FR 968

FINAL REPORT

GRANT #RG95AST02

R 968

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(1) **(A) Contract Number :** RG/95/SE/02

(B) Title of project : Development of a teaching method on environmental pollution for tertiary level education.

(C) Institute where research was carried out : Department of Chemistry, University of Colombo.

(D) Chief Scientific Investigator and co-investigators : Dr. S. A. Fernando.

(E) Date of award : 1995 December.

(F) Date of completion : 1998 April.

(G) Total allocation : Rs. 220,000/-

(H) Total spent : Rs. 220,000/-

(I) No. Of Research Assistants/ Technical Assistants and period of service :
Three research assistants.

Research Assistant #1
(Mr. N. Talawatta) - 09 months(Jan 96' to Sep 96')
Resigned from the position due to personal reasons.

Research Assistant #2
(Miss. L. B. T. Shiromi) – 02 months(Feb. 97' to Mar.97')

Research Assistant #3
(Miss. A. S. D. Jayawardena) – From Jan. 97' to date.

(J) Whether RA has registered for, or obtained, postgraduate degree :

The Research Assistant registered for the M.Phil degree 01/01/1997.

(2) Description of research carried out :

The industrial revolution, urban and economic development of the country have been created an era of tremendous prosperity in a part of the country's whole economy. On the other hand, it also brought with it a serious threat to the environment. Since then, rain forests have been decimated, harmful gases spewed into the atmosphere, poisonous fluids poured into the rivers, lakes and the sea etc., and almost every abuse possible , has been heaped upon our planet earth. These problems have arisen due to the ill-planned activities of some "educated" citizens of the country. As we know most of the politicians with the help of the administrative people are handling the development projects of the country and most of them at the administrative sections in the government are with the background of tertiary education. Therefore university system function in the country plays a vital role in producing decision-makers and expertise in industrial, economic, agricultural, engineering, medical and several other areas. It is the responsibility of the educators who design tertiary level curriculum in various subjects, to create a product having an environment conscious mind. This is an essential task because result of any human activity ultimately end up with causing some sort of environment impact directly or indirectly. In order to have eco-friendly activities people should be ecologically literate well.
Also with the rapid development of various types of technological activities in the industrial sector of the country educational institutions have a responsibility to train people who can be fitted in to the modern technology. Among the primary, secondary and tertiary levels of education future professionals are being trained via the tertiary level education. Analytical chemistry, industrial chemistry and environmental chemistry are the major areas which have to be integrated in this regard. By having such an integrated system undergraduates can be trained on industrial aspects as well as environmental problems associated with raw materials and by products. The above project – *"Development of teaching method on environmental pollution for tertiary level education"* have been focussed on multidisciplinary methods of achieving a integrated system of analytical, industrial and environmental sciences.

To meet these demands, it is essential that the tertiary level chemistry students acquire a basic understanding of the sources, reactions, industrial applications, effects and fates of chemical species in water, soil and air environment. The study of environment related aspects and its applications integrated with general chemistry is the arena in which these goals are addressed.

Every citizen as a professional and a non-professional is involved in making decisions that affect our environment. In order to make decisions that contribute to environmental improvement, non-chemists also need a basic background in environmental aspects. The dual goals of preparing both future environmental chemists and environmentally literate citizens, is the main responsibility of the entire university system of the country.

2.1 RESEARCH DESIGN

An interdisciplinary project was proposed in the year of 1995. As a part of this project, a survey was conducted initially to get an idea about the available methods and courses related to environmental education for tertiary level. This survey was conducted during the 1996 &1997 calendar years. In order to have an idea on overall system ten national level Universities and affiliated university collages were selected and sent letters to all departments in those universities, which have a faculties of four or more. In some instances information gathered through an interviews held with the Heads of the departments and lecturers responsible for the relevant subject. Information were collected under following categories ;

- Nature of environment related courses (undergraduate and postgraduate courses) available in particular field of study.
- Identification of various areas related to environment education (content of the syllabus).
- Identifying the practical components carried out, related to present environment problems.
- Number of students trained in these areas.
- Merits, Demerits and effectiveness of present environmental education programs.

Table I represent the selected universities for this survey;

Table I - Institutions selected

- University of Peradeniya
- „ „ Colombo
- „ „ Jaffna
- „ „ Kelaniya
- „ „ Sri Jayawardenapura
- „ „ Moratuwa
- „ „ Ruhuna
- Sabaragamuwa University of Sri Lanka
- Open University of Sri Lanka
- Nothern Province Affliated University College

When comparing the available system of environmental science education between 1996 and 1997 we were unable to see a much difference and the results obtained by this survey will be discussed at the later part of this report.

According to our conclusions we developed a new strategy and it is essential to mentioned that all the activities stated in the research plan have been carried out according to the concept of 3A's and 3R's. Figure I represent the major areas of this concept.

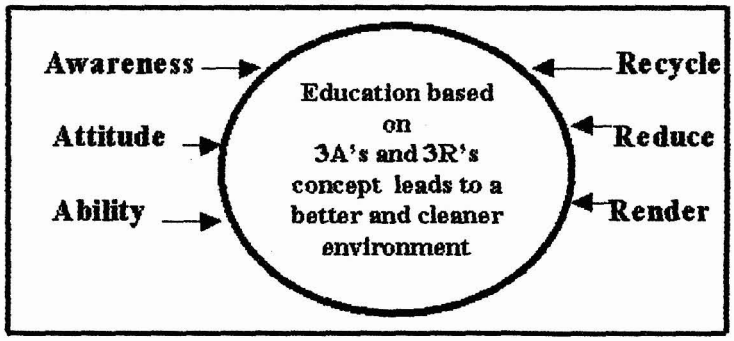

Figure I - 3A's and 3R's concept.

All the six aspects have a good relationship with each other and we think it is a successful teaching method which can integrate advance theories with the surroundings. Also this creates an integrated program of analytical, industrial and environmental sciences.

(3) Results obtained and discussions :

3.1 DATA & DATA ANALYSIS

According to the responses received from the various faculties departments number of environmental related courses offered by each department / faculty are depicted in Table II.

Table II – Departments / Faculties offering Environment related courses

University	Faculty	# of Departments	Out of all the departments # of Depts. offering Envi. related courses
Colombo	Arts	6	2
	Education	No departments	offer one course related to environment related areas.
	Law	,,	,,
	Finance & Management	2	not a single course is available
	Science	7	5
	Medicine	14	1
Peradeniya	Agriculture	6	6
	Arts	14	2
	Engineering	2	2
	Science	5	3
	Veterinary	6	no courses available to teach environmental education.
	Medicine	14	1
	Dental	-	-
Ruhuna	Science	7	2
	Humanities & Social Sciences	-	-
	Medicine	-	-
	Agriculture	-	-

(Table II contnd....)

University	Faculty	No. of Departments	Out of all the departments # of Departments offering Environment related courses
Sri Jayaward--ena Pura	Applied Science	6	3
	Medicine	13	1
	Arts	9	1
	Management Studies & Commerce	7	not a single course is available
Kelaniya	Science	10	3
	Humanities & Social Sciences	12	1
	Medicine		
Moratuwa	Engineering	10	2
	Architecture & Quantity surveying	2	no courses related to environment education
Sabaragamuwa	Applied Science	2	2
	Social Sciences & Languages	2	1
	Business studies	2	not a single course is available
	Agricultural Sciences	3	3
Jaffna	Science Arts Commerce Management Studies Medicine Agriculture	Out of six faculties only the Dept. of Botany sent us a reply confirming that they offer one course related to Environment education	
Nothern Province Affiliated University College	There are no separate departments. Three Diploma Courses available and one core course is available on Environmental studies for students who follow English and Mathematics		

(Table II contnd....)

University	Faculty	No. of Departments	Out of all the departments # of Departments offering Environment related courses
Open University of Sri Lanka	Engineering & Technology	5	2
	Humanities & Social Sciences	5	2
	Natural Science	6	2

Other than the faculties there are few other institutions attached to some universities and they also contribute to spread environment related programs among students as well as public. Among them Center for Environment Studies (CES), Post Graduate Institute of Agriculture (PGIA) , Post Graduate Institute of Science (PGIS) at the University of Peradeniya is involved in designing and teaching fairly high number of environment related programs such as diplomas, M.Sc s , M.Phill s and Ph.D. s. Table III shows the available programs in those institutions.

Table III – Various Institutions and Centers attached to University of Peradeniya

Name of the Institute / Center	Nature of the program
PGIS (Post Graduate Institute of Science)	M.Sc – Environmental Science - Industrial chemistry
PGIA (Post Graduate Institute of Agriculture)	M.Sc – Environmental Economics - Natural Resource Management
CES (Center for Environmental Studies)	Workshops on EIA for the post-graduate students & Public and private sector people. Certificate course in environmental awareness. Post-Graduate Diploma in Environmental Assesment

According to the above data (Table II & III) we can clearly see that majority of environment related courses offered by the faculty of science in each university. The departments most often mentioned were Botany, Zoology and Chemistry. Apart from the faculty of science, faculty of agriculture deals mostly with the environment related areas in their curriculum. But there are only three agricultural faculties among the ten universities which have about 1400 students enrolled to study these courses each year. It is fairly a low number when comparing the total student population selected for tertiary education and it is

number when comparing the total student population selected for tertiary education and it is about 30 000 per year. When considering the merits and demerits of the present system of particularly the environment-related education following facts can be given; (in Table IV).

Table IV – Merits and Demerits of the present situation

Merits	Demerits
Students studying in the science faculty have wide exposure to this area.	Most of the courses at science faculties lack practical programs to practice students to solve current environmental problems.
Among the large number of departments at Art faculties only Geography and Geology departments offer few courses related to environment education.	Apart from the students who are following Geography and Geology in faculty of Arts do not exposed to any of the courses related to this area during their stay at the university.
Students at faculty of law have a compulsory theory course in their final year.	This course does not have any practical program.
	None of the students studying at Commerce, Computer and Management academic streams never get an opportunity to study on environ ental aspects and it's pollution.
	Medical faculty has about fifteen departments only one department offer a course related to environment related areas.
	Dental science & Veterinary science students (about 700 / year) do not study a single course related to environment problems and related areas.
Civil and Chemical Engineering departm- -ents cover considerable amount of theory & practical programs.	Other departments at the Engineering Faculty have not involved in teaching environment related areas.

(Table IV contnd...)

Merits	Demerits
CES at University of Peradeniya have started a new Diploma course to educate students in all the faculties and it is important to note that it is open to general public who are interested.	Although such a diploma course is available it is not a compulsory course for students. Majority do not follow this as it is optional. When comparing the number of students enrolled in various academic streams in each year for tertiary education , very few number of students (10%) get exposed to the environment related subjects Practical involvement in solving real world environmental problems is very low at the undergraduate level. Most of the available courses such as Environment chemistry /science have designed without any practical course. Majority of undergraduates do not follow these courses as they are optional.

According to the survey, distribution of undergraduate programs in Environmental education and related fields among various academic streams is limited and inadequate as sixty percent of the environmental courses are designed without practical components. Hence, all the university authorities should recognise the importance of teaching and learning environmental aspects for the science and non-science students at tertiary level.

Integrated system of teaching environmental aspects with the subject matter will be the most appropriate way to approach at this stage. It will be beneficial to both students as well as the country.

3.2 PROPOSED STRATEGY

Developing and restructuring of integrated teaching method to teach environmental aspects and related fields for tertiary level was undertaken with six principle objectives. It is based on 3A's and 3R's concept and shown in the Figure II.

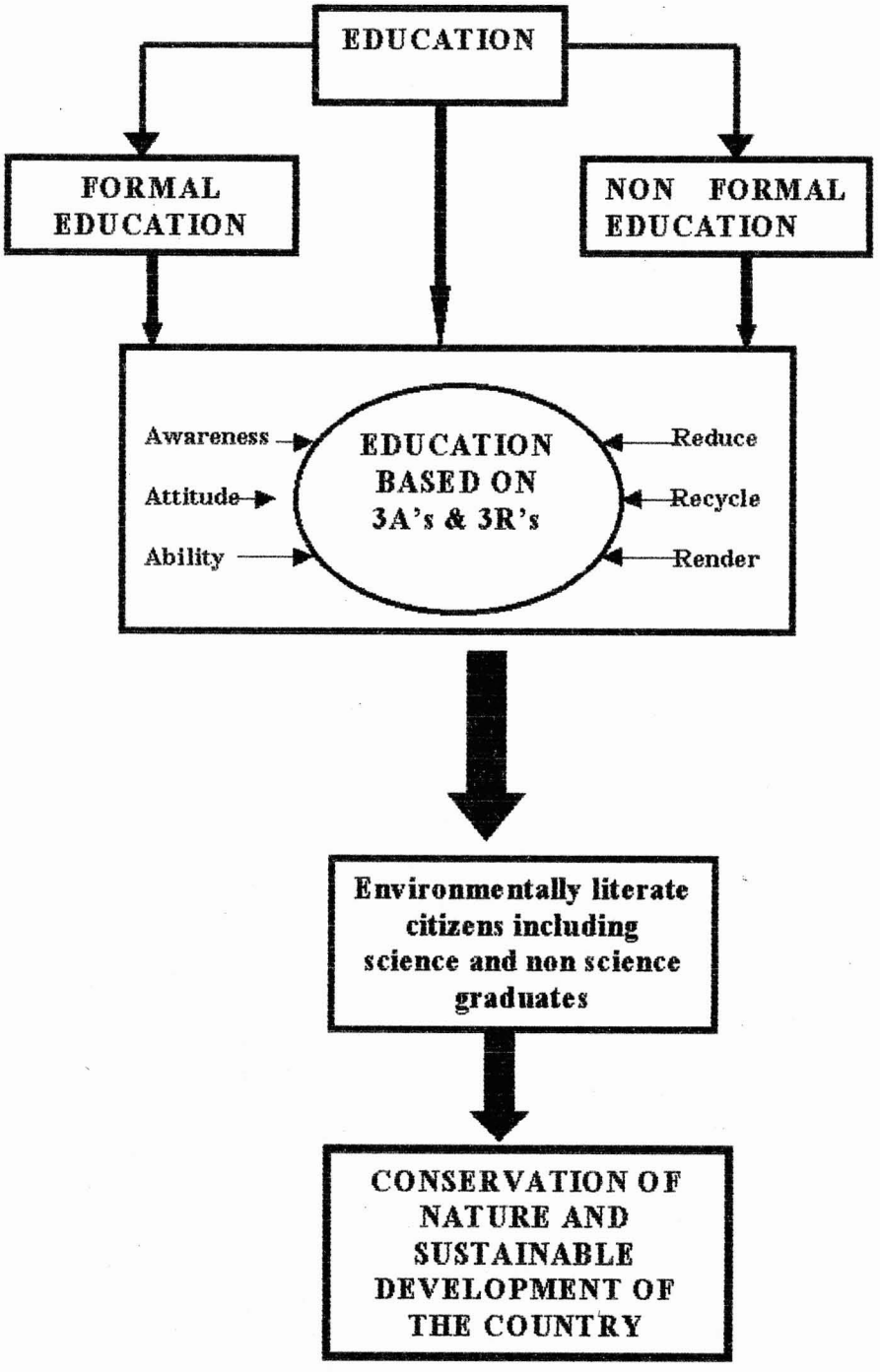

Figure II – Concept of six objectives.

As an initiative step, revision of the Quantitative Analysis course was undertaken with the above mentioned concept associated with six major principles. The first is to make aware of students on environmental and industrial aspects within the laboratory and out side the laboratory. The second objective was to change the attitude of the students via proper awareness and increase their creative thinking. Development of ability is the third objective and this can be achieved by careful planning of the new method. The fourth , fifth and sixth objectives are well interrelated and can be introduced to students as the method of " Resource Management".

3.3 INTEGRATED PROGRAM

This can be explained in a stepwise process and each step is interrelated.

- Change of laboratory arrangement from traditional arrangement to more safer and cleaner arrangement.
- Introducing environmental , industrial and safety aspects thorough awareness programs.
- Redesigning of laboratory experiments and introducing resource management.
- Designing a small wastewater treatment plant and wastewater treatment method to treat laboratory wastewater.

3.3.1 Change of laboratory arrangement

Since 1950 , there is a unique pattern of arranging chemicals and glassware in all teaching laboratories at the Department of Chemistry , University of Colombo. It should be noted that there is a greater probability of having a similar arrangement in laboratories at the other universities as well. Figure III shows the traditional arrangement of the acids , bases and other chemicals in the student's working station.

Figure III - Traditional way of arranging Laboratory

Under this arrangement one cupboard was given to each student and only he/she can use the tools in it. Also a set of fourteen reagent bottles have been provided to each student in a shelf at each working station. Table V shows the comparative description on availability of reagents;

Table V – Reagent bottles available at each shelf

Inorganic lab (2^{nd} & 3^{rd} years)		Organic lab (2^{nd} & 3^{rd} years)	Elementary lab (1^{st} year)
conc. Hydrochloric conc. Nitric conc. Sulphuric dil. Hydrochloric dil. Nitric conc. Ammonia dil. Ammonia Sodium hydroxide		conc. Hydrochloric conc. Nitric conc. Sulphuric dil. Hydrochloric dil. Sulphuric dil. Nitric	conc. Hydrochloric conc. Nitric conc. Sulphuric dil. Hydrochloric dil. Sulphuric dil. Nitric conc. Ammonia Ammonium chloride Ammonium carbonate Ammonium hydroxide Barium chloride Calcium chloride Sodium phosphate Ferric chloride
# of reagent bottles ($250\ cm^3$)	9	6	14

Table VI indicates the total volumes of reagents required to fill about forty shelves.

Table VI – Total volume required to fill $250\ cm^3$ bottles

Laboratory	# of reagent bottles ($250\ cm^3$)	# of students per session	Total volume of reagents (L)
Inorganic	9	40	$90\ \frac{(9\times40\times250)}{1000}$
Organic	6	40	60
Elementary	14	40	140

As shown in Table VI there are several disadvantages of having such an operation;

- The initial cost and refilling cost is very high.
- Unsafe and waste generation can not be minimised.

  Out of these safety of the students is more questionable because under the bench (working area) there are fixed lines of gas / electricity supplies and in case of an acid or base spill , there is a possibility of forming a fire.

- All the above mentioned reagents are on the bench throughout the year.

  Some of the reagents have never been used or used once or twice for the applicable experiments.

- As all the chemicals are freely available there is a greater probability of irresponsible handling.
- This arrangement will enhance the unnecessary exposure of students to chemicals and their vapours.
- Hazardous waste generation can not be minimised because of this arrangement.
- Benches, equipment and other items in the laboratory get damaged rapidly and surfaces of the benches become discoloured fastely due to acid/ base spills.
- Significant foreign exchange has to be paid on these chemicals, and the cost that has to be paid rapidly increasing year by year.

By considering all the above disadvantages of the traditional arrangement, development of Analytical / Inorganic Chemistry laboratory with a new set up, considering the 3A's & 3R's concept was started in 1996.

Major steps of modified arrangement

Step 1

All the chemicals stored at the student working areas were removed. Each working station was indexed by pasting the numberplates. A set of glassware and other necessary tools were allocated for each working station. Table VII lists the items supplied at each working station;

Table VII – Set of glassware and other tools /student

Bench	Rack	Beside the rack
2 – 500 ml Beakers 2 – 250 ml Conical flasks 1 – 50 ml Burette holder 1 – Metal stand 2 – Funnels 1 – Watch glass 4 – Pipettes 1 – Glass rod 1 – Wood stand 1 – Wash bottle 1 – Bunsen burner	1-250 ml Volumetric flask 1- 50 ml Measuring cylinder 1- 10 ml „ „ 1- Test tube rack 2- Boiling tubes 10- Test tubes	1 - Cleaning brush 1 - Pair of tongs 1 - Test tube

It should be noted that there are no any reagent bottles supplied to each student in any experiment. Required chemicals for experiments were provided on the relevant practical day. Three sets of conc. and dilute acids and bases required were placed inside the fume hood and students were not allowed to bring those bottles to their working station. Also the reagents that are required for experiments were never prepared excessively. Students are permitted to use only the specified amount (volumes etc.) of reagents and they are provided in containers.

Step 2

The next step was to provide safe storage conditions for all the chemicals available within the laboratory, because the good and safe storage conditions play a vital role among the good laboratory practices. Moreover, the improper storage practices obviously results fires, explosions and accidental spillage. In order to establish a proper storage facilities, well planned procedure was designed and it can be explained briefly as follows;

- Preparing a list of all the chemicals available in the laboratory
- From the list , prepare a reactivity class compatibility chart. In this chart chemicals can be classified as acids, flammables, reactives, water sensitive chemicals, etc.).
- Also develop a physical separation based upon chemical compatibility.
- After completing all the above work, arrange each class in an alphabetical order.

- Store them in separate cupboards away from the working area. Label each cupboard with the relevant letter.

- Keep a dated inventory in order to know what is available in the laboratory.

- Store only the smallest volume necessary.

Figure IV – Safe storage method of chemicals

Step 3

Storage of all the glassware safely and cleanly was another area that was considered. As the individual cupboards given to students were vacant we stored all the excess glassware in those cupboards, separating one type of glassware for each cupboard.
This method has greatly reduced the unnecessary breakage of glassware in the laboratory.

Step 4

In order to provide green environment within the laboratory we placed flowerpots at vacant areas. The lab attendant and the students properly maintained these plants. Although these are additional work it provided fresh, green environment to the laboratory and made the environment cool and pleasant for working.

Figure V – Modified arrangement of the laboratory

When comparing the earlier arrangement and the modified arrangement of the laboratory (Figures II & V) new arrangement provides cleaner and safer environment. Maintaining the laboratory with the new arrangement is a continuos process and it can be a good lesson for students to have an idea about laboratory management.

3.3.2 Awareness program

We thought of having a proper awareness program on safety aspects, Good Laboratory Practices and environmental impact due to local chemical industries, after obtaining the results of the questioner given to second year students at their first day at the Analytical chemistry laboratory. This questioner was designed sixteen simple questions and fifteen minutes was allocated to answer the questioner. According to the student's opinion they were willing to know more information on above aspects.

A scheme was developed to educate students on the areas of;

- Safe handling of chemicals
- Good Laboratory Practices (GLP)
- Safe disposal methods of chemicals, glass trash and other wastes
- Safe storage of chemicals
- Handling of accidental spillage, fires and explosions.

Some information was included in the leaflets designed by us. These leaflets include GLP, general safety symbols and hazardous chemical symbols. Furthermore, a set of cards was prepared including all the standard symbols available in the world. These cards were attractive because symbols were displayed with their standard colours and meaning of the symbol was also included. These cards were used to teach how to identify safety signs indicated in particular area, bottles, chemical storage cupboards, etc. The lessons were given during the laboratory hours and students were eager to know the information.

A set of GLP was prepared including the behaviour within the laboratory. This document was titled as " General Laboratory Guidelines". Each set was given to students prior to the first laboratory exercise. Students were asked to follow the mentioned rules and they were inspected throughout the laboratory period by the instructors in charge of that laboratory period. [Attached to Appendix I]

Another teaching aid prepared was the " Safety Manual". This was specially designed for the chemical laboratories and it can be used as a good information source of following areas;

- Safety signs , hazards involved in chemicals and prevention methods

- Standard safety signs available (prohibitive , warning , safe condition , mandatory , chemical hazard symbols with lettering , standard colour codes for fire extinguishers , etc.)

- Importance of wearing personal protective equipment during work
- Nature of pollutants and routes of exposure
- Types of hazards involved in the laboratory
- Various fire extinguishers and fire prevention
- Hazardous chemical labeling and maintaining MSDS
- Safe storage of hazardous chemicals and handling of accidental spillage
- Safe arrangement of chemicals and glassware
- Safety training for students and staff
- Safe methods of laboratory waste disposal
- First aid in a laboratory in case of an emergency.

This manual will be a great help to students as well as workers prior to start working in any kind of laboratory. Further information are given in Appendix II.

Further more, we can no longer afford to put students in the laboratory without some training in laboratory safety. In order to give a proper training they should be aware of the importance of laboratory safety and how it link with outside environment. However, the need for undergraduate safety training is important to function the laboratory safely. Also it would be less expensive for country to hire chemists and non-chemists who already have training in laboratory safety and could move quickly into the specific training required for their job. Therefore it is essential that students acquire an understanding of the above aspects.
The awareness program covers not only the safe laboratory practices but also the industrial pollution related to local industries. To achieve a complete descriptive report a computer software program was developed considering ten local industries. The detailed information on processing steps were included in this program. All the selected industries are tabulated in the table VIII.

Table VIII – Names of the selected industries in Sri Lanka

- Rubber Industry
- Leather Industry
- Cement Industry
- Glass „
- Ceramic „
- Textile „
- Sugar cane „
- Tea processing „
- Iron and Steel „
- Water purification

These industries have been selected randomly and contribute a wide range of products and unwanted and recyclable materials to the environment. In order to have a descriptive account of each industry, information was collected under the following topics;

- History of the industry
- Development of the industry
- Importance of the industry
- Institutions and organisations related to particular industry in Sri Lanka.
- Geographical distribution of the industry
- Raw materials used for the industry
- Chemical process and processing steps
- Various types of products manufactured
- Environmental pollution by the industry
- Necessary steps carried out to control or minimise the environmental impact due to industries

The information gathered related to above topics were useful to demonstrate the information of industries in a systematic manner. After a careful study, necessary details were included in the software program. To fulfil the above stated requirements and to present them in an attractive format, the well-known Netscape Navigator (Generally called Netscape) has been used. This provides facilities to create web pages complete with graphics, text and links. Furthermore, this program was mainly developed to browse the information related to

industries. The students enable to go through this package and randomly select necessary data on any of the industry. (a complete printout of this program is attached to Appendix III). Presenting information using a variety of styles, including maps, diagrams, tables and flow charts we think that this package will become a major reference source which students would be motivated to turn to whenever they have a question or needed specific information about industrial pollution and cleaner technology.

Another reading material developed under this program is the directory of polymers (attached to Appendix IV). This is a reference source that has been designed for the students interested in polymer industry, it's pollution, recycling and reusing methods. This directory includes information under following categories;

- Definition and the classification of polymers
- Development of some commercial polymers
- Commonly used polymeric materials and their products
- Product information provided by LANKEM Agrochemical division
- Commonly used polymeric materials and their recyclable – reusable properties
- Pollution caused by polymeric materials and Health hazards involved in some polymers
- Methods to prevent pollution due to polymeric materials

3.3.3 Introducing methods of Resource Management

Resource Management based on three R's already been initiated and their objectives are shown as follows ;

- **Reduce** the scale of the chemical reactions
- **Recycle** products and reagents
- **Render** (minimise) waste environmentally acceptable for disposal (safe handling).

There are many reasons to be concerned about resource management and the two major reasons are ;

- a desire to minimize unnecessary exposure of students to hazardous chemicals
- a desire to protect environment.

Apart from those , teaching resource management gives students a sense of responsibility for keeping a cleaner environment. Moreover , chemical resource management provides an excellent way to teach descriptive chemistry , chemical reactions , fundamental chemical principles and practical applications of chemistry to students. We would like to describe our efforts to introduce 3R 's (Resource Management) as a part of the laboratory practical program.

As this laboratory is used to teach Analytical Chemistry for the second and third year (general degree) students , about 250 are get enrolled to follow the practical programs in each year. Introducing 3R's into the laboratory experiments is the main goal. All the experiments were restructured with following aspects;

Reduction of the experimental scale

This is mainly the reduction of the volumes of reagents required for the experiments. In order to achieve better results it was required to reorganize the whole experimental procedure of each experiment. Introducing micro scale apparatus instead of macro scale apparatus was also done to enhance the reduction of experimental scale. There are many advantages of establishing this method and this will reduce the cost of chemicals , minimize the waste generation and minimize the exposure of students to chemicals.

Recycling techniques

Recycling techniques can be introduced to students via the laboratory experiments. There are several techniques that we can practice within the laboratory. It should be noted that some of the techniques have already been implemented and some are still in the development stage. The recycling technique we can practice in the laboratory is that , using the product of one experiment as the reactant of the next experiment.

Eg : In the experiment # 201 students were supposed to prepare primary and secondary standards as the first laboratory exercise and store in the labeled bottles. The part of the experiment # 202 was designed in such a way to use the product of previous experiment (# 201) as the reactants of the second experiment (# 201).

Another way of practicing recycling technique is that , using the product of one experiment in an unrelated subsequent experiment.

Eg : Solvents used for the solvent extraction by one experiment by one group is recovered and used again for the same experiment that has to be done by the second group(Experiment # 302 – Solvent extraction , 3rd Year practical).

Recovering reactants or additional product by pooling all the samples of students and evaporating the solvent or allowing to product to crystallise slowly is another recycling technique that was introduced in the experiment # 204. The title of the experiment # 204 is , Introduction to Homogeneous Precipitation and it's application in chemical analysis. In this experiment the ultimate product of Ni^{2+} precipitation is dissolved in conc.HNO_3 and collected into a beaker. Although the product is impure it can be used again for teaching purposes.

Rendering (minimization) methods

The techniques under this category are mainly focused on generating waste environmentally acceptable for disposal. In order to achieve this we were taken steps to introduce waste disposal methods to some experiments. A simple schemes were designed and attached them at the end of the procedure.

E.g. : Neutralising of acidic or basic solutions prior to discard. By careful planning acidic by product of one experiment can serve to neutralise the basic by product of another.

When considering the waste minimisation techniques within the laboratory, proper labelling and storage of all the chemical containers is very essential because it will directly help to minimise the cost as well as the waste generation.

It should be noted that this system is not simply add-on to the traditional set of laboratory experiments. It is an integral part of each experiment and our approach requires that experiment to be planned in sequence and in combination for the greatest benefit.

3.3.4 Designing a small wastewater treatment plant

Rising population, rapid urbanization and increasing industrialization all threaten to make good quality water a scarce source. With the chemical industry making complex chemicals, the wastewater has become more complex. Excessive use of these chemicals causes heavy metal contamination of underground and surface water. Although teaching laboratories and research and development laboratories use chemicals excessively there is no pretreatment methods for the wastewater coming out from these laboratories. It is essential to remove the pollutants emitted in order to lessen their detrimental effects on the environment.

Different strategies of waste control, conservation and cost effective waste treatment technologies such as reusing and recycling methods helps to reduce the volume of waste. Practicing these strategies should be started from the classroom. Especially the chemistry students must have an interest on waste treatment methods. The awareness of the students regarding above objectives can be improved within the classroom or laboratory. This method will help students to think about pollutants and waste products generated due to the activities they have been undertaken in a laboratory or any other place they work. Also students should be aware of chemical principles involved in industrial processes, as well as in which pollutants and waste products are generated and how they can be removed for disposal or reuse. Having an in-house water treatment unit operated by students, give the responsibility of treating waste generated by themselves before releasing to the environment. Apart from that having a small scale waste water treatment plant within the laboratory will enhance awareness of students.

Principles of plant design

Students were asked to collect all the solutions to the glass bottle (20 L) provided, at the end of their practical sessions. This is a part of the experiment and students learn not to discard chemical solutions straight away to the sink without a proper treatment. This small plant was designed to introduce following theoretical principles to the students as they apply to a real physical and chemical waste treatment process;

- colloidal solutions
- coagulation
- flocculation
- precipitation / sedimentation
- adsorption mechanism by natural adsorbents
- filtration
- reduction of BOD and COD by aeration process
- neutralization

Normally wastewater treatment process seek to remove suspended solids, colloids, and soluble matter (organic / inorganic) using several methods involving physical, chemical or biological principles. The wastewater treatment plant in this laboratory is designed to treat wastewater mostly with inorganic materials and lesser amount of organic materials. Physical and chemical processes play a vital role in the treatment method designed in the laboratory.

Experimental design

The source of the wastewater is the laboratory experiments. Various chemicals are used in the laboratory and table - VIII shows these chemicals with respect to the experiments carried out in the laboratory. Wastewater is a mixture of these chemicals.

Table VIII - Chemicals in wastewater with respect to the experiments

Experiment #	Chemicals used
Expt 201	Hydrochloric acid, Sodium carbonate, Ammonium chloride, Phenolpthalein, Methyl orange, Methyl red
Expt 202	EDTA, Ammonia/Ammonium chloride buffer, Ca, Mg & Zn ion solutions , EBT indicator, Sodium Hydroxide, P & R indicator, Calcium carbonate
Expt 203	Potassium tetraoxalate, Ammonium oxalate,Hydrochloric acid, Methyl red indicator, Saturated ammonium, Sulphuric acid, Potassium permanganate, EDTA
Expt 204	Ni & ferric ion solutions, Citric acid, Aqueous ammonia, Dimethyl glyoxime
Expt 205	Devards's alloy, Sodium hydroxide, Boric acid, Methyl red, Sulphuric acid, Aqueous ammonia
Expt 206	Potassium thiocyanate, 5-sulpho salicylic acid, ferrous & ferric ion solutions ,1-10 phenanthrolin,

The series of steps carried out during the treatment process can be categorized as physical, chemical and biological. For each process to be functioned separate units were prepared and they are labeled as unit A, B, C and D. the set up of the treatment plant including those units is shown in Figure VII. Figure VIII shows the series of treatment steps involved during the entire treatment process.

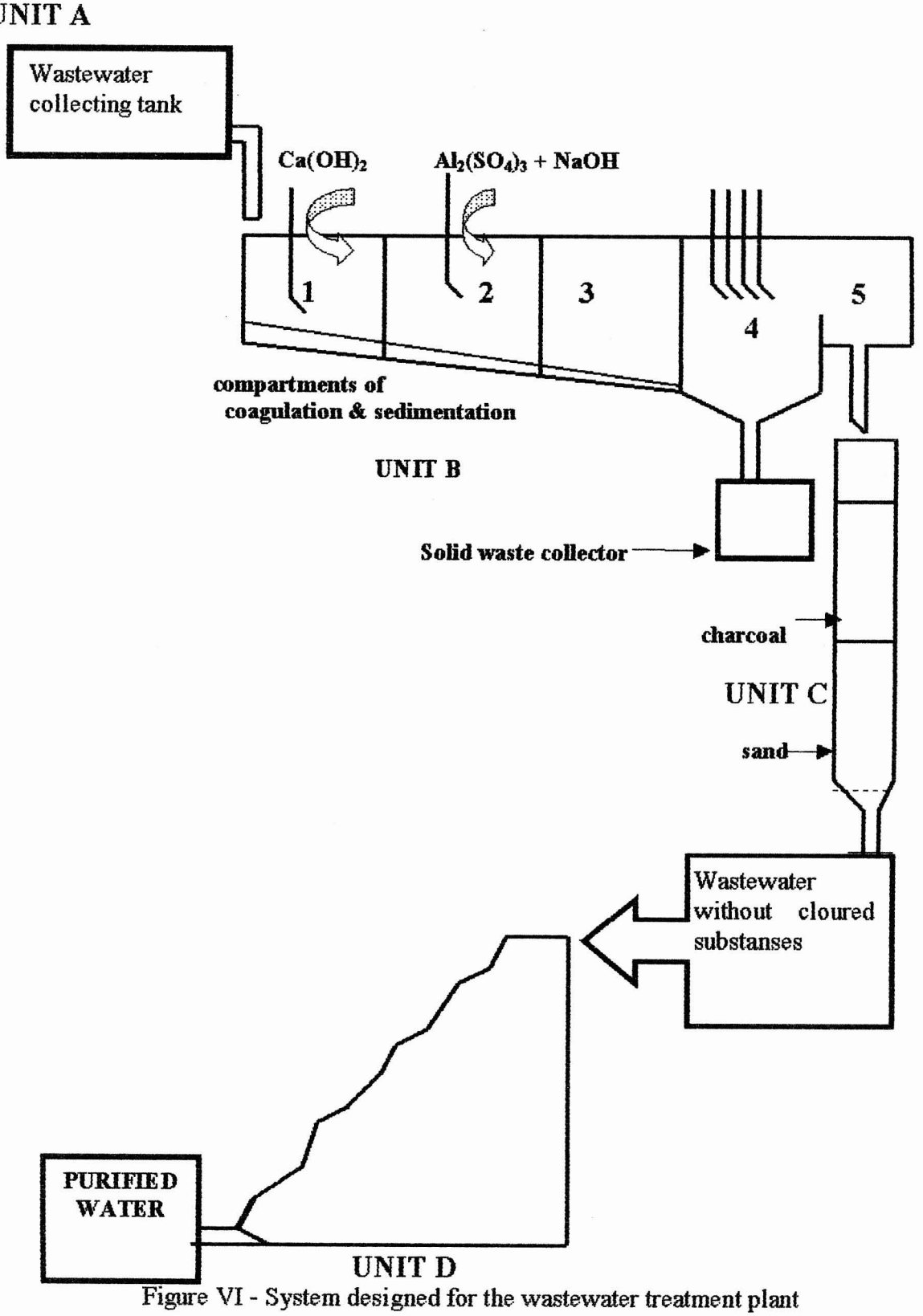

Figure VI - System designed for the wastewater treatment plant

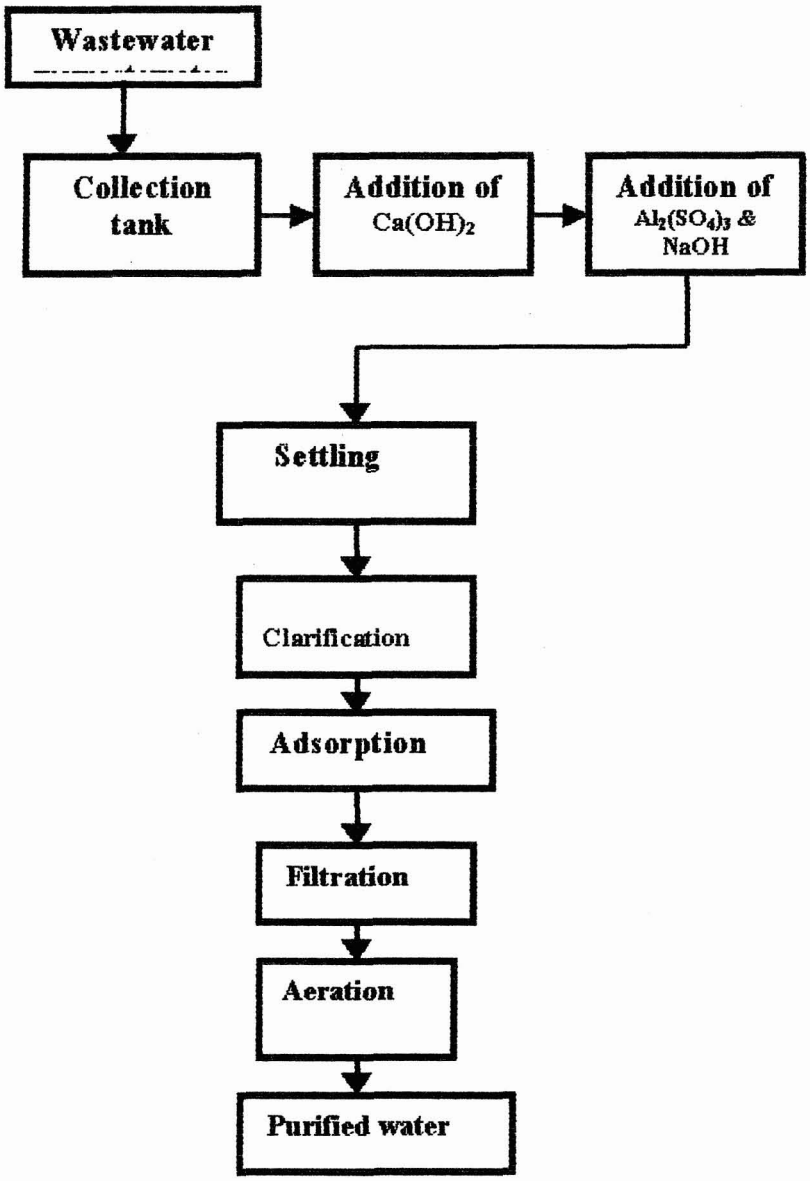

Figure VII - Process flow sheet of laboratory wastewater treatment.

Operating mode

Unit A (Wastewater collecting tank) :-

After each experiment students were asked to collect all the solutions to a 20 L glass tank labeled as wastewater collecting tank. This glass tank has a side tap which can be controlled the flow of water to the next unit. All the solutions remains in the tank for some time allowing primary sedimentation process. This process helps to remove the greater part of the

heavy, suspended solids in the wastewater. According to the observations wastewater collected had higher intensity of colour and acidic nature.

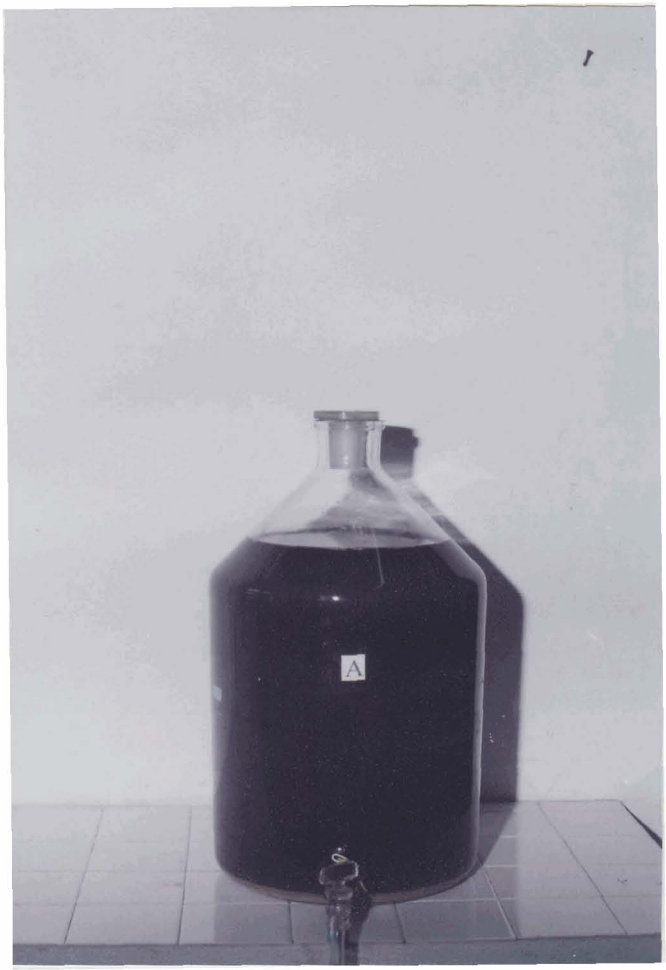

Figure VIII – Wastewater collection tank

Unit B (Precipitation, coagulation and clarification) :-

Precipitation, coagulation and clarification processes were carried out in unit B. This unit is prepared with transparent plastic sheets. A single tank is divided into five compartments in which the different chemical and physical processes are being carried out. Stirring is done in the compartments one and two. Each compartment is separated by a barrier and flow occurs through a opening at the barrier wall. There are drains fitted at the bottom of each compartment to remove solid waste materials. The compartments four and five are not completely separated and it is designed to overflow the clarified water into the compartment five. In the compartments one and two chemicals are added and it is described as follows.

Addition of Lime (compartment one) :-

At the compartment one lime is added. Rapid stiring is essential to react wastewater with lime. In the compartment one various ions of the wastewater start to react with lime. Main purpose of adding lime is to increase the pH of the wastewater and thus formation of

precipitate containing Ca and Mg salts. These precipitates settle at the bottom of the compartment and much of the solid materials remain in suspension and requires the addition of coagulants to settle the colloidal particles. Reacting wastewater with lime require at least 45min time and through the small hole in the barrier, supernatant flows to the next compartment.

Addition of coagulant (compartment two):-

The finely divided solids and soluble metal salts pass to compartment two where the coagulant aluminium sulfate is added. Addition of the coagulant is followed by the addition of sodium hydroxide which brings the pH close to the value that results in minimum solubility of the metal of the coagulant used. When aluminium sulfate is used small amount of sodium hydroxide is added until a pH of about 7 is reached by at this pH the solubility of the Al^{3+} cation in water is minimum. These form gelatinous hydroxides of their respective metals. After some time gelatinous substances settles down at the bottom of the compartment. At this stage there is a drastic reduction of the colour intensity of the wastewater.

Sedimentation(compartment three) :-

Wastewater then flows to the compartment three. Further settling of particles, suspended solids, finely devided solids such as colloids occurs and proper settling require at least one hour. Stiring is not required at this stage.

Clarification (compartment four) :-

Some extent of the colloidal materials and wastewater flows to the clarification tank. Here particles are separated to produce clarified water. Removal by sedimentation is based on the difference between the specific gravity of the suspended solid particles and the liquid. Slow stirring occurs at the surface water of the compartment and sedimentation occurs slowly. After a specific period of time clarified water overflows to the compartment five. This wastewater can be further decolorized or neutralized if necessary.

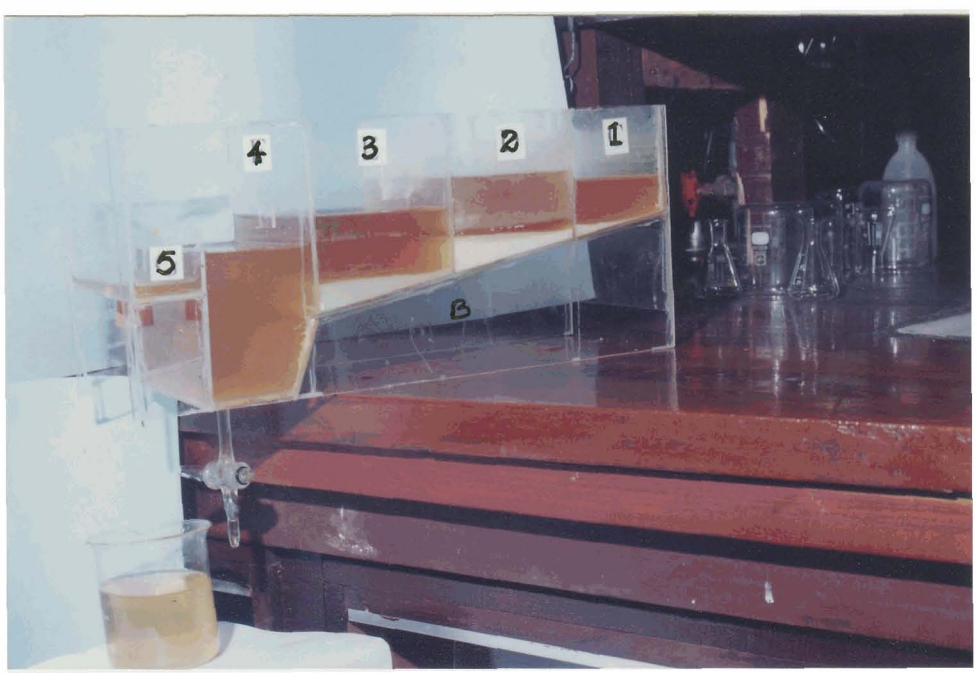

Figure IX – Steps of chemical addition and forming precipitation

Unit C (Adsorption and filtration) :-

As this treatment plant is a teaching model we thought of having a combined process of purification. Twenty seven inches long glass column with a sintered glass trap at the bottom was used for both filtration and adsorption processes. Purified sand particles was packed at the bottom of the column and the top layer of the column is the granules of the activated charcoal. Wastewater flows over the charcoal bed slowly (retention time is farely high) and then flows through the sand column and comes to the purified water collecting container.

Filteration :-

This is the process by which water is get rid of suspended and colloidal impurities it contains and the number of microorganisms is reduced. The overall removal of impurities associated with the process of filteration is brought about by a combination of different processes. The more important of these are mechanical straining, adsorption and sedimentation.

Adsorption :-

Activated charcoal column function as a filter and cause certain kinds to adhere to the surface(adsorption) and thus helps to remove organic, inorganic and biological impurities that impart odor, color and taste.

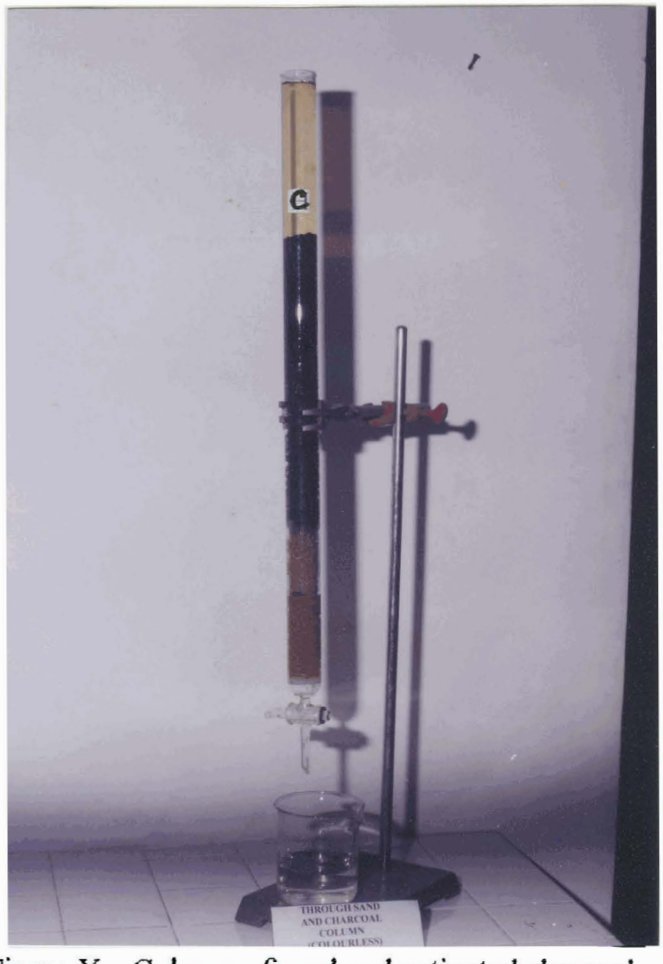

Figure X – Column of sand and activated charcoal

Unit D (Aeration) :-

The sedimentation process leads the less contaminated wastewater to the process of aeration. During this process air is brought into intimate contact with water for the purpose of promoting movement of volatile substances and gases to and from water. Atmospheric O_2 also is absorbed for chemical oxidations of iron and manganese from insoluble to soluble form. Excess CO_2 and substances such as sulfide, methane, ammonia are removed , thus improving the taste and ordour of water. Among the other inorganic and organic substances which can be removed to a some extent are phenols, amines, Cr^{+6}, CN^- , SO_3^{2-} and H_2S. Reduction of CO_2 content of the water is a very important task which we can achieve during this process. Aeration unit designed in this model has a staircase shape and fixing small barriers on the water flowing surface has increased the surface area. This process should be carried out for a particular period of time in order to achieve good aeration. Also we can recycle the once aerated water three or four times before releasing to the environment.

Figure XI – Aeration unit

The units A, B, C and D should be kept on line in order to operate effectively.
Laboratory wastewater purified by this manner gave satisfactory results and large volume of wastewater collected by students was purified and released to the environment safely. The experiments were conducted using wastewater and a hypothetical solution. The changes of various parameters such as pH, conductivity, absorbance and temperature were measured at the each treatment step.

The observations which have done at each step are included in the Table- IX.

Table IX - Variation of parameters during the treatment process

Description	pH		Conductivity (mS/cm)		Temperature (^{0}C)		Absorbance (620nm)	
	Waste water	model sample	waste water	model sample	waste water	model sample	waste water	model sample
Prior to Treatment	1.66	6.10	20.00	23.50	29.4	29.4	0.045	1.40
Compa. 1	7.84	12.28	14.10	30.50	29.5	29.5	0.035	1.25
Compa. 2	8.62	12.46	15.10	30.50	29.7	29.7	0.025	1.25
Compa. 3	7.79	12.19	15.00	30.50	29.8	29.8	0.015	1.25
Compa. 4	7.52	11.92	15.00	30.50	30.1	30.1	0.005	1.25
After passing through the column	6.66	6.56	10.10	11.40	30.1	30.1	0.00	0.00
After aeration (treated water)	6.66	6.56	10.10	11.40	30.1	30.1	0.00	0.00

Wastewater collected undergo primary sedimentation process initially, removing the greater part of the heavy and suspended solids. pH of the medium increased by the addition of $Ca(OH)_2$ and rapid stirring increases the reaction rate. Wastewater react with lime resulting precipitate containing Ca and Mg salts. According to the results highest precipitate occurs at the compartment one indicating the removal of Ca and Mg salts excessively. Much of the solid materials remain in suspension. $Al_2(SO_4)_3$ added followed by a small amount of NaOH will bring the pH of the medium to a close value that results in minimum solubility of the metal of the coagulant used. At this stage there is a formation of gelatinous hydroxides of the respective metals in the medium. Heights of the precipitate in each compartment were measured and shown in figure III. During adsorption and filtration, removal of colored substances occurs. Activated charcoal is a natural adsorbent which can adhere organic, inorganic materials to its surface. Sand filtration removes suspended and colloidal impurities. Wastewater get colorless and negligible values obtained for absorbance indicates the removal of colored impurities. Further purification done via aeration. During aeration air is brought into intimate contact with water for the purpose of promoting movement of volatile substances and gases to and from water. Reduction of conductivity, acidity and absorbance were observed at several steps.

The simple physical principles can be used to explain the separation of soluble and insoluble solids and liquids from the bulk of wastewater. Although there are some problems regarding good process control, having this type of purification unit helps to reduce the waste and increase the pollution control. Apart from all these students will be trained to think about the environment protection as part of their chemistry lesson.

(4) Conclusions drawn and recommendations, if any, for implementation ;

The integrated method of teaching environmental and industrial aspects in the proposed way focuses on real-world problems and contemporary issues. Use of critical thinking skills to identify and address these concerns is essential to success in the program. Students must not only be familiar with current environmental problems but they also need to learn to identify key issues and criteria, seek alternatives and draw warranted conclusions. To day's employers and various establishments are interested in technically trained graduates who have this practical problem solving skills. It is essential to practice flexible settings to teach environmental and industrial aspects in which students can acquire a strong science based technical background along with critical thinking skills. The different approaches described here and the general design of the environmental aspects can be implemented in other universities considering different academic streams. Also it should be one of the important missions of to days educators to teach chemists as well as non-chemists, including political office holders, the legal profession and economists about the fascinating and essential discipline of environmental aspects.

New program designed including above steps

When teaching chemistry at the introductory level, it should be a task of presenting Chemistry as a multi-faceted and dynamic discipline. In addition to addressing basic principles of chemistry, the skilful lecturer should incorporate such ancillary topics as industrial applications, environmental impact of those applications, nature of pollutants and research work related to chemistry – environment and industry.

When planning a well rounded general chemistry course, an effort should be made to provide meaningful experience that will remain with the student long after the final examination.

We have developed an integrated program linked to the chemistry curriculum that can be practised within a laboratory environment. The resources used for the development of an integrated program were predominantly generated in-house, but were also obtained from the literature.

Nature of the new program

New topics to be addressed during the laboratory period
• Providing reading materials and lecturing on GLP , safety rules and importance of lab safety. Reading materials – General Laboratory Guidelines Leaflet " Laboratory Guidelines to Safer & Cleaner Environment" - Manual of Laboratory Safety - Cards on Safety Signs • Brief lessons on correct method of using equipment in the laboratory. • Demonstrations on using fire extinguisher, safety shower, eye washing equipment. • Importance of using personal protective equipment during working in the laboratory should be explained clearly and monitoring the students on this aspect. • Proposing students to design simple waste disposal methods for the waste generated by themselves. • Asking students to prepare small reports on various chemicals they are handling during the experiments, toxicity of the chemicals, routes of exposure, environ--mentally acceptable levels, health effects caused at higher concentrations and precautions to be taken when handling these chemicals. • Practising Resource Management during the experiments.

- Teaching industrial applications of chemicals-

  The software program designed on " Chemical Industries in Sri Lanka" is a quick reference source available at the Laboratory and students can be used this program and expand their knowledge.

  - Booklet on " Polymers , their re-cycling and reusing techniques can be used as a teaching material.
  - Small projects on determination of Pb ,Cr , Fe in the industrial /laboratory wastewater.
  - Assigning projects related to chemicals and environmental impact caused by the chemicals used in industries.

- Encourage them to prepare posters illustrating real environmental problems in Sri Lanka.

In recent years due to the demand of ecologically literate citizens by the industry, the undergraduate chemistry programs have to sought new ways to provide students with a better over all view of chemistry and the way it is applied in the real world. Some reports pointing out the importance of seeking alternative approaches to undergraduate instructions. One such alternative approach is the use of integrated methods to teach chemistry in laboratories. An integrated method refers to the use of experiments that teach techniques or principles obtained from two or more areas (Analytical, Environmental & Industrial aspects). The advantages of this type of laboratory is that it presents the student with a more realistic picture of how chemistry is performed in an environmental or industrial setting and help students to see the interdependence of different disciplines.

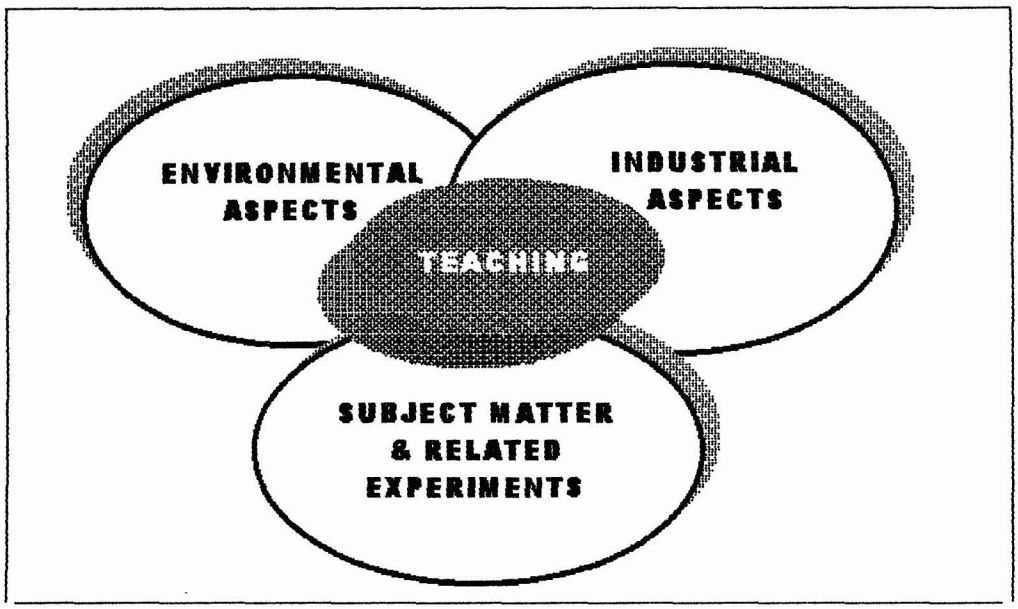

Figure XII – The interaction between subject matter, environment and industrial aspects.

Although this type of program required greater time and commitment of the lecturer, demonstrators and minor staff, it will allow more efficient utilisation of time allocated for laboratory experiments and also give students a more holistic view of chemistry in environmental and industrial applications.

Another area that is to be considered is that the applying of above discussed environmental and industrial related aspects to the non-science students. In major universities, the appeal of science to the non-science students is very small. By making an effort the available programs of non-science students can be restructured, to teach fundamentals of scientific principles, environment and related areas , industrial pollution with greater integration of subject matter. This is very important because in future these graduates become decision makers of the country and it will be an advantage to have an environment conscious mind with them to serve the country 's economy as well as the nature with out causing any damage.

It can be concluded that integrated programs of environment with subject matter should be recognised as an important part of university education. Universities should take initiation to enhance, reorganise and upgrade their educational programs by adding a new environment related course or improving existing programs in Environment science / Environmental chemistry because the sustainable development of the country depends on the minds of ecologically literate citizens.

(5) (A) Citation of periodicals reporting work done under his contract giving author, title, journal, volume and page number :

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(B) Other relevant literature references : N/A.

(6) An explanation from any significant departure from the level of activity foreseen by the contract : N/A.

Grantee(s) signature :

SAFD

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Comments of the Head of the Department:

During the project, documents have been prepared on information collected on - good laboratory practice, Lab safety, purification of laboratory water for reuse, which could be used by the undergraduate students as reference material. Work satisfactory & Recommended

Signature of the Head / Department :

SHewage

Dr.(Mrs) S. Hewage
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Signature of the Dean / Faculty of Science:

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