DEVELOPMENT OF LOW-COST EDUCATIONAL MATERIALS FOR CHEMISTRY

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ABSTRACT

Chemistry is a practical and experimental science. Various attempts were made worldwide to design and implement Chemistry curricula to reflect this practical nature of Chemistry. In Africa, whereas there had been many donor-supported initiatives to equip Chemistry labs, these initiatives did not succeed in sustaining practical Chemistry in the continent. One avenue to solve this problem is to engage African chemists, chemistry teachers and their students in designing and developing low-cost educational materials for Chemistry teaching and learning. This paper tries to highlight the principles and approaches towards the development of low-cost Chemistry materials from locally available materials. It finally lists the procedures used to develop low-cost materials for Chemistry teaches in Ethiopia. *[AJCE, 2(1), January 2012: Special Issue]*

INTRODUCTION

The teaching of Chemistry in Africa has been dominated by theoretical lectures and that has been limiting our students' understanding of the various chemical concepts and principles. Such an approach coupled with the abstract nature of the subject interferes with students' creativity and innovation capacity. On the other hand, most African countries do not have the financial capacity to equip schools and colleges with the needed equipments and materials to teach Chemistry as a practical enterprise.

One way to deal with this paradox is to build the capacities of chemistry teachers and teacher educators in the design and development of low-cost educational tools from locally available materials. Low-cost educational materials in Chemistry refer to a diversity of tools used for teaching and learning purposes. Such materials include improvised chemistry apparatus, kits, hand-made models of chemical substances, charts, tables, educational games, etc.

Several attempts have been made to provide guiding resources in the field of the development of low-cost educational materials, mainly initiated by UNESCO. One such resource is the report of a regional workshop in Asia and the Pacific in 1978 on the design, development and evaluation of low-cost educational materials (1). This resource is not just for Chemistry but for a variety of subjects. But the principles and experiences shared in the report are very useful. The Ministry of Education (MOE) of Ethiopia, in collaboration with the Chemical Society of Ethiopia (CSE), also produced a guideline in 1990 (2) for Chemistry teachers after conducting a workshop that aimed at testing the proposed models and apparatuses for Chemistry teaching and learning. A third resource that is worth mentioning is the document produced in 1993 by the World Bank (3) on the constraints and opportunities of equipment for science education.

This paper therefore attempts to review such initiatives and tries to highlight lessons to be learnt for the present day Chemistry education in Africa.

RATIONALE FOR LOCALLY MADE LOW-COST EDUCATIONAL MATERIALS

Many African countries have been receiving equipment donations for improving science education. According to the World Bank discussion paper (3) large investments have been made to improve the teaching science in developing countries although their effect has been in many cases far less than expected. The main reasons mentioned for the lack of success despite huge investments are: technical unsuitability of the equipment, educational unsuitability of the equipment, faults in the procurement procedures, high cost of the equipment, lack of teacher and technician training, lack of incentives to use the equipment, faults in the distribution, inadequate supply of consumable materials, and inadequate maintenance, repair and replenishment.

On the other hand, the benefits of low-cost and locally produced equipment are lower cost, easier maintenance and repair, better availability of spare parts, higher relevance to the curriculum, higher local content, contributions to self-reliance, and flexible adaptation for new topics in the curriculum (3).

CLASSIFICATION OF LOW-COST MATERIALS

There are different ways of classifying and categorizing low-cost materials. For instance, UNESCO (1) identified the following five ways:

i. The available materials in the natural environment as well as scraps/discards from commercial and domestic use. They may be freely and easily available. Typical examples are seeds, shells, bottle caps, packing materials, fused bulbs, etc.

ii. The available materials which are easily accessible in the environment but the purchase of which could be within the reach of the schools. Examples in this category could be battery, bulb, wire, etc.

iii. The available examples of prototype materials prepared by teachers and specialist for possible wider dissemination. Examples are charts, periodic tables, simple models or kits which are either distributed by government agencies or sold commercially.

iv. Educational materials which need the use of machines. Films, slides and film-strips require projectors. Audio tape requires a tape recorder.

v. Materials such as radio programs, television programs, videotapes and films which most often are made for wider utilization to justify the high cost. The use of these materials in the classroom depends largely on the teacher's skill and competence.

In the 21st century, modern information and communication technologies (ICTs) also provide an opportunity for low cost based teaching and learning. The use of open-source and free software that are made for educational purposes is now becoming common in most institutions, provided that the needed infrastructure is in place.

There are different approaches to the supply of locally produced equipment in different countries. Possible types of production are (3):

- production by teachers and students
- establishment of central production units in the country
- central development and assembly of equipment and kits,
- decentralized development and production
- a combined approach (probably the most frequent)

In general, in developing and using low-cost materials it is necessary to consider the level at which the materials are used (such as elementary school, secondary school and colleges). The materials should also be judged from the point of view of certain criteria such as the amount of money needed, the involvement or participation of various groups (such as teachers, students, community, specialists, etc), the environment from which the materials are obtained and the extent of utilization. The following table summarizes these points (1).

Classification of materials	**Criteria**			
	Money	**Participation**	**Environment**	**Utilization**
a. Freely available	No	Pupil/teacher	Local	Limited
b. Accessible and easily available at low cost	Low	Pupil/teacher/community	Local	Limited
c. Available commercially	Medium	Teacher/other personnel	Partly local	Medium
d. Mass media or distant learning systems	High	Specialist/other personnel	Not local	Widest

PRODUCTION OF LOW-COST EDUCATIONAL MATERIALS

Many types of equipment can be developed at a low cost and still retain the precision needed for school Chemistry (3). It is however important to determine what precision range is actually needed for teaching Chemistry at each level. The development of low-cost educational materials should also take into account the psychological, instructional, and production aspects (1).

The psychological aspect refers to a consideration of i) the target group, ii) the types of experience that would best stimulate the group in terms of age, intellectual level, socio-cultural background and interests, and iii) a clear identification of the actual needs for low-cost materials.

The instructional aspect refers to a consideration of the educational objectives that the educational materials may help to achieve. The objectives may involve different types of knowledge, skills and attitudes.

The production aspect refers to the development of the actual materials, being guided by the psychological and instructional aspects. This aspect need to take into account the availability, cost and flexibility of use of the materials, the persons to be involved and types of skills expected of them in the production, and finally quality factors that play important role in the performance and durability of the product.

An example of the production of low-cost materials for Chemistry teaching the author of this paper had the chance to participate is the production of the **Ethiopian Chemistry Teacher's Sourcebook: Vol.1, Models and Materials** (2). This Sourcebook was developed through a hands-on workshop held in Addis Ababa from 22 January to 2 February 1990. The Sourcebook describes the procedures for developing low-cost Chemistry models and laboratory materials for use in the Ethiopian schools. The descriptions are presented into languages, namely Amharic (the official language in Ethiopia) and English. I therefore conclude this short essay by presenting a selected copy of the described materials in the Appendix and by citing the message in the Preface of the Sourcebook that states as follows (2):

> "Chemistry should be fun" is the theme of one of the pages of this sourcebook. Chemistry must not be taught only by lecturing or chalk and talk.
>
> This sourcebook is a book of ideas for better teaching, learning and assessment through practical doing. It offers suggestions on how to teach practical chemistry with locally available materials and resources. It will stimulate the creativity of teachers and learners, to use their practical skills for the improvement of

chemistry lessons. It will help students to be acquainted with subject-oriented language through activities which induce free speaking situations. It will help to train student in basic lab skills which will lead to later use of sophisticated equipment.

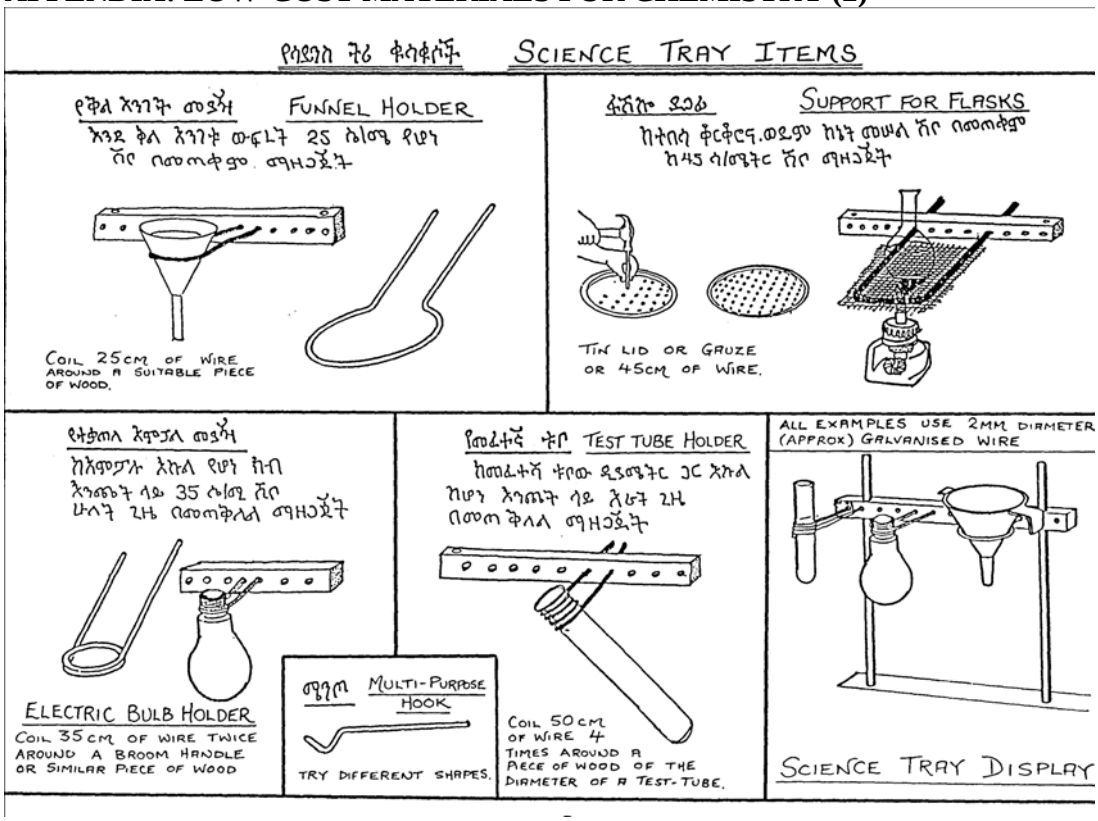
All the materials described have been devised, constructed and tested during the pilot workshop. Most of them can be constructed at low or even no cost with a few tools and materials by the technically untrained.

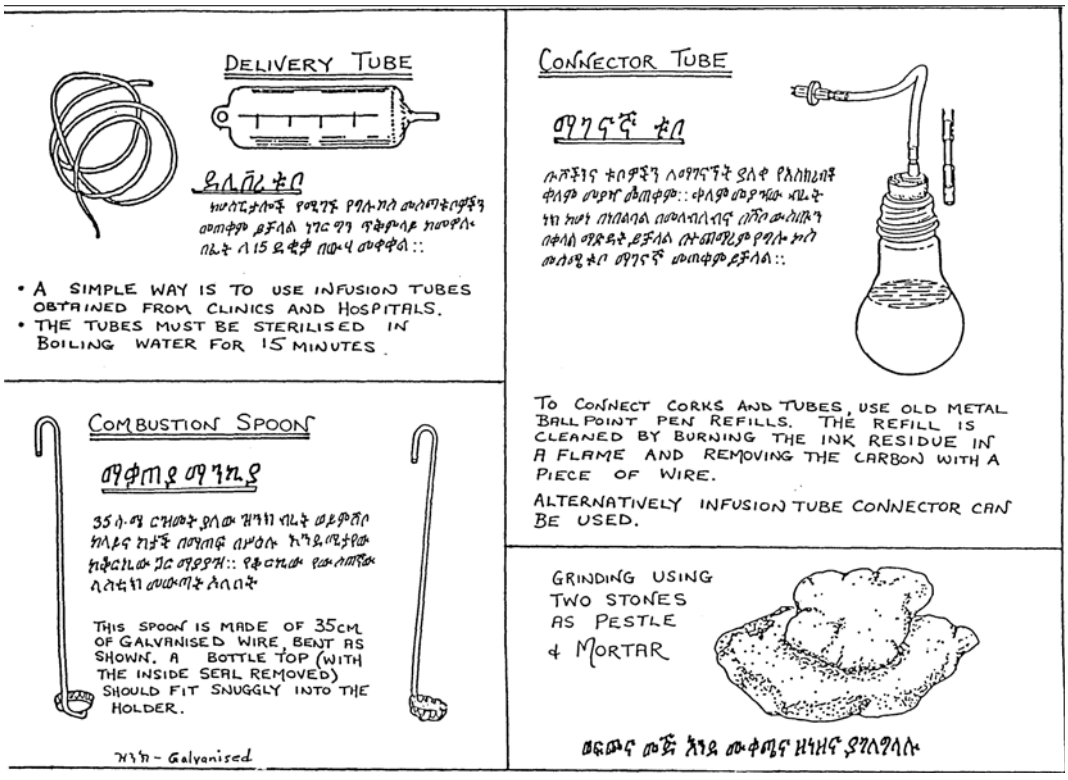
To emphasize the approach of "learning by doing" it is recommended that students construct as many items as possible.

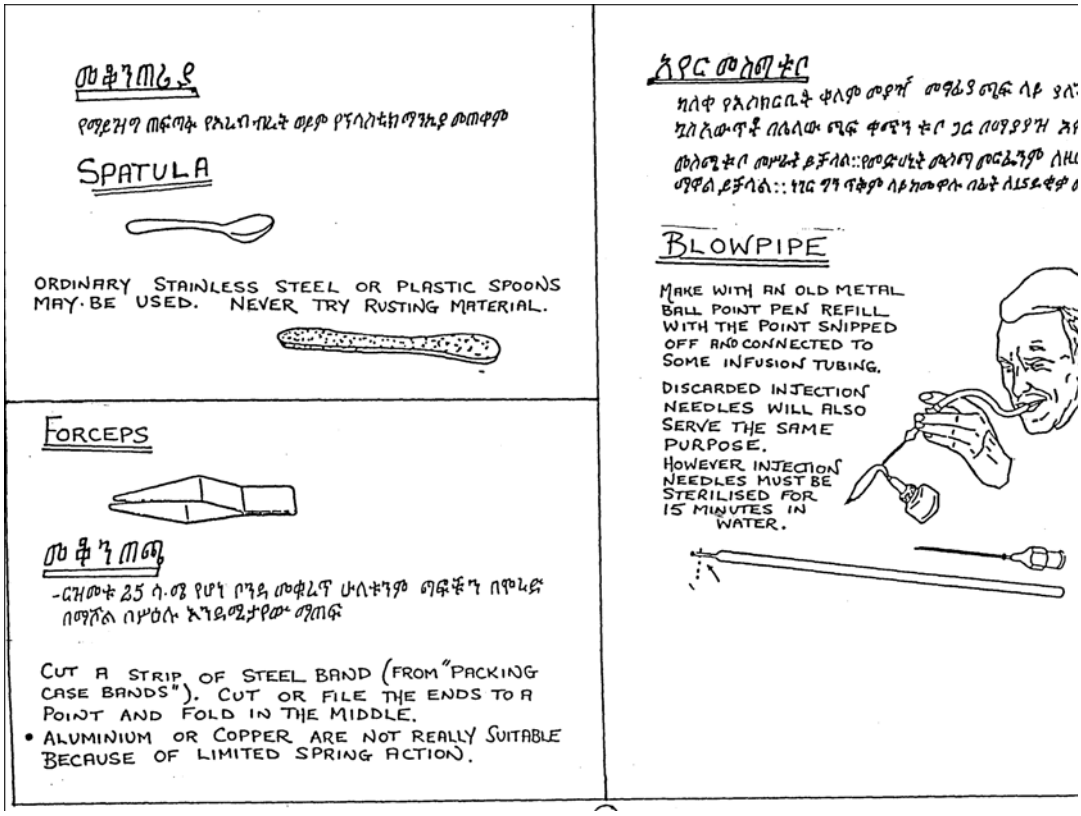
REFERENCES

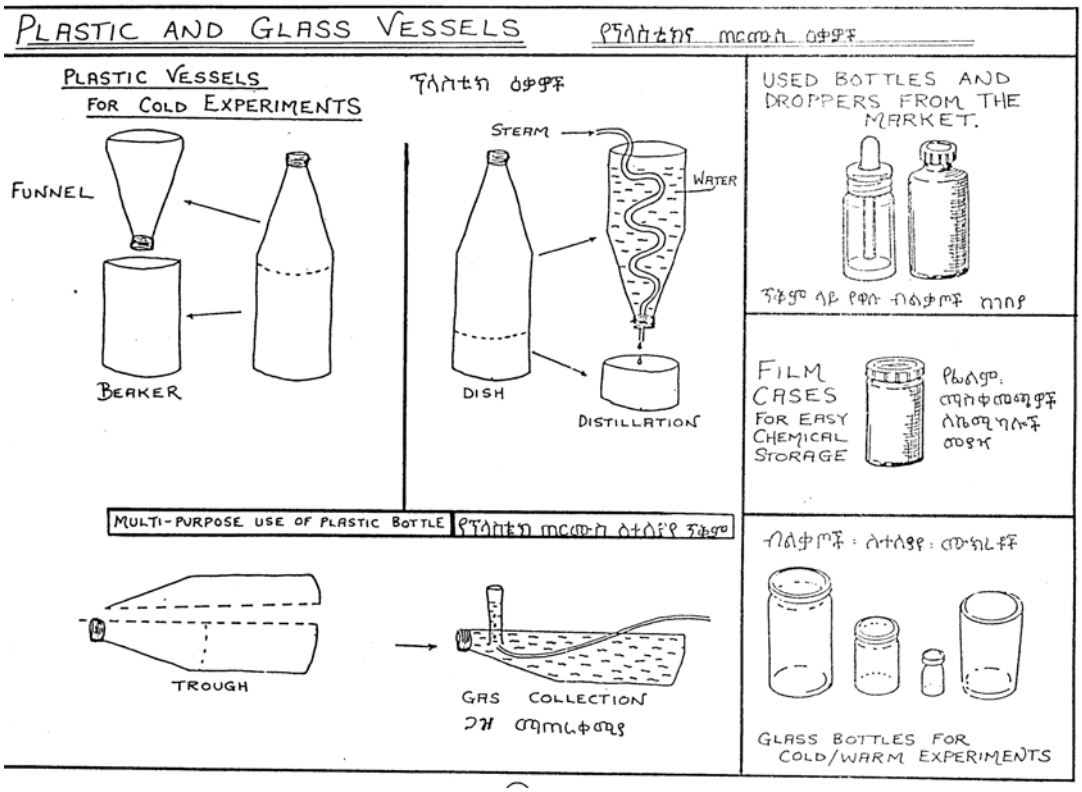
1. UNESCO (1978). Design, Development and Evaluation of Low-cost Educational Materials: Report of a Regional Workshop. UNESCO Regional Office for Education in Asia and Oceania: Bangkok.
2. MOE and CSE (1991). Ethiopian Chemistry Teacher's Sourcebook: Vol.1, Models and Materials. EMPDA: Addis Ababa.
3. Musar, A. (1993). Equipment for Science Education: Constraints and Opportunities. The World Bank.

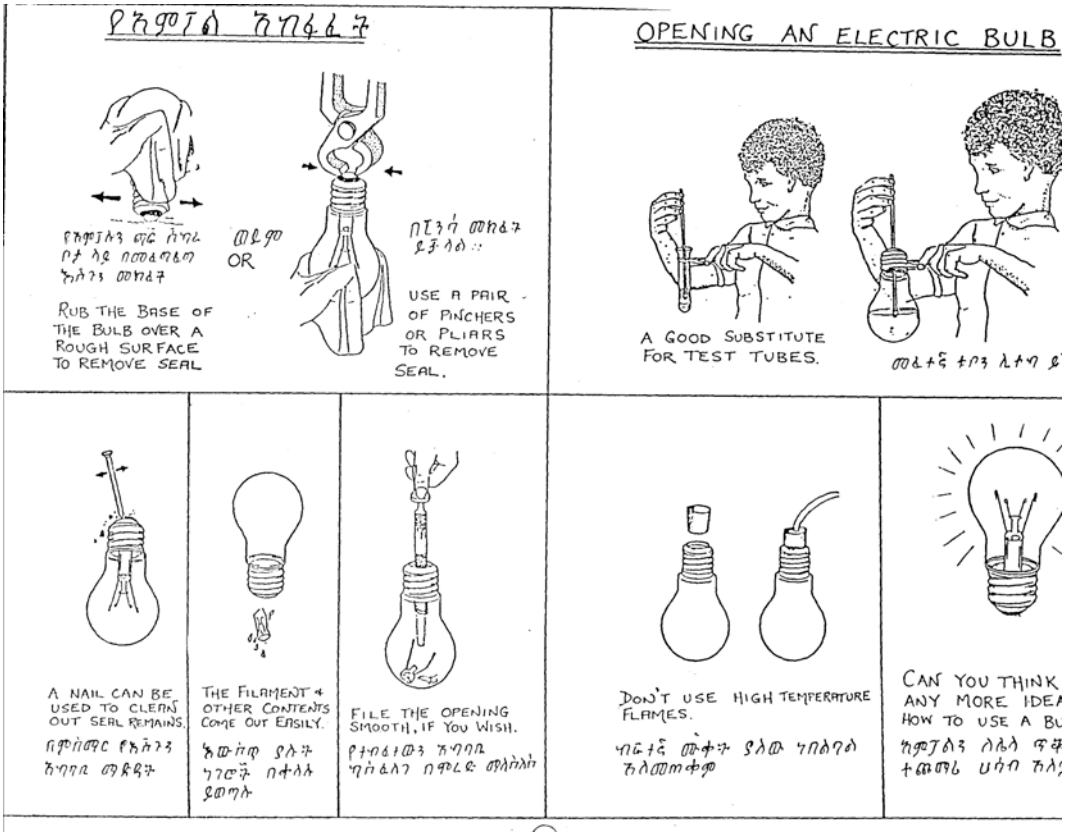
APPENDIX: LOW-COST MATERIALS FOR CHEMISTRY (2)

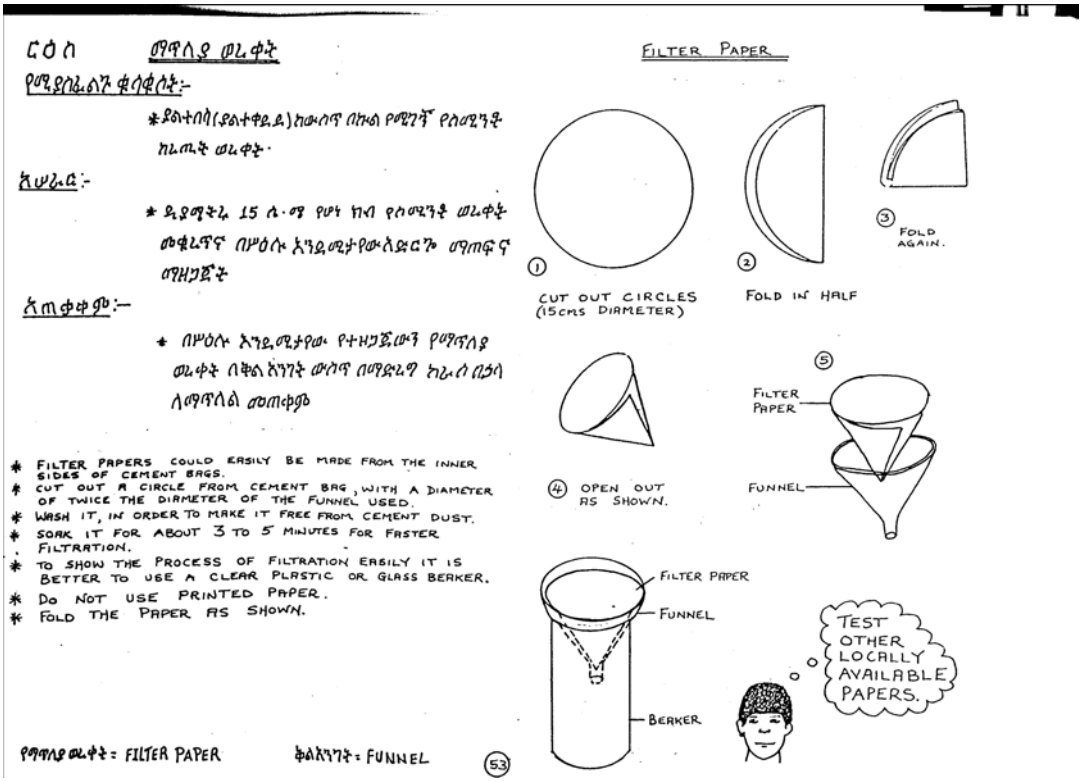





መቆንጠሪያ
የማይዝግ ጠፍጣፋ የአኒብብሊት ወይም የፕላስቲክ ማንኪያ መጠቀም
SPATULA
ORDINARY STAINLESS STEEL OR PLASTIC SPOONS MAY BE USED. NEVER TRY RUSTING MATERIAL.
FORCEPS
መቆንጠጫ
-ርዝመቱ 25 ሳ.ሜ የሆነ ቦንዳ መቁረጥ ሁለቱንም ጫፍቹን በሞሪድ በማሾል በሥዕሉ እንዲሚታየው ማጠፍ
CUT A STRIP OF STEEL BAND (FROM "PACKING CASE BANDS"). CUT OR FILE THE ENDS TO A POINT AND FOLD IN THE MIDDLE.
• ALUMINIUM OR COPPER ARE NOT REALLY SUITABLE BECAUSE OF LIMITED SPRING ACTION.
ልዩ መስጫ
BLOWPIPE
MAKE WITH AN OLD METAL BALL POINT PEN REFILL WITH THE POINT SNIPPED OFF AND CONNECTED TO SOME INFUSION TUBING.
DISCARDED INJECTION NEEDLES WILL ALSO SERVE THE SAME PURPOSE.
HOWEVER INJECTION NEEDLES MUST BE STERILISED FOR 15 MINUTES IN WATER.


PLASTIC AND GLASS VESSELS
የፕላስቲክና ጦርሙስ ዕቃዎች
PLASTIC VESSELS FOR COLD EXPERIMENTS
ፕላስቲክ ዕቃዎች
FUNNEL
BEAKER
STEAM
WATER
DISH
DISTILLATION
USED BOTTLES AND DROPPERS FROM THE MARKET.
ፕቅም ላይ የዋሉ ብልቃጦች ከገበያ
FILM CASES FOR EASY CHEMICAL STORAGE
የፌልም ማስቀመጫዎች ለኬሚካሎች መያዣ
MULTI-PURPOSE USE OF PLASTIC BOTTLE
የፕላስቲክ ጦርሙስ ስተለያየ ፕቅም
TROUGH
GAS COLLECTION
ጋዝ ማጠራቀሚያ
ብልቃጦች ፡ ለተለያዩ ፡ ሙክሪቶች
GLASS BOTTLES FOR COLD/WARM EXPERIMENTS


የአምፖል አከፋፈች
OPENING AN ELECTRIC BULB
የአምፖሉን ሥር ስጣሪ ቦታ ላይ በመፈጣጨጥ ኤሉንን መክፈት
RUB THE BASE OF THE BULB OVER A ROUGH SURFACE TO REMOVE SEAL
ወይም OR
በፒንሳ መክፈት ይቻላል ።
USE A PAIR OF PINCHERS OR PLIARS TO REMOVE SEAL.
A GOOD SUBSTITUTE FOR TEST TUBES.
መፈተኛ ቱቦን ሊተካ ይ
A NAIL CAN BE USED TO CLEAN OUT SEAL REMAINS.
ቀምስመር የኤሉንን ሽጣጣቢ መጽዳት
THE FILAMENT & OTHER CONTENTS COME OUT EASILY.
ኤውስጥ ያሉት ነገሮች በቀለሉ ይወጣሉ
FILE THE OPENING SMOOTH, IF YOU WISH.
የተጠፈጠውን ሽጣጣቢ ካስፈለገ በጭረዱ ማለስለስ
DON'T USE HIGH TEMPERATURE FLAMES.
ከብቴኛ ሙቀት ያለው ነገልግለ ሽለመጠቀም
CAN YOU THINK ANY MORE IDE HOW TO USE A BU
ኣምፖልን ለሌላ ጥቅ ተጨማሪ ሀሳብ ሽለ


ርዕስ ማጥለያ ወረቀት
የሚያስፈልጉ ቁሳቁሶች:-
*ያልተበሳ(ያልተቀደደ) ክውሰጥ በክፊል የሚገኝ የሲሚንቶ ከረጢት ወረቀት·
አሠራር:-
* ዲያሜትሩ 15 ሴ·ማ የሆነ ክብ የሲሚንቶ ወረቀት መቁረጥና በሥዕሉ እንደሚታየውለድርጉ ማጠፍና ማዘጋጀት
አጠቃቀም:-
* በሥዕሉ እንደሚታየው የተዘጋጀውን የማጥለያ ወረቀት ለቅል እነገት ውስጥ በማድረግ አጊራሰ ቢታለ ለማጥለል መጠቀም
* FILTER PAPERS COULD EASILY BE MADE FROM THE INNER SIDES OF CEMENT BAGS.
* CUT OUT A CIRCLE FROM CEMENT BAG, WITH A DIAMETER OF TWICE THE DIAMETER OF THE FUNNEL USED.
* WASH IT, IN ORDER TO MAKE IT FREE FROM CEMENT DUST.
* SOAK IT FOR ABOUT 3 TO 5 MINUTES FOR FASTER FILTRATION.
* TO SHOW THE PROCESS OF FILTRATION EASILY IT IS BETTER TO USE A CLEAR PLASTIC OR GLASS BEAKER.
* DO NOT USE PRINTED PAPER.
* FOLD THE PAPER AS SHOWN.
የማጥለያ ወረቀት = FILTER PAPER
ቀልእነገት = FUNNEL
53
FILTER PAPER
① CUT OUT CIRCLES (15CMS DIAMETER)
② FOLD IN HALF
③ FOLD AGAIN.
④ OPEN OUT AS SHOWN.
⑤
FILTER PAPER
FUNNEL
FILTER PAPER
FUNNEL
BEAKER
TEST OTHER LOCALLY AVAILABLE PAPERS.

EASILY AVAILABLE CHEMICALS

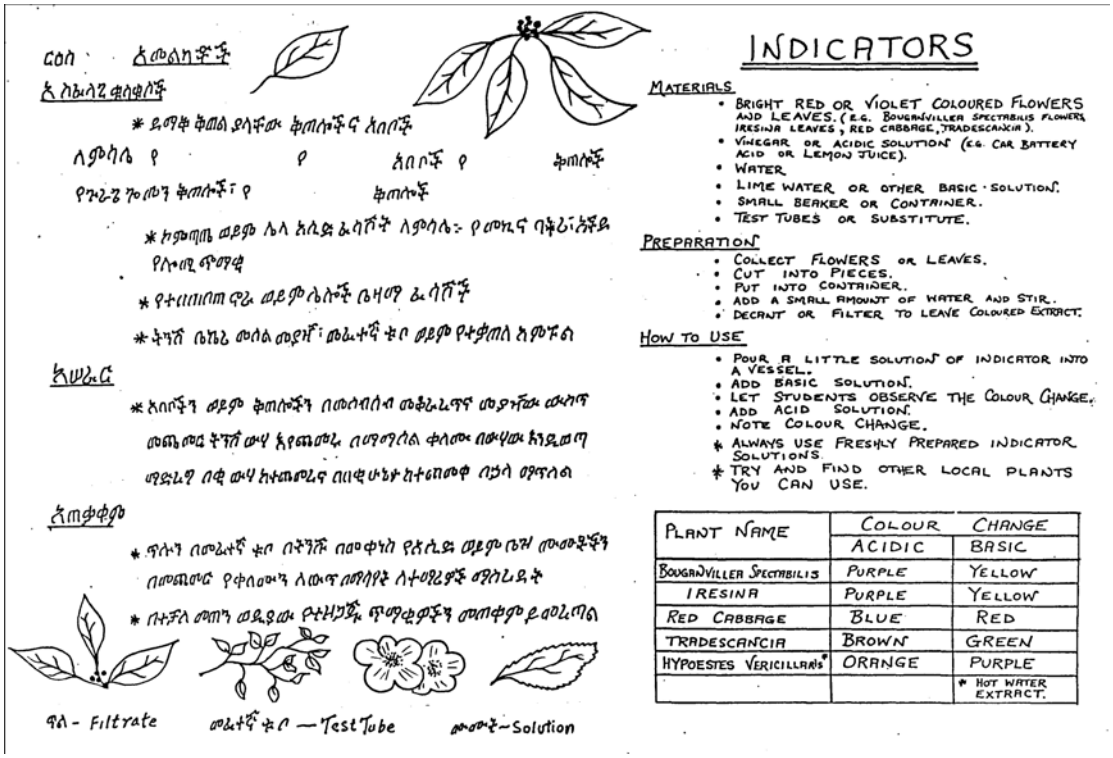
GROUP	FORMULA	SCIENTIFIC NAME	AMHARIC NAME (COMMON NAME)	SOURCE
ACIDS	H_2SO_4	SULPHURIC ACID	አሸዋ	CAR BATTERIES, BATTERIE FILLING STATIONS
	CH_3COOH	ACETIC ACID	ጎምጣጤ	MARKETS, GROCERIES
	H_2CO_3	CARBONIC ACID		MINERAL WATER
BASES	NaOH	SODIUM HYDROXIDE	ሶዳ	MARKET
	$Ca(OH)_2$	CALCIUM HYDROXIDE		BUILDING MATERIAL SHOPS
	$Mg(OH)_2$	MAGNESIUM HYDROXIDE		DRUG STORES
	$Al(OH)_3$	ALUMINIUM HYDROXIDE		DRUG STORES
SALTS	NaCl	SODIUM CHLORIDE	ጨው	MARKET
	Na_2CO_3	SODIUM CARBONATE		ORDINARY ASH
	$NaHCO_3$	SODIUM BI CARBONATE		MARKET
	$CaSO_4$	CALCIUM SULPHATE	ጂሶ	BUILDING MATERIAL SHOPS
	$MgSO_4$	MAGNESIUM SULPHATE	የእንግሊዝ ጨው	DRUG STORES
	$CuSO_4$	COPPER SULPHATE		MARKET
ORGANIC CHEMICALS		GLUCOSE, STARCH and other CARBOHYDRATES		MARKET, DRUG STORES
		FATS / OILS	ቅባትና ዘይት	SLAUGHTER HOUSES, PLANT OILS
		PROTEINS	ፕሮቲን	FOOD, FRUITS, EGGS etc.
		PETROLEUM DERIVATIVES	የነዳጅ ዘይት ውጤት	FROM FILLING STATIONS

(54)

METALS	Fe	IRON	ብረት	MARKET
	Zn	ZINC		DRY CELL BATTERIES
	Al	ALUMINIUM	አሉሚኒየም	MARKET
	Cu	COPPER	መዳብ	MARKET
	Ag	SILVER	ብር	OLD COINS
	Sn	TIN	ቆርቆሮ	USED TIN CANS
	Sb	ANTIMONY	ጉሉ	MARKET
NON-METALS	S	SULPHUR	ድኝ	MARKET
	C	CARBON		MARKET
	J	IODINE	ካቦዲን	DRY CELL, DRUG STORES
OXIDES	CaO	CALCIUM OXIDE	ኖራ	BUILDING MATERIAL SHOPS, MARKET, PHARMACY
	Fe_2O_3	IRON OXIDES		IRON RUST
	Fe_3O_4			BLACKSMITH
	Mn_2O_2	MANGANESE DIOXIDE		DRY CELL BATTERIES
	CO_2	CARBON DIOXIDE		PREPARED BY ADDING ACID TO SODIUMCARBONATE OR SODIUMBICARBONATE
	H_2O_2	HYDROGEN PEROXIDE	ሃይድሮጂን	MARKET, PHARMACY

CRYSTAL STRUCTURE OF SOME ETHIOPIAN MINERALS

STRUCTURE	MINERAL	OCCURENCE IN ETHIOPIA
MONOCLINIC	GYPSUM	ABAY GORGE
HEXAGONAL	QUARTZ	WOLLEGA, SIDAMO, HARRAR
TRICLINIC	FELDSPARS	HARRAR, SIDAMO
PYRAMIDS	CALCITE	HARRAR, TIGRAY, HUGHER, AKBO
CUBE	HALITE	HASSAWA, ASSAB, DALLOL



PLANT NAME	COLOUR CHANGE	
	ACIDIC	BASIC
BOUGAINVILLER SPECTABILIS	PURPLE	YELLOW
IRESINA	PURPLE	YELLOW
RED CABBAGE	BLUE	RED
TRADESCANCIA	BROWN	GREEN
HYPOESTES VERICILLARIS*	ORANGE	PURPLE
		* HOT WATER EXTRACT.