NOTES ON SELECTING MERCURY REDUCTION ACTIVITIES

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Introduction

A major component of the UNDP GEF Project is the replacement of mercury thermometers and sphygmomanometers since they are the largest sources of mercury releases from the health sector. In countries and regions where growing demand for non-mercury alternatives and new regulations have encouraged manufacturers to increase the supply of alternatives, prices of alternatives have dropped and the replacement of mercury thermometers and sphygmomanometers has become a cost-effective activity.

The UNDP GEF Project is committed to these activities even though they may not necessarily be the most cost-effective mercury reduction options in some project countries. Moreover, where digital thermometers are the only available alternatives, they would constitute a net increase in energy consumption during use due to the need for batteries. The project hopes that encouraging more hospitals and countries to commit to replacing mercury thermometers and sphygmomanometers will result in more non-mercury alternatives becoming available, including galinstan and alcohol-dye thermometers which do not consume energy during use. An increase in supply of alternatives will gradually reduce the unit costs and make these replacements more cost-effective in the future.

In addition to replacing mercury thermometers and sphygmomanometers, many other options exist to reduce mercury in a health facility. These include the replacement of mercury-containing dental amalgam, laboratory fixatives and preservatives that contain mercury, gastrointestinal tubes, mercury electrical switches, and fluorescent lamps. This note addresses the question of whether the UNDP GEF Project should work on other mercury replacement activities in addition to introducing mercury-free thermometers and sphygmomanometers (blood-pressure device). This replacements of mercury-containing fluorescent light bulbs and esophageal dilators are provided as examples. The general approach can be used to prioritize other mercury reduction activities in light of budget constraints.

General Approach

In general, the decision to engage in a specific mercury replacement activity, in addition to the substitution of mercury thermometers and sphygmomanometers, should be based on eight factors:

1. Overall environmental impact
2. Cost-effectiveness of the activity
3. Total installed capital cost of the activity
4. Operating costs resulting from the activity

5. Availability of mercury-free or mercury-reduced products
6. Impact on energy consumption
7. Ease of implementation
8. Acceptance by the healthcare facility management and staff.

The overall environmental impact refers to the total amount of mercury eliminated in the facility as a result of the activity. Since mercury thermometers and sphygmomanometers are used widely and break often, they constitute the major source of mercury releases from a healthcare facility. For this reason, mercury thermometers and sphygmomanometers have the highest priority. In the case of mercury devices that break frequently or consumable items such as mercury-containing fixatives used in pathology, the environmental impact could be measured in grams of mercury removed per year. Additionally, the mercury-free or mercury-reduced products should not contain other bio-accumulative, persistent and toxic substances as much as possible. They should not result in a net increase in pollutant emissions or greenhouse gases.

Cost effectiveness compares the monetary input and the desired outcome of two or more activities. In our case, the monetary input is the incremental cost of the activity under consideration in relation to the current practice. The desired outcome is the reduction in mercury. Thus, the cost effectiveness is measured as the incremental cost-effectiveness ratio calculated in US dollars per gram of mercury removed. The cost effectiveness of an activity under consideration should be compared with the cost effectiveness of substituting mercury thermometers and sphygmomanometers. If the budget permits, activities that are more cost effective could be given priority after the substitution of mercury thermometers and sphygmomanometers.

The total installed capital cost refers to the one-time cost of replacement, including capital and installation costs, importation costs, shipping, and one-time any training required. The total installed capital cost of an activity under consideration should be compared to the GEF funds available to the model healthcare facility. Operating costs, which include labor, cost of electricity and other utilities (e.g., water, steam, fuel, etc.), maintenance, and disposal, should also be compared.

In order to implement an activity under consideration, mercury-free or mercury-reduced products should be readily available in the country or at least easily imported during the life of the project.

In addition, the use of mercury-free or mercury-reduced products should not increase energy consumption as much as possible. The process of replacement should be relatively easy and the new products should be accepted by the facility management and staff without difficulty.

EXAMPLES: FLUORESCENT LAMPS, ESOPHAGEAL DILATORS AND HISTOLOGY FIXATIVES

This section uses fluorescent tube lamps, esophageal dilators and laboratory fixatives as examples, and provides some preliminary calculations for a hypothetical hospital scenario. Some numbers used in this example have been taken from various sources and others are imaginary, therefore the numbers may not reflect the actual values in the country. The actual values should be computed using country-specific figures.

MERCURY THERMOMETER REPLACEMENT: A hypothetical model hospital uses mercury thermometers that contain 0.7 grams Hg each and cost $1. The model hospital records an average of 840 mercury thermometers broken per year. They are to be replaced with digital thermometers that cost $15 and use alkaline type LR41 button batteries which cost $1 each. An analysis of usage shows that 80 digital thermometers are needed in the hospital. Each digital thermometer battery has a lifespan of 300 hours and contains 2% mercury by weight. This amounts to about 0.012 grams of mercury in the battery for every digital thermometer.[1]

Further research on usage shows that each digital thermometer will need its battery replaced once a year. Data from other hospitals in the country suggest that this type of digital thermometer lasts for two years with extensive use.

MERCURY SPHYGMOMANOMETER REPLACEMENT: The hypothetical hospital uses mercury sphygmomanometers that contain 200 grams of mercury each and cost $70 a piece. They are to be replaced with gearless aneroid sphygmomanometers which are mercury free and cost $90 each. The hospital currently has 50 mercury sphygmomanometers.

FLUORESCENT LAMPS: The model hospital uses 500 mercury-containing, straight 120-centemeter (4 ft) long, 25-millimeter (1-inch) diameter, T8 ceiling fluorescent tube lamps throughout the facility. The old fluorescent lamps have an average life of 20,000 hours when turned off only once during a 12 hour operating period. The old lamps contain about 25 milligrams of mercury (25 mg Hg) per lamp, and cost about $1 per lamp. The lamps are rated at 36 W with 3350 lumens, a color temperature of 5000K, and a color rendering index of 82.

Research in the country indicates that a possible mercury-reduced alternative is a low-mercury fluorescent lamp which is available from a local source. The lamp is rated at 32 W and has an average lifespan of 30000 hours. (Note: This figure is taken from the manufacturer and may be based on the lamp being turned off only once every 12 operating hours; as much as possible, an average lifespan based on actual working hours should be used.) The lamp has 2950 lumens, a color temperature of 5000K, and a higher color rendering index of 85. Each lamp contains 1.7 mg Hg and costs $5.

Some new low-mercury lamps may not need a special ballast. However, if one is needed, a high-efficiency, electronic ballast serving 2 to 4 lamps costs about $15 to $20 each. The example below assumes that the lamps will work with the existing ballasts and no new ballasts are necessary.

ESOPHAGEAL DILATORS: The model hospital uses mercury-containing esophageal dilators (bougies). Two sets of esophageal dilators are in regular

[1] Note: In many countries, the cost of digital thermometers is almost the same as that of a mercury thermometer. Some LR41 batteries have as low as 0.1% mercury by weight and mercury-free LR41 batteries may be available.

use. Each dilator contains 900 grams of mercury and costs. Each set costs \$3400. Research in the country indicates that a safer non-mercury alternative using tungsten gel instead of mercury is available at a cost of \$3000 per set. Interviews of clinicians at hospitals that have started to use the alternatives show that the tungsten bougies perform just like the mercury bougies. No changes in techniques are required. Doctors and nurses see an advantage in that any leaks or breakage of a mercury bougie inside the patient would be much more toxic than if a tungsten alternative is used.

HISTOLOGY FIXATIVE: The histology department of the hospital laboratory uses 150 liters a year of a laboratory fixative solution that contains mercuric chloride and formaldehyde. Each liter of fixative solution costs \$35 and contains 0.04 g Hg. A new mercury-free and formaldehyde-free alternative is now available in the country. It uses zinc chloride and acetic acid instead. An analysis by the hospital indicates that it would require the same amount of solution for histological fixation and has the added advantage of reducing fixation time. The mercury-free solution costs \$40 per liter.

1.0 Overall Environmental Impact

MERCURY THERMOMETER REPLACEMENT: Mercury replacement will eliminate 588 gram of mercury released into the environment per year. The 80 digital thermometer batteries account for 0.96 grams of mercury per year. This is a net decrease of 587 g Hg per year.

MERCURY SPHYGMOMANOMETER REPLACEMENT: Replacing mercury sphygmomanometers with mercury-free blood pressure devices will eliminate 10000 g Hg from the facility. If one were to assume that each mercury sphygmomanometer lasts 15 years, this averages to about 670 g Hg per year eliminated.

FLUORESCENT LAMPS: If all 500 old lamps are replaced, the overall mercury reduction amounts to:

23.3 mg x 500 = 11650 mg Hg or 11.65 grams Hg

In other words, the replacement of all 500 lamps in the hospital is equivalent to replacing about 17 mercury thermometers with digital thermometers.

In addition to reducing mercury releases, the new technology in the above example also has reduced lead content. Since it lowers energy consumption by 11%, this also means less CO_2 and other pollutant emissions associated with energy generation.

ESOPHAGEAL DILATORS: Replacing the hospital's two esophageal dilator sets will eliminate 1,800 grams of mercury from the facility. If one assumes that esophageal dilators last about 7 years, this averages 270 g Hg eliminated per year.

HISTOLOGY FIXATIVE: Replacing the mercury-containing fixative with the new solution will eliminate 6 grams of mercury per year.

2.0 Cost Effectiveness of the Activities

For comparison, the cost effectiveness of mercury thermometer and sphygmomanometer substitution will be computed first. The figures used below are taken from various sources or are imaginary so they may not reflect the actual values in the country.

MERCURY THERMOMETER REPLACEMENT: Using two years as a basis, one estimates that 1680 mercury thermometers will be broken during that period at a cost of $1680. This corresponds to 1176 g Hg. Those mercury thermometers can be replaced with 80 digital thermometers costing $1200 and 80 additional LR41 batteries costing $80 for a total cost of $1280. The batteries account for 1.92 g Hg.

For the situation thus described, the incremental cost is:

$1280 - $1680 = - $400 (cost savings)

The reduction in mercury for the two years is:

1176 g – 1.92 g = ca. 1174 g Hg

Therefore, the cost effectiveness of mercury thermometer substitution is:

- $400 / 1174 g = - $0.34 per g Hg removed

This means a saving of 34¢ per gram of mercury removed.

MERCURY SPHYGMOMANOMETER REPLACEMENT: Assuming the same lifespan, the cost effectiveness of mercury sphygmomanometer substitution is:

$20 / 200 g = $0.10 per gram Hg removed

FLUORESCENT LAMPS: As a quick assessment, only the capital cost of the lamps will be used for comparison. Calculating the capital cost requires knowing the average lifespan of the fluorescent tube and the total number used in the facility. Assume a basis of 50,000 operating hours (about 10 years) for convenience. Because of differences in lifespan, the number of lamps needed in one fixture for 50,000 hours of operation is:

50,000 hrs / 20,000 hrs per old lamp = 2.5 old lamps

50,000 hrs / 30,000 hrs per new lamp = 1.67 new lamps

The corresponding costs of the lamps for 50,000 hours of operation are:

2.5 old lamps x $1.00 per lamp = $2.50

1.67 new lamps x $5.00 per new lamp = $8.35

Therefore, the incremental cost associated with the new lamp for 50,000 hours of operation is:

$8.35 - $2.50 = $5.85

The amounts of mercury found in the lamps needed for 50,000 hours of operation are:

2.5 old lamps x 25 mg per lamp = 62.5 mg Hg

1.67 new lamps x 1.7 mg per lamp = 2.8 mg Hg

The reduction in mercury in one fixture per 50,000 hours is:

62.5 mg – 2.8 mg = 59.7 mg Hg or 0.0597 grams Hg

Therefore, the cost effectiveness is:

$5.85 / 0.0597 g = $98 per gram of Hg removed

ESOPHAGEAL DILATORS: The hospital's two esophageal dilator sets cost a total of $6,800, corresponding to 1800 g Hg. Replacing these with two tungsten dilator sets will cost $6,000. The incremental cost is a cost savings of:

$6000 - $6800 = - $800 (cost savings)

Assuming that same lifespan for the mercury and non-mercury dilators, the cost effectiveness is:

- $800 / 1800 g = - $0.44 per gram of Hg removed

This means a savings of 44¢ per gram of mercury removed.

HISTOLOGY FIXATIVE: The hospital spends $5250 per year to purchase the mercury-containing fixative. The new solution will cost $6000 a year and eliminate 6 grams of mercury. The cost effectiveness is:

$750 / 6 g = $125 per gram of Hg removed.

3.0 Total Installed Capital Cost of the Activity

One needs to determine if funds are available after the primary activities (mercury thermometer and sphygmomanometer replacement) are undertaken.

MERCURY THERMOMETER REPLACEMENT: The total capital cost for two sets of 80 digital thermometers amount to $2400.

MERCURY SPHYGMOMANOMETER REPLACEMENT: The capital cost of replacing all 50 mercury sphygmomanometers amount to $4500.

FLUORESCENT LAMPS: In the hypothetical example of the fluorescent lamps, we will assume that ballasts, fixtures, tube clips, end guards, and other accessories do *not* have to be replaced. We will also assume that the old lamps will be replaced gradually, that is, only when they have burned out or are broken and have to be replaced. Therefore, there are no incremental costs for installation.

To replace 500 old lamps, the total capital cost required is $2500.

If there is not enough in the budget to cover the full cost, it may be possible to replace only a small percentage of the old lamps in order to demonstrate the technology in selected spaces in the hospital and encourage the model facility to move towards greater mercury reduction.

NOTE: There are expensive "non-mercury" fluorescent lamp replacements available in some countries. The LED fluorescent lamps do not contain any mercury but have only been in use for a few years. They are reported to last longer (usually around 100,000 hours of operation), require less power, and can fit standard fixtures. Another option to consider if the budget is limited is to demonstrate both the mercury-reduced lamps and the mercury-free LED lamps in a few selected areas of the hospital.

ESOPHAGEAL DILATORS: Replacing the hospital's two esophageal dilator sets will cost $6000.

HISTOLOGY FIXATIVE: Replacing the mercury-containing fixative with the new solution will cost $18000 per year.

If there is enough in the budget for these secondary activities, then it would be worth doing it according to the priorities.

4.0 Operating Cost Resulting From the Activity

MERCURY THERMOMETER REPLACEMENT: The batteries ($80 per year) and minimal maintenance are the main operating costs.

MERCURY SPHYGMOMANOMETER REPLACEMENT: Maintenance, including calibration, is the main operating cost. Mercury blood pressure devices should also be maintained and calibrated although many are not. For this analysis, the operating costs will be assumed to be the same as for mercury sphygmomanometers.

FLUORESCENT LAMPS: Assuming no changes in the operating hours and in the electricity rates, there will be a net savings in operating costs as a result of replacing the old lamps. Since the replacement lamps have a lower wattage, 32 W, compared to 36 W for the older lamps, there will be a savings of 11% in electrical costs. For example, if the lights are kept on for 14 hours per day, each old lamp will consume 184 kWh per year compared to 163 kWh per year for a new lamp. Assuming electrical rates of $0.10 per kWh, this means a savings of $1000 per year in reduced electrical costs if all 500 lamps are replaced.

Labor costs would also be slightly less because of the less frequent need to replace the new lamps which have a longer lifespan. In countries where the law requires special disposal of mercury-containing lamps, the new lamps would have much lower disposal costs, typically a reduction of about $0.30 per lamp.

ESOPHAGEAL DILATORS: Maintenance (cleaning) costs are the main operating costs but these would be no different from the operating costs of the mercury dilators.

HISTOLOGY FIXATIVE: The disposal costs of the fixative (which contains zinc) will be less than the disposal costs for mercury.

5.0 Availability of Mercury-Free or Mercury-Reduced Products

The hypothetical scenario assumes that new fluorescent lamps, tungsten gel esophageal dilators, and mercury-free fixatives are available in the country.

6.0 Impact on Energy Consumption

The use of digital thermometers is a net increase in energy use as reflected in the cost of the batteries. The new lamp will reduce energy consumption by 11%, equivalent to a reduction of 21 kWh per year for each lamp.

7.0 Ease of Implementation

Assuming no new ballasts or accessories are needed and no special training required, the replacement procedure for the new lamps will be identical to past practice. Since the new lamps will be installed only when an old lamp is burned out or broken, there is no added burden to the facility to implement this activity. The interviews with other hospitals in the country confirm that the techniques for using mercury-free dilators and fixatives are practically identical to the mercury devices.

8.0 Acceptance by the Healthcare Facility Management and Staff

The new lamps have similar lumens (the light power as perceived by the human eye), the same color temperature of 5000K (natural sunlight), and a better color rendering index (the ability of a light source to reproduce the colors of objects as closely as possible to natural light). Hence, members of the staff should not notice much of a difference in the lighting of their spaces. The management may be concerned with the higher cost of the mercury-reduced lamps but may accept the new technology if they understand the importance of reducing mercury pollution to the environment and if they realize the significant annual savings in electrical costs and other operating costs.

It is expected that the staff in the model facility would be interested in the new mercury-free dilators since they will reduce potential toxic effects on their patients and eliminate the need for mercury clean-up in the event of a leak or spill. It is also anticipated that the laboratory medical technician would be satisfied that the new fixatives will work just as well as the old mercury-containing solution.

CONCLUSIONS

Deciding which mercury reduction or elimination activities to undertake requires weighing the pros and cons and a judgment by the technical consultant based on the above-mentioned eight factors. The following table summarizes the results of the sample analysis.

	Mercury thermometer replacement	Mercury sphygmomano-meter replacement	Mercury fluorescent lamp replacement	Mercury esophageal dilator replacement	Mercury fixative replacement
Overall environmental impact	587 g Hg removed *per year*	10 000 g Hg removed	11.65 g Hg removed	1800 g Hg removed	6 g Hg removed *per year*
Cost effectiveness	-$0.34 per g Hg removed (savings)	$0.10 per g Hg removed	$98 per g Hg removed	-$0.44 per g Hg removed (savings)	$125 per g Hg removed
Total capital cost	$2400	$4500	$2500	$6000	$18000
Operating cost	$80 per year for batteries	Same as mercury devices	-$1000 per year (savings) and reduction in labor and disposal costs	Same as mercury dilators	Reduction in disposal costs
Availability	Available	Available	Available	Available	Available
Energy consumption	Increase due to battery use	Same as mercury devices	11% reduction	Same as mercury dilators	Same as mercury fixatives
Ease of implementation	Requires minimal training	Requires some training	No problems expected	No problems expected	No problems expected
Acceptance	May require awareness-raising	May require awareness-raising	No problems expected	Easy acceptance expected	No problems expected

This analysis suggests that replacement of esophageal dilators and fluorescent lamps are good mercury reduction options after the primary activities for the hypothetical model facility. In the example, replacement of mercury dilators are very cost effective and would result in cost savings and a significant reduction in mercury. Replacement of mercury lamps are not as cost effective and remove fewer amounts of mercury but result in significant savings in operating costs and a marked reduction in energy consumption.

Note that the above analysis is hypothetical and is intended only to demonstrate an approach for selecting mercury reduction options under the UNDP GEF Project.

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