the situation in 1995.

<table>
<thead>
<tr>
<th>Operating agency</th>
<th>Number of water supply systems</th>
<th>Population served</th>
<th>Number of water supply systems with disinfection</th>
<th>Percentage of water supply systems with disinfection</th>
</tr>
</thead>
<tbody>
<tr>
<td>AyA</td>
<td>138</td>
<td>1,381,147</td>
<td>113</td>
<td>81.9</td>
</tr>
<tr>
<td>Municipalities</td>
<td>36</td>
<td>729,530</td>
<td>15</td>
<td>41.7</td>
</tr>
<tr>
<td>CAARs</td>
<td>1024</td>
<td>671,744</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Private companies</td>
<td>63</td>
<td>13,860</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

With PAHO support, and the support of PROQUIM, MASICA and SANEBAR programs, Costa Rica has made every effort to address the issue of water disinfection, and has worked with equipment for the on-site production of sodium hypochlorite. PAHO initially donated 250 units of such equipment.

In Costa Rica, the use of equipment for on-site production of sodium hypochlorite is known by the acronym of “DEIS” technology, (the Spanish for on-site electrolytic disinfection). Different equipment is used, such as Clorid L-90 and Clorid L-450; Dipcell 40-45 gr.; Sanilec 2, Sanilec 6, Sanilec B-100; and Oxi 1.0. In San Jose, there are trade representatives who sell this equipment.
Costa Rica is the only Central American country with a real institutional policy on drinking water disinfection. AyA, through the Bureau of Rural Water Supply Systems, has developed a systematic training program on DEIS technology, which has been planned in the following stages:

- **FIRST STAGE:** Dissemination of the technology and training.
- **SECOND STAGE:** Dissemination and promotion of the technology at community level.
- **THIRD STAGE:** Coordination of the logistics for the installation.
- **FOURTH STAGE:** Monitoring of the installation.

The development and additional follow-up has been carried out by the Disinfection Section of AyA, as shown in the following table:

**Table 4 - Equipment for on-site production of sodium hypochlorite in Costa Rica work program**

<table>
<thead>
<tr>
<th>Description</th>
<th>Number of units of equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment installed up to mid-1997</td>
<td>224</td>
</tr>
<tr>
<td>Equipment to be installed in 1997</td>
<td>87</td>
</tr>
<tr>
<td>Supplies in storerooms in 1998</td>
<td>154</td>
</tr>
<tr>
<td>Equipment to purchase and install in 1998</td>
<td>200</td>
</tr>
<tr>
<td>Total expected for 1998</td>
<td>665</td>
</tr>
</tbody>
</table>

In addition, the above actions are supported by a Program for Preventive and Corrective Maintenance; a local company will be hired to perform preventive maintenance four times a year. During the first year, AyA will cover the costs and for the future these costs are expected to be covered by the Administrative Committees of Rural Water Supply Systems.

The work already carried out has improved the bacteriological quality of drinking water. Monitoring carried out by AyA in its water supply systems showed the following results:
### Table 5 - Bacteriological quality

<table>
<thead>
<tr>
<th>Effect obtained</th>
<th>Year</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water with adequate bacteriological quality</td>
<td>1990</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>1992</td>
<td>99</td>
</tr>
</tbody>
</table>

#### 3.3 Nicaragua

In Nicaragua, the Ministry of Health is responsible for seeing to water quality and water treatment in rural areas. The Instituto Nicaraguense de Acueductos y Alcantarillados, INAA, is responsible for the urban and semiurban water supply systems. With the cholera outbreak, a “High-level Commission for the Struggle against Cholera” was formed, for joint efforts to prevent and control the disease.

The effective and planned actions began with support from PAHO, which initially donated 59 units for on-site production of sodium hypochlorite. Of this equipment, 24 units were allocated to INAA and 35 to the Ministry of Health, to formally initiate water disinfection activities.

PAHO support has covered equipment and staff training. Actions have therefore been two-fold:

- Production and distribution of sodium hypochlorite at the local level using Dipcell equipment.
- Health education and monitoring, both for the application of disinfection measures, and for the community’s response. This line of action assesses the impact of the water quality improvement work.

With a reasonable quantity of equipment for the production of sodium hypochlorite (Dipcell), an additional operation and maintenance plan was established to optimize the production and distribution of hypochlorite, maintaining 95% of the equipment in operation.

In 1992 and 1993, 59 units were installed and in 1996, 82 installed units were recorded.
Table 6 - Number of units of equipment per manufacturer

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Production capacity (LB/DAY)</th>
<th>Hypochlorite concentration %</th>
<th>Installed quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIPCELL</td>
<td>0.5–1.0</td>
<td>0.5–0.7</td>
<td>75</td>
</tr>
<tr>
<td>SOLAR DIPCELL</td>
<td>0.5</td>
<td>0.5</td>
<td>15</td>
</tr>
<tr>
<td>SANILEC 1</td>
<td>1.1</td>
<td>0.5–0.7</td>
<td>1</td>
</tr>
<tr>
<td>SANILEC 2</td>
<td>2.2</td>
<td>0.5–0.7</td>
<td>2</td>
</tr>
<tr>
<td>SANILEC 6</td>
<td>6.6</td>
<td>0.5–0.7</td>
<td>2</td>
</tr>
<tr>
<td>B-100 SANILEC</td>
<td>100</td>
<td>0.8</td>
<td>1</td>
</tr>
</tbody>
</table>

The equipment was installed in SILAIS, hospitals, health centers and posts, and in the treatment plants for urban and rural water supply systems.

In the case of equipment installed in institutions of the Ministry of Health, these State institutions are responsible for the operation and maintenance of the equipment, as well as for the distribution of the hypochlorite produced.

The methodology used can be summarized in two main aspects:

- Production of sodium hypochlorite in a center of the Ministry of Public Health (SILAIS, hospital, laboratory, health center, health post), with the participation of operators.
- Distribution of sodium hypochlorite, through health workers, to the centers or beneficiary communities (markets, penitentiaries, police stations, rural localities).

It is important to point out that some health units are highly developed and have the capacity to manage the quality control of the sodium hypochlorite produced. Such is the case of the National Program for the Control and Prevention of Cholera, which has experience in the assessment of operation and maintenance of hypochlorite-producing equipment, especially using solar energy; and the Regional Epidemiological Laboratory of Grenada, which has experience in conducting controlled tests on different qualities of salt, the degree of concentration obtained in the solutions, and degradation of hypochlorite along time.

In the case of facilities operated by INAA, this institution provides technical and financial support for the operation and maintenance of the equipment, as well as training for the operators.

On the other hand, it should be noted that Nicaragua is the Central American country which has systematic experience in the use of equipment for the production of sodium
hypochlorite applying solar energy; on the Atlantic Coast, fifteen production units are operated by solar panels.

Finally, it can be indicated that with PAHO support, a proposal has been made to set up a systematic program of supervision and follow-up for the operation and maintenance of the equipment, as well as for the production and distribution of sodium hypochlorite.

3.4 Honduras

The Ministry of Health, through its Department of Population Risks where the Department of Environmental Sanitation is located, is the entity responsible for the control and monitoring of water quality.

With regard to disinfection, PAHO has supported actions to provide safe, disinfected water. The PROQUIM and SANEBAR projects have provided valuable support to promote the use of different technological alternatives.

Honduras possesses equipment such as Dipcell, Sanilec, and Clorid, installed in water supply systems (on distribution tanks), hospitals, and health centers.

Three systems are used to distribute sodium hypochlorite:

- Distribution in water supply systems:

  The equipment producing sodium hypochlorite is placed on distribution tanks. All the water in the supply system is disinfected by means of an intermittent dripping system (hypochlorination system).

  In this case, it proved necessary to build booths to protect the equipment. They have different designs and have been built with reinforced masonry.

- Manual distribution:

  Manual distribution is carried out with the support of institutional personnel and community promoters, who distribute it from the production centers (hospitals, health centers, etc.) to the households of every beneficiary community. Penitentiaries and police stations are also supplied with the disinfectant.

  Health workers play a very important role in the distribution of sodium hypochlorite, since they are the distribution agents for small communities and households.

  In addition, it should be noted that thanks to co-ordination between the institutions, police vehicles have been used to distribute hypochlorite containers.
• Chlorine banks

Under this system, community leaders purchase or collect the disinfectant (sodium hypochlorite and calcium hypochlorite) from production-distribution centers located at strategic geographic points. These centers are usually health centers, municipalities and others.

It should be noted that it was in Honduras that the following terms were coined, with PAHO technical support:

• DEIS: On site electrolytic disinfection
• MOGSADOR: Equipment for on-site production of mixed oxidants
• HIPOMOGSADOR: Equipment for on-site production of sodium hypochlorite

PAHO has not only contributed technical assistance to the country, but has also donated equipment.

Since the late 1980s, equipment has been used to generate oxidant gases, including the use of solar panels to produce energy for the operation of traditional equipment, since electric power often failed in rural communities.

This was the case in the community El Volcán, in the department of Comayagua, where an oxidant gas generation set was working with satisfactory results, until, when PAHO support and follow-up came to an end, the community did not continue with the project, especially when failures started occurring in maintenance and operation appeared. To date, however, the solar panels are in a good condition.

An interesting experience was the design of an injector of sodium hypochlorite at the outlet of the wells. The designer, a health promoter, has called it the “chlorine feeder valve”. It is a mechanical device that does not require electric energy. When the well pump is operating, water flows through the discharge pipe. A by-pass in the discharge feeds the chamber of the “feeder valve”. Within it, an inverted float raised by the pumping opens the valve and allows the outflow of sodium hypochlorite from the chamber, which is then deposited at the bottom of the well through a half-inch PVC pipe. When pumping is suspended, water stops flowing through the by-pass and chlorination is suspended.

3.5 El Salvador
In the Republic of El Salvador, the control and monitoring of water quality is seen to by the Basic Sanitation Section, Department of Environmental Sanitation, Division of the Environment, of the Ministry of Public Health and Social Welfare.

Since 1994, the Basic Sanitation Section has established general strategies for the use of equipment for on-site production of sodium hypochlorite. According to these strategies, health centers and units produce and distribute the disinfectant, and the sanitary chiefs of the health units coordinate the activities, while the health promoters take care of distribution at the community and household levels.

It should be emphasized that health promoters and administrative personnel have coordinated actions for the production, maintenance and distribution of sodium hypochlorite. Staff training was necessary at the institutional and community levels and personnel at both levels are carrying out their activities with enthusiasm.

A singular characteristic should be pointed out, i.e. the fact that some national hospitals are responsible for the production of hypochlorite, using part of it to cover their basic needs such as disinfection of surgical material, disinfection and bleaching of patients’ clothes, disinfection of floors, and sanitary facilities. The remaining product is distributed to peripheral communities with the assistance of health workers.

The “rural household disinfection” strategy, adopted in 1994, included the following basic actions:

- Household visits by health promoters and sanitary inspectors.
- Direct household disinfection by health workers. During these visits, users are advised and trained.
- For each unit of equipment producing sodium hypochlorite, a production and distribution plan should be drawn up.
- Sanitary sweepings should be used to promote the use of household disinfection, educate the community, and disseminate the technology.
- At first, work was carried out in communities with a health promoter.
- These communities were provided with raw materials and logistics for hypochlorite distribution.

As a complement to the strategies adopted, “vignettes” were pasted onto the hypochlorite containers of 500 milliliters, so that the users would always have at hand the instructions on how to use it. In El Salvador the solution has been called “Puriagua”.

Health workers show enthusiasm in carrying out their tasks as scheduled, although it is estimated to be an activity with high wear and tear on health promoters. There are places where the plan is working well and others where enthusiasm has waned. Therefore, health authorities should seek mechanisms to maintain the level of operation and efficiency which will contribute to health of the population.
3.6 Guatemala

Guatemala has been working with technologies for the on-site production of sodium hypochlorite since 1987, when tests were carried out with two MOGGOD equipment units under the responsibility of the Executing Unit of the Rural Water Supply System Program of UNEPAR and the Institute of Municipal Promotion, INFOM. Equipment of 0.5 kg and 1.0 kg of chlorine was installed in the communities of Pueblo Nuevo, Usumatlán, Zacapa, and Santa Catarina Pinula, Guatemala.

The experience was positive, confirming the effectiveness of the sodium hypochlorite in water disinfection. The results were presented at the First International Seminar on Disinfection Units by Oxidant Gases, held in 1987 in Lima, Peru.

In 1994, the PROQUIM project donated 20 Dipcell units, which were distributed among drinking water institutions, such as UNEPAR, INFOM, and the Division of Environmental Sanitation, DSM. In 1996, the PAHO/GTZ project began with the direct participation of the Ministry of Health, through the Health Area of Escuintla and the Health District of Escuintla. The Instituto Guatemalteco de Seguridad Social, IGSS, with the Community Teams of Escuintla, Masagua, and Santa Lucia Cotzumalguapa, which are municipalities of the Department of Escuintla, also participated.

In all cases, the PAHO/Guatemala Representative Office provided technical assistance, through consultants hired specifically to provide advice and follow-up on the program activities. PAHO also provided technical assistance and installed the equipment within the jurisdiction of each institution in different parts of the country.

The production and distribution centers vary according to the specific circumstances of the projects carried out by PAHO.

The PROQUIM project, for example, distributed 20 units among the three institutions mentioned above. The equipment was installed depending on the coverage of each institution, in urban water supply systems in different parts of the country, in rural water supply systems, and in Health Area Departments.

In the case of the PAHO/GTZ project, equipment has been installed directly in the beneficiary communities, and each community has created a micro-cooperative with a governing board. The governing board is responsible for the production, operation, distribution, and monitoring of the sodium hypochlorite. At present, they are considered economically self-sufficient to operate the equipment, purchase materials, and distribute the disinfectant. They are supported by the sanitary inspector of the Health District of Escuintla and the health inspectors of the Instituto Guatemalteco de Seguridad Social. The project acquired three Sanilec 2 to carry out household disinfection.
It should be added that there are some communities that are both producers and beneficiaries, and others that are beneficiaries only. The communities use either pick-ups or collective transportation to distribute the disinfectant.

Large volumes of sodium hypochlorite are distributed in plastic containers of different capacities. Each household has plastic containers of 20 liters in which to prepare drinking water and plastic containers of 250 milliliters to distribute sodium hypochlorite for family use.

Within the PROQUIM project, by the end of 1993, the projects were implemented in all the mentioned places. Then, follow-up by the responsible institutions failed and some communities began to operate disinfection activities deficiently. In some places the project has come to a complete stop. It would seem that the institutions in the drinking water sector were not sufficiently aware of the disinfection potential, even though in a technical seminar for the managers of these institutions, the participants made the commitment that from that moment on all water supply systems would incorporate the disinfection process, including the local production of hypochlorite: a promise that has not been kept.

The drinking water sector is currently being reorganized and it will take some time for it to integrate and redefine its objectives. However, it would be a positive step if INFOM managers were informed about the advantages of the disinfection technology so that they would include it in the implementation of the new models of water supply systems, with beneficial results for the population.

4. Aspects of disinfection

4.1 Technical aspects

Bearing in mind the experiences relating to on-site production of sodium hypochlorite or oxidant gases, in this section we present a summary of the main considerations in Central America.
4.1.1 **Equipment**

Since the last decade, tests have been carried out with new technologies for on-site production of disinfectants to demonstrate their advantages and application especially in the more depressed areas of the countries of the region.

The general principles of operation are described below with the two generations of equipment developed:

- **Equipment producing “mixed oxidant gases generated on site”,** consisting basically of one box or recipient with electrodes (anode and cathode) with two chambers divided by a semipermeable membrane. The anode cell contains a sodium chloride solution (brine) while the cathode cell contains water or a diluted solution of sodium hydroxide. The electrodes are connected to a power source with a regulator that transforms normal alternating current (110 volts) to a lower direct current voltage. The electric flow in the solution causes the electrons to move through the solution, and the chlorine ions eventually go toward the anode, while sodium ions go toward the cathode. As a result, ozone, nascent oxygen, hydroxyl radicals, perhydroxyl radicals, chlorine dioxide, hydrogen peroxide and other gases (species of oxygen) are produced.

- **Equipment for on-site production of sodium hypochlorite.** The process is similar to the above, but the semipermeable membrane has been eliminated, generating dissolved oxidants, instead of oxidant gases. The equipment consists of a power source and electrodes submerged in a plastic container with a sodium chloride solution that after a period of electrolysis produce a diluted solution of sodium hypochlorite and small volumes of hydrogen gas.

The equipment currently being used in the region is the following:
Table 7 - Equipment used in Central America: comparison of its main characteristics

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Amperage of the cell</th>
<th>Voltage of the cell</th>
<th>Watts required by the cell</th>
<th>Grams of chlorine available in 24 hours</th>
<th>Salt consumption in 24 hours (kg)</th>
<th>% salt conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLORID L-30 (1)</td>
<td>(1)</td>
<td>(1)</td>
<td>10</td>
<td>300-450</td>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>CLORID L-90</td>
<td>45</td>
<td>5.2</td>
<td>234</td>
<td>900-1,350</td>
<td>3.0</td>
<td>27.3</td>
</tr>
<tr>
<td>CLORID L-450</td>
<td>240</td>
<td>5.2</td>
<td>1,248</td>
<td>4,500-6,750</td>
<td>16</td>
<td>27.7</td>
</tr>
<tr>
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<td>13</td>
<td>182</td>
<td>500</td>
<td>2.4</td>
<td>34.8</td>
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<tr>
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<td>14</td>
<td>16</td>
<td>224</td>
<td>1,000</td>
<td>5.1</td>
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<tr>
<td>SANILEC 6</td>
<td>22.5</td>
<td>24</td>
<td>540</td>
<td>3,000</td>
<td>15</td>
<td>32.8</td>
</tr>
<tr>
<td>DIPCELL 20/25</td>
<td>20</td>
<td>8-12</td>
<td>200</td>
<td>550</td>
<td>3.6</td>
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<tr>
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<td>450</td>
<td>1,080</td>
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<tr>
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<td>900</td>
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</table>

NOTE:
Data were obtained from the catalogs of manufacturers and complemented with information from the document “Avances en América Latina de la tecnología para la producción de desinfectantes a nivel local”, by Fred M. Reiff, PAHO/WHO Regional Adviser.

(1) No data available

4.2 Distribution of the disinfectant

With regard to sodium hypochlorite distribution, two options are being used in the region:

- DISTRIBUTION IN WATER SUPPLY SYSTEMS

When sodium hypochlorite is applied directly into water supply systems, reinforced masonry booths are built over the distribution tanks to protect the equipment and its incorporated hypochlorinator. Honduras and Guatemala have used their own designs. In Costa Rica the above procedure is used in rural water supply systems, while in other cases, auxiliary facilities are built inside drinking water treatment plants.

- COMMUNITY AND HOUSEHOLD DISTRIBUTION

The second option is to transfer hypochlorite in plastic containers (5, 10, 20 liters) to the places of consumption, which can be rural communities, other health units, penitentiaries, etc. From these places, hypochlorite is distributed in smaller containers (250-500 ml) to disinfect drinking water drawn from hand-
dug wells or nearby streams. Nicaragua, Honduras, El Salvador, and Guatemala have been using this system.

Another alternative currently being used in Guatemala is the creation of micro-cooperatives for the production, distribution, operation and maintenance of equipment, and even the marketing of the hypochlorite.

4.3 Social and community aspects

There can be no doubt that the interaction of the different social aspects, in which community participation plays an important role, is the key to meeting the planned goals in this type of community project.

The programs carried out in the region were all planned and scheduled by health authorities. However, once the disinfection project was implemented in the communities, emphasis was given to local participation. It is interesting to observe that members of the water committees or administrative boards really take care of the technology on behalf of their own communities.

Nevertheless, it should be taken into account that to make the projects sustainable, the initial efforts of the communities should be given strong support so they can be consolidated and the systems can continue to work even after health authorities or sponsoring institutions have phased out.

4.4 Political and legal aspects

It should be stressed that the political will of high-level authorities is necessary if proper strategies are to be introduced or maintained for water quality and disinfection.

In this context, Costa Rica is the only country of Central America that has defined a strategy according to global policies established by the Government. The results of this type of decision are evident, as seen in Tables 3 and 4.

The health authorities of Nicaragua, Honduras and El Salvador have also established overall strategies that have kept disinfection projects working relatively well. However, government changes usually imply the transfer and dismissal of health personnel, making it impossible to perform the follow-up of the programs.

In Guatemala, a proposed bill was cautiously presented to the Congress of the Republic to make it obligatory for all the mayors of the country to supply disinfected water to the communities under their jurisdiction. However, these initiatives were not successful and only when a crisis arises are any attempts made to solve problems, such as in the recent outbreaks of cholera and hepatitis in the north-eastern region of the country.
4.5 Financial aspects

Disinfection projects are implemented when resources are available. This type of project involves expenditure on equipment, operation, training, and follow-up, and if such expenses are not considered in the annual budget, the actions that have been started risk losing their objective and sustainability.

In the region, only Costa Rica through the Instituto Costarricense de Acueductos y Alcantarillados has allocated part of its budget to new equipment, operational staff training, and maintenance of in-service equipment.

In the case of other countries of the region, PAHO has contributed all the equipment, training, and follow-up, as observed in Table 1.

5. Main factors of success

Throughout the experiences, partial success and concrete achievements have been obtained. In order of priority the conditions considered decisive for success were:

- PAHO support

There can be no question that without PAHO support through its different projects, it would not have been possible to reach the current state of disinfection development. Since the 1980s, PAHO has donated the first units of equipment for oxidant gas generation to assess their operation. Subsequently, the PROAGUA, PROQUIM, MASICA, and SANEBAR projects have decisively supported the actions in each country, including the current PAHO/GTZ project.

- Co-participation of health authorities

In the countries of the region, health authorities have contributed through their sanitation departments. With this substantial contribution, in countries such as El Salvador, Honduras, and Nicaragua, disinfection projects have attained relative sustainability; the resources allocated to meet the needs of the population are still limited.

- Willingness and dedication of sanitary operators

The willingness and dedication of sanitary operators contribute to the success of this sector. In general, it is the health technicians who maintain the operation of this type of programs. Despite their low income, they make every effort to keep the programs working. It should be pointed out that it is the sanitary
operators of El Salvador, Honduras, and Nicaragua who have maintained the enthusiasm and leadership in the region.

- Community participation

Finally, active community participation cannot and must not be underestimated since it is the community that maintains the actions carried out for its own benefit. An example is given by the rural communities of Escuintla in Guatemala, where one of the micro-cooperatives is made up of women only. Undaunted by initial difficulties, these women have become the key personalities who ensure the ongoing operation of the pilot project for household disinfection.

6. Conclusions

The main conclusions of the experiences in Central America are described below:

- The MOGGOD equipment generates oxidants with a considerable effect, due to the presence of several gases that are powerful biocides.
- The oxidant gases generated not only eliminate bacteria (Vibrio cholerae, Salmonella typhymurium, Escherichia coli), but also protozoa (Giardia lamblia and cysts) and viruses (rotavirus).
- The action of oxidant gases is highly effective and requires only a few seconds of contact time to exercise its biocide action.
- The efficiency of sodium hypochlorite is the same as that of calcium hypochlorite; careful dosage is recommended.
- The equipment and its products are used to fullest advantage when installed in the distribution tanks of water supply systems, since all the water in the system is disinfected.
- Household and community distribution requires a great deal of co-ordination among health authorities and beneficiaries. In addition, it requires constant follow-up in the first years of operation until the families adopt new habits.
- The amount of equipment installed in the different countries should guarantee a multiplier effect of the disinfection, provided an adequate production-distribution process be established as well as a program defining the coverage goals and evaluating achievements.
- In the case of Costa Rica, AyA has set in place a policy for water disinfection. There is mass utilization of disinfection equipment supported by grassroots organizations that guarantee its use and maintenance.
- In the case of Honduras, chlorine banks usually represent an economic burden that surpasses the capacity of health authorities. The operation, maintenance, storage, packaging, transportation and distribution costs of sodium hypochlorite, demand resources that are not available in health units.
In the case of household disinfection in Guatemala, the demonstration project has been accepted and women are the ones heading the micro-cooperative committee.

Equipment is not operating adequately because of lack of training of the operators (operation hours, water volume, salt dosage).

Many units of equipment present incrustations (sediments of calcium carbonate) on the electrode plates because the maintenance indicated by the manufacturer is not being given.

The voltage and amperage of the electric current is not stable, causing damage to the equipment.

Authorities from health departments, municipalities and communities are not aware of population requirements, and the great potential of the equipment is wasted.

Hydrochloric acid at 5%, necessary for the cleaning and preventive maintenance of electrolytic cells, is not available.

In the case of household distribution, there are not enough containers available to facilitate the transfer of hypochlorite. In general, there is a lack of formal planning for the production of sodium hypochlorite and control of its use.

The total beneficiary population is unknown.

The high turnover of operators affects the operation and maintenance of the equipment.

A constant updating of knowledge on water, contamination, and disinfection is required.

When sodium hypochlorite is used through a hypochlorinator, no adequate feeders are available.

To date, household disinfection projects carried out in Guatemala, have had relative sustainability thanks to community participation. In the case of El Salvador, Honduras, and Nicaragua, the projects have been sustained thanks to the responsible attitude of the health workers involved.

There is educational material to support the different projects. This is the case of Guatemala, Honduras and El Salvador.

A change in food and drinking-water handling habits is perceived at the household level.

7. Recommendations

After selecting the communities in the region where the equipment will be installed, it is necessary to train the personnel involved in the installation, operation, maintenance, and follow-up (communities, municipalities and health workers).

Health units should establish a systematic follow-up or monitoring plan for the installed equipment at least once a month, to ensure its correct operation and maintenance.
• It is important to provide tables for equipment control and maintenance, as well as to motivate users to participate in the procurement of inputs for operation and maintenance (salt, hydrochloric acid, vinegar).
• Each equipment unit should have an adequate container for cleaning the incrustations of bicarbonate on the electrode, which can be a PVC cylinder measuring four inches by one meter high.
• Health unit directors should attend to the needs for on-site production and distribution of hypochlorite (containers, salt, hydrochloric acid, etc.)
• The equipment for on-site production of sodium hypochlorite should be installed in ventilated areas with a hose inside the container to evacuate hydrogen gases generated during the production of hypochlorite.
• The present location of the on-site production equipment should be revised. It should be located in places where there is a higher demand or which are farther away from health centers, in order to reduce long-distance distribution costs.
• At the level of health units, operators need to be trained in equipment maintenance, production control, disinfectant distribution, ways to measure chlorine concentration, and determination of chlorine residual.
• Health technicians and personnel in charge of hypochlorite distribution need to be trained in the advantages of chlorine in drinking water disinfection.
• There should be a regular assessment of the health impact of free distribution of chlorine for drinking water disinfection among beneficiaries.
• In general, it can be concluded that equipment is being used reasonably well, although not to full capacity. The exception is the equipment with continual amperage problems due to irregular power supply.
• It is recommended that regular refresher courses be conducted on operation and maintenance of on-site sodium hypochlorite production equipment and on the use of chlorine in drinking water disinfection. It would be desirable to organize a Permanent Committee of Drinking Water Disinfection in each country, responsible for the planning, co-ordination, follow-up and assessment of disinfection activities within their own country. This Committee should operate also at the Central American level.
• This Permanent Committee of Water Disinfection at the Central American level, should be responsible for the planning, coordination, follow-up, and assessment of disinfection actions in the region, as well as for the exchange of experiences and for the development of appropriate technology according to local conditions. The publication of a half-yearly newsletter and visits among the different countries would promote the exchange of experiences and raise interest in on-site sodium hypochlorite production technologies.
8. References

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