International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 22 No. 1 August 2020, pp. 232-239

Laboratories in Geosciences: Some Tips for Management

Erkan AYDAR

Hacettepe University, Department of Geological Engineering,

06800, Beytepe, Ankara, Turkey

Abstract – Scientific, technical, and technological researches depend on laboratory studies and the data produced in laboratories and the quality of these data. Laboratory equipment and studies reflect the quality of laboratories, from sample acceptance to result reporting. Laboratory Management in Earth Sciences is vital in the management of equipment and personnel. Very good labs can become labs that cannot function with bad management. For this reason, the LIMS system should be established in laboratories, all transactions such as job and personnel tracking and training, student training, consumable stock control, and management, should be open, transparent, sustainable and accessible. In this article, the general introduction of the Earth sciences laboratories and information about the problems that can be encountered in practice and their management are given.

Keywords – Geosciences, Laboratory, Management, LIMS

I. INTRODUCTION

Laboratories are the kitchen of scientific, technical, or technological research. Any dictionary can give the meaning of the term as "a room or building or a place equipped for scientific experiments, research, observation or teaching, or for the manufacture of drugs or chemicals, or testing and analysis or practice in a field of study". The word laboratory generally means the location of the machinery and equipment required for analysis and tests in a targeted subject for a purpose. Etymologically, the word Laboratory is derived from the Latin word Laborare (https://www.merriam-webster.com/dictionary/laboratory).

Laboratories are set up for scientific research (VA Design Guide, 1995) and technological research, health, education (McComas, W.F., 2014), engineering problem solving, industrial product testing, etc. Laboratories can include all devices comprising very simple equipment to highly sophisticated high-tech devices. The development of laboratory devices, the increase of their examination capacities, their sensitivities, measurement capacities, application areas are parallel to the technological development of humanity. As technology develops, manufactured laboratory devices become more technological and sophisticated. Those high-tech equipment lead to the development of new technology and analysis systems. There is an egg-chicken relationship. Management systems have been established for the functioning of laboratories. Running a lab offers great similarities to running a company. In laboratories, personnel management, budget, and business management, quality control, customer satisfaction, creation of modern working environments, use of modern machinery and equipment, stock management (for consumables), daily, weekly work programs, short, medium and long term strategic planning, setting periodic targets, internal evaluations, ensuring workplace safety, maintenance and repair of devices to produce high-quality work, transparent management and accessible work programs, organization and delivery of in-service training to the personnel, international standards in production (ISO, DIN, ASTM, etc) are fundamental.

The universities and research institutions have created their laboratory management systems. In general, those management systems are based on occupational safety for the staff or students. The quality management systems have been well established in medical sciences. For example, WHO (World Health Organization) (2011) provides 12 Quality System Essentials in Laboratory Quality Management System Handbook as follows; Organization, Personnel, Equipment, Purchasing and inventory, Process control, Information management, Occurrence management, Assessment, Facilities and safety, Customer service, Process improvement, Documents and records. Besides Clark (1995) reports eight core principles in the essence of the philosophy of management and its processes; leadership, behavior, environment, planning, structure, values, communication, and innovation. In addition to quality management systems, standards such as EN ISO 9001 and EN ISO 17025 also bring some rules to laboratories. All these standards and Quality Management Systems are related to workflow and occupational safety. Sandquist (2013) states that the Laboratory manager is very important in laboratory management which is divided into four main categories as Planning, Organizing, Leadership, Controlling.

Moreover, running a lab poses many challenges, including managing people, projects, and finances and establishing workplace practices that encourage productivity, safety, ethics, and high employee morale (Pain, 2012). Although laboratories attract specific attention especially in medical sciences, they have an important place in all fields of science.

For this reason, since there are very few studies about the operation, use of space, the people and organizations to be served, who the devices should provide service to, and their qualifications specific to the Earth Sciences Laboratories, a focus on the Earth Sciences Laboratories is needed and so is targeted in this article.

II. Earth Sciences And Laboratories

In its broadest sense, geology is the study of Earth- its interior and its exterior surface, the rocks and other materials that are around us, the processes that have resulted in the formation of those materials, the water that flows over the surface and lies underground, the changes that have taken place over the vastness of geological time, and the changes that we can anticipate will take place soon (Earle, 2015). In Geosciences, besides scientific research, engineering problems are also sought and solutions are produced. The wide content of geology makes the geological problems very different and diverse. Such different problems can be answered with different methods and research possibilities. While research opportunities in geology were very limited 100 years ago, geologists only had hammers and observation powers. In the last 100 years, many different types of equipment have been developed and continue to be developed for many different purposes. In this paper, only basic laboratories will be mentioned.

2.1. Thin Section Laboratory

It is the laboratory where rock or mineral samples and even sediments sampled by a geologist or geological engineer during the field studies are first processed. At the same time, concrete, ceramic, etc samples are also prepared for further research in this laboratory. According to the purpose of the study, the main goal is to make thin sections that will be useful for structural, textural, and mineralogical examinations of the samples. It is not a research laboratory, but a laboratory where samples are made suitable for research. Its basic equipment are large size rock saw cutters, slab cutting machine and lapping devices, hot plate, precision cutting machines after mounting on the glass for resectioning and thinning of samples, polishing devices, abrasive sandpapers, polishing powders, pads, cloths, lapping glass, ultrasonic washing devices. It is a labor-intensive production. In particular, if the samples are the loose materials or brittle geological material or clastic material or samples that swell in contact with water, such as the clay, the samples must be mounted with epoxy resin using a vacuum device, cured in ovens and polished with lapping machines to obtain a smooth surface. Afterward, the samples will be ready to examination (for ore microscopy or Mineral Microanalysis or vitrinite reflections if the sample is organic), or thin-section can be produced from the mounted loose materials. The most basic consumables are adhesives such as microscope slide, coverslip, saw discs, abrasive discs, epoxy, Araldite, etc, thinning and polishing powders (SiC and/or Silica) and/or diamond-based polishing fluids, abrasives, and pastes, alcohol, acetone, distilled water, thin section boxes. All workplace safety rules must be applied in a Thin Section Laboratory. Especially in stone cutting operations, as the cutting discs are cooled with water, a wet environment occurs. In this case, the waterproofing of electrical devices must be necessary. Laboratory personnel should wear insulated clothing against water and electricity. Cutting devices must have emergency stop buttons. Wastewater and filters should be cleaned continuously with periodic maintenance. Waste must be collected continuously and properly disposed of regularly. Besides, personnel should use headphones, as cutting operations are extremely noisy. Working alone should never be done in this laboratory. During the working period, there should be at least two people in the environment. Laboratory management should be transparent, the laboratory should have its page in the electronic environment, the workflow should be shown on this page, the person requesting should know approximately when the work will be completed. Also, consumable stock quantities should be continuously monitored electronically and orders should be made before materials are exhausted. The workload of the personnel should be determined in monthly, quarterly and six-month periods, periodic workloads of the laboratory should be determined, and the threshold times should be determined for personnel management and supply of consumables. Digital infrastructure should be established for any online reservation, request for analysis. Financial incomes should be paid to the relevant unit of the institution and spent on laboratory modernization, the supply of consumables, etc.

2.2. Material Sizing Laboratories

The main point in geological research is to take enough or even more samples from the geological material in the area under investigation. For the purpose, geological materials are subjected to macroscopic, mesoscopic, microscopic visual inspections. Usually, micron and even nanometer scaled visual and chemical examinations are needed. Sizing is a very important point for further investigations.

2.2.1.Core drilling

Core drilling provides the cylindrical material removing from the host material. The core drillers can be different in size and capacity according to the aim and objectives of the work.

Before the construction of large engineering structures, the cores can be drilled with drilling machines to determine the engineering properties of the soils, rocks. Moreover, earth scientist needs the cores in geothermal wells for technological tests, sedimentological works and paleoclimate works, etc. The diameters of the cores can be variable and sampled with portable hand-held core drillers from the field. In addition, core samples can be also taken with laboratory type drills form the large blocks transported to the laboratory. The cores for rock mechanics are larger in diameter than the cores taken for paleomagnetism, AMS (Anisotropy of Magnetic Susceptibility), ultrasonic, or other geophysical studies that are generally 2.5 cm in diameter. Besides, much smaller cylinders (<1 cm) are needed in micro-CT X-Ray studies that have become widespread in recent years.

2.2.2. Rock/Slab Saw Machine

Saw cutters are required to cut and dimension geological materials and core samples. Transverse and sagittal cutting of the core samples requires great precision. In transverse cuts, the upper and lower surfaces must be completely parallel to each other for quality results in advanced measurements. The saws used in cutters are also in the form of continuous rim diamond blades or segmented diamond blades. While segmented blades are preferred for large, hard specimens, continuous rim diamond blades should be used for more precise cuts. Water is used as a saw cooler in cutting processes. Unlike the cutters in the thin section laboratories, the table of core cutting machines is longer. When cutting samples, weathered surfaces can be scraped or cutaway. Security rules are the same as the thin section lab.

2.2.3. Crushing and Grinding Laboratory,

The crushing is required first in further works on the mineralogical, chemical, and technological properties of geological samples, determining the fracture morphology of fragmented rocks, such as aggregate, railway ballast, etc., and separation of minerals and fossils. Laboratory crushers are the same as industrial type crushers. Jaw crushers are used as primary crushers. The hard rocks are first to cut into small pieces with cutters or chipped with a hammer, dried, and then the small pieces are fed into the crusher's bunker. In crushing and grinding processes, the crusher or grinding device settings to be selected are directly related to the grain size of the geological material to be examined. If very fine-grained material is desired, the jaw crusher mouth opening can be narrowed down to zero. In addition, roller crushers are also frequently used in laboratories. In general, it can give effective crushing and even very fine-grained materials in relatively medium-hard and soft materials. Other crushers like conical, hammer, impact crushers are less common types in laboratories.

Grinding, on the other hand, is mainly carried out in laboratories with ring mills (pulverizers). Apart from that, if excessive feeding can be done, a ball mill can also be used. Pulverizers are made of tungsten carbide or agate. Especially if sensitive analyzes such as trace elements and rare earth elements are required, grinding with agate will prevent contamination. Especially, the geological material to be sent for chemical analysis must be ground finer than 63 micron and therefore pulverizers are preferred.

As crushing-grinding processes generate dust, the ventilation-aspiration systems should work effectively in the laboratory. Otherwise, occupational health problems are created for staff and a high risk of sample contaminations will be present. In this noisy working environment, the staff should also use earmuffs.

2.2.4.Screening, Fractioning

The screening and fractionation are performed for the purpose, after crushing and grinding processes, or on the loose materials or sediments sampled directly from the field. Laboratory scale vibrating sieve sets are widely used. Sieve size generally ranges from 125 mm to 5 microns. The flocculation may occur due to particle cohesion when the grain size decreases during screening so wet screening may be chosen for very fine-grained materials.

The sieving process starts after the suitable sieve set is selected and emplaced on the vibration screen shaker. After the process is over, before working with other materials, they must be washed with distilled water, then kept in ultrasonic washers, cleaned of grains, dried in the oven, and put into boxes for further use. Screening is a very dusty process. Employees must work with masks, earmuffs, and appropriate clothing. Physical intervention into the sieves harms the sieve meshes, that it is highly recommended to avoid. Laser or optic sizers have also started to find widespread use in grain size analysis. The screens themselves are consumables due to the abrasive effects of the materials. Laboratory staff should be aware of this, as wear and deformation may occur over time, and the sieve should be replaced when necessary. Also, distilled water, chemicals, acetone, and alcohol for cleaning processes, and paper towel are the main consumables.

2.2.5. Mineral and Fossil Separation Laboratory

Mineral and Microfossil separations follow almost the same procedure. They are separated for the radiometric age determinations (feldspars, zircons, micas, clay minerals, apatite, calcite, etc), isotopic analysis, mineral properties, paleontological purposes, to determine the industrial usage area, to design the economic operation scenario of a mineral deposit, etc.

It is important to know the abundance, grain size, interconnections with other constituents, purity of the concerned mineral, inclusions prior to application of the separation procedure. For example, the interested constituent is coarse and frequently presented, a quantity like human hand size would probably enough, on the other hand, if the concerning ingredients are in micron size, several kgs of the bulk sample are needed to have enough quantity. After the specimens are disintegrated, crushed, milled, the appropriate sieved fraction depending on the grain size of the mineral/fossil will be selected. The coarse fractions like -500+125 microns are suitable for the radiometric datings, isotope works. If needed, the fractions must be processed by one or successively numerous following methods; magnetic separations (with electromagnetic separators like mostly used Frantz, or roll separators with rare earth magnets with vibration feeders, or wet magnetic separations), heavy liquids, gold pans, gravity methods, acids, flotation for successful beneficiation. Hand-picking under the binocular microscope is also a very common method. Mineral separation is a process that must be done very carefully and patiently. During each stage separated material should be checked with a binocular microscope, then it is immediately confirmed whether there is a need for more disaggregation of the material. Separated fractions are washed in distilled water or alcohol to remove all dusty particles. In the end, the fractions are dried in the oven. Each laboratory may have its method and procedures. Main consumable materials are chemicals (including for fossil separations; acids, bases, Hydrogen peroxides, heavy liquids, etc), alcohol, acetone, paper towels, gloves, masks, distilled water.

Special methods and devices can also be used to separate the clays. The ground clay fraction is washed with liquids such as acid and hydrogen peroxide, and impurities such as carbonate and organic matter are removed from the environment. Then the decantation or centrifugation method is used for the separation of the samples. Sometimes, ethylene glycol and glycerol are used in case of the swelling clay presence. In the end the sample is dried in the oven and desiccator and transferred to the analysis laboratory.

2.3. Analytical Laboratories

2.3.1. Soil and Rock Mechanics Laboratories

According to Kalinski, (2011), "*Soil can exist as a naturally occurring* material *in its undisturbed state, or as a compacted material. Geotechnical engineering involves the understanding and prediction of the behavior of soil. Like other construction materials, soil possesses mechanical properties related to strength, compressibility, and permeability. It is important to quantify these properties to predict how soil will* behave *under field loading for the safe design of soil structures (e.g. embankments, dams, waste containment liners, highway base courses, etc.), as well as other structures that will overly the soil*."

In soil mechanic labs, in general, following tests are performed: Moisture Content, Specific Gravity, Liquid Limits, and Plastic Limits, Analysis of Grain Size

Distribution, Classification, Compaction, Dry Unit Weight, Hydraulic Conductivity, Consolidation Tests, Shear Strength Tests, Compressive Strength Test, Triaxial Shear Strength Test (Kalinski, 2011).

About rock mechanics, Riecker (1984) resume as "*Rock mechanics is the theoretical and applied science of the mechanical behavior of rock; it is that branch of mechanics concerned with the response of rock to force fields imposed by the physical environment. This broad definition suggests the manifold* applications *within rock mechanics. Scientific consumers—including structural geologists, tectonophysicists, and seismologists—focus on interpreting the chaos of deformed rocks. Engineers work to find better ways of breaking rocks or keeping them from breaking. They deal with a host of engineering problems such as surface foundations, excavations, slope stability, underground openings and boreholes, construction materials, comminution by drilling, blasting, crushing, and subsidence"*. Rock masses are generally an inhomogeneous, inelastic, discontinuous, and anisotropic medium; such properties make its characterization rather complex and difficult (Ceballoz et al., 2014). As rock mechanics and rock engineering is an applied discipline, it requires an intensive field and laboratory works. The measurement can be done either in the field (in-situ), or in the laboratory. The main purpose of these studies is to examine all the physical and chemical changes that the rocks are or will be exposed to, in order to solve the engineering problem. A laboratory must be equipped to realize following tests, (besides the geophysical equipements such as Electric Resistivity, Magnetometers, Gravimeter, Sismic,etc): (List of tests are from Hacettepe University Soil and Rock Mechanics Lab web site: "Determination of water content, Unit volume weight determination (natural, dry, saturated), Determination of water content, Unit volume weight determination (natural, dry, saturated), Water absorption tests, Porosity, Index of stability against dispersion in water, Point load strength index test, Disc shear index test, Schmidt hardness hammer test, Uniaxial compression strength, Tensile strength (by Brazilian method), Triaxial compression strength, Determination of modulus of elasticity and Poisson ratio, Direct shear test with portable rock shear box, Shear test with direct shear device with deformation control, Sonic velocity experiment, Freeze-thaw test, Methylene Blue Test, Accelerated mortar prism test, California transport rate (CBR) test, Los Angeles Abrasion Test, Sieving, Direct shear test for Aggregate and Rock material (www.jeomuh.hacettepe.edu.tr/KayacToprak.html#).

2.3.2 Mineral Analyses Laboratories

Analyses of geological materials can be qualitatively or quantitatively reported. As the raw geological materials rarely go to the analytical laboratories without any pre-treatment or preparation, the quality of the work realized in the laboratories before mentioned controls the overall analytical quality of the results. Microscopy serves for the first recognition of the organic or inorganic samples. Microscopes used in geological research can be (1) Binocular Transmitted Light Microscope (Stereo Microscope with some moderate magnifications, they are replaced by digital microscopes equipped with a camera), (2) Polarizing Microscope (crossed Nicols; with a polarizer and an analyzer), (3) Metallurgical Microscopes (Reflected Light Ore Microscopes). Some special microscopes are also operational like Inverted Microscopes, Confocal Microscopes, Atomic Force Microscopes, or some 3D Infinite Focus Microscopes.

Besides, versatile Scanning or Transmission Electron Microscopes allow visualizing the samples in micron or nanometer scales or even the lattice of the material. Scanning Electron Microscopes (SEM) work, regardless of brand, with the same principles: an electron gun at the top, a column where magnetic apertures aligned to serve to centralize the electron beam, a chamber below the last aperture and wobbles lens. A SEM classically equipped with Secondary Electron Detector (SE) and Back Scatter Detector (BSE). These detectors help to create the images on topographical mode (SE) or the images according to the atomic numbers of the constituents. They allow investigating morphology, structure, texture, homogeneity of the samples. SEM is mostly operated under high vacuum generated by diffusion pumps, or turbomolecular pumps or similar pumps, but, there are also some modes or devices permitting to work on the low vacuum to atmospheric. Various brands call under different names defining same low vacuum SEM's as Variable Pressure SEM, Extended Pressure SEM, or Environmental SEM. The gun properties also control the quality of imaging. Tungsten filaments are widely used filament type. Besides, LaB6 filaments exist and give more accurate images. Some new FIB-SEM (Focused Ion Beam-SEM) machines start to find a market in SEM World. The difference in FIB that an ion beam is used in FIB, rather than the electron beam in SEM.

In SEM studies, if it is to be worked in the high vacuum environment, the material should be coated with a metal to ensure conductivity of the sample surface for that the electrons flow over, impeding the electron charging at the surface. As these coating materials have high surface conductivity, they increase the signals and image quality. If the purpose of the study is limited by taking the images, gold or gold-palladium coating is more adequate, but if qualitative and quantitative analyzes are required in the study, they must be coated by the carbon. Sputter coaters are used for these processes. Different spectrometers or detectors can be mounted on the SEM. Energy Dispersive Spectrometer (EDS or EDX) allow performing qualitative and quantitative analyses. Their analytical performance on major elements is similar to WDS (Wavelength Dispersive Spectrometer-EPMA, Cubukcu et al., 2008). While EDS was cooled with liquid nitrogen in the past, now it is possible to work more comfortably with Peltier cooling systems. The operating temperature of the EDS detector varies between -15 and -25 degrees. Achieving this value will also ensure the correct analysis. With its rotary pumps, High Voltage Units, and other components, SEM is a stand-alone device that produces heat. When the ambient temperature rises, both the vacuum values and the detector temperature increase. To avoid this, the environment must be cooled by air conditioning to ensure that the device reaches its performance. On the other hand, if WDS spectrometers are mounted on SEM, the device turns into an Electron Probe Micro Analysis (EPMA or Microprobe) device. In EPMA devices, spectrometers contain diffraction crystals such as LIF, TAP, etc., and each crystal is dedicated to the measurement of some elements. In other words, a point chemical analysis with a single spectrometer takes 5-10 minutes, while the same measurement with 4 spectrometers takes about 1 minute. With the WDS spectrometer, both major, trace, and rare earth element analyzes can be performed if the required standards are installed. While analysis sensitivity is higher than EDS analysis and lower than Laser Ablation ICP-MS and SIMS analysis. The most basic consumables of SEM laboratories are filaments, apertures, Carbon rodes or filaments or Gold targets, Pump oils, Argon or Nitrogen Cleaning gas, stubs, carbon tapes, silver pastes, aluminum tapes, acetone, alcohol, paper towels. Recently, Micro-CT (Computerized Tomography) machines find extensive applications in geosciences. These devices allow illustrating deeply the interior of the samples concerned. This undestructive method has promising. Radiation safety rules must be set up and applied in this laboratory.

Some software package working together with the EDS-SEM makes Mineral Liberation Analyses (MLA) that we need in process mineralogy or Ore Enrichment Facilities. MLA gives information about the efficiency of the mineral enrichment process (Magnetic Separation, Flotation etc.

XRD method is one of the other common mineral analysis methods. The powder samples are fed to the device and the X-Ray beam is sent to samples from X-Ray Tubes. The mineralogical composition of the whole rock or the type of separated clay minerals is determined with X-Ray Diffraction. In the past, scientists have used the cards to read XRD spectra and 2Θ value for each peak to find to the mineral. However, now this work is done by software with XRD data. Nevertheless, the mineralogical composition should be verified by checking the given mineral probability list by the expert. The XRD laboratory is a radiation-emitting laboratory, and the radiation safety rules must be applied with great care.

Raman Spectroscopy is another method to characterize geological materials. By definition, Raman spectroscopy is based on the capturing of inelastically scattered light. Chemical composition, mineral identification, and structural characterization, gemstones, archeological artifacts can be studied by Raman spectroscopy. The advantages of Raman spectroscopy are its non-destructive nature, small sample amounts can be studied and no sample preparation is necessary (Thomas, 2015).

2.3.3. Chemical Analysis Laboratories

Chemical analyses in Geosciences can be performed on all types of matter, regardless of the state of the matter. They can be a matter in solid, liquid, or gas states.

Organic materials like coal, shale, petroleum, and its derivatives are also a matter of interest. Carbon, hydrogen, nitrogen, sulfur, and oxygen in solid or liquid samples are determined by various analytic equipment. Those laboratories have also the calorimeters. The macerals are the organic counterparts of the minerals in the inorganic geological matter. Vitrinite, a type of masceral, reflectance is important to measure by a microscope equipped with a photometer, or a digital camera. Since organic materials such as carbon and coal are extremely polluting, organic material preparation should be done in laboratories dedicated only for this purpose, although similar sample preparation laboratories are needed.

Chemical analyses are based on the measuring of absorption, emission, diffraction of energy radiation. There are many different chemical analysis devices and methods. Somes are XRF (X-Ray Fluorescence), AAS (Atomic Absorption Spectroscopy), ICP-OES (Inductively Coupled Plasma-Optic Emission Spectrometry), ICP-MS (Inductively Coupled Plasma-Mass Spectrometer) with a LA (Laser Ablation) equipment (LA-ICP-MS), SIMS (Secondary Ion Mass Spectrometry), TIMS (Thermal Ionization Mass

Spectrometry) and many more methods and devices. In addition, gas and liquid samples can be analyzed in gas and liquid chromatography. The operating principles of each device are given by the manufacturer. For all methods and devices, the users should pay attention to preparing samples and using the laboratories as "Clean Rooms". All safety rules must be applied at the highest level in these laboratories. Chemical analyzes are extremely costly laboratories, and each requires chemicals, carriage gases, cooling gases, crozet, sample holder, liquid/powder cups, sample film, standards, etc.

III. Running Of A Geoscience Laboratory

Laboratories and their needs are extremely complex operations. Laboratory managers, technical personnel, staff job descriptions, laboratory equipment, work management, occupational safety, work production following international standards, timely analysis, the satisfaction of laboratory users, in-service training of staff, student training in academic laboratories, laboratory accreditation, maintenance and repair operations, the supply of consumables, financial management, transparency are the basic issues in the running of a laboratory.

Although solid, liquid, or gas samples are the matter of the subject in earth sciences, the solid samples are dominant among the geological samples.

For the management of laboratories, many software has been developed by different companies under the name of LIMS (Laboratory Information Management System) in the world and presented to the service of laboratories as free or working on subscription (monthly payment) or purchased. Their working algorithms are reachable easily on the internet. With the help of LIMS, Sample Management (Sample Tracking, Workflow, etc), Quality Assurance (Stability, Reproducibility, Certificates, Accreditation, Analyzes following International Norms), Staff and Student Management, Laboratory Execution, Planning, Consumable tracking, Financial Management, Laboratory Inventory Management, Reporting and Documentation, Quotation and Invoicing, Maintenance Management are carried out transparently. Coplen (1998) mention briefly the major benefits of this system installed in an isotope laboratory including (i) an increase in laboratory efficiency, (ii) reduction in the use of paper, (iii) reduction in workload due to the elimination or reduction of retyping of data by laboratory personnel, and (iv) decreased errors in data reported to sample submitters.

IV. Conclusion

A laboratory is the kitchen of a research institution. Laboratories can include all devices from very simple equipment to highly sophisticated high-tech devices. Laboratories;

- It should be managed as a commercial enterprise,

- Laboratories must have their own Strategic Plans and SWOT analyzes must be done,

- Laboratories should be established following ISO (17025), DIN, etc., and other international standards,

- Tests, productions and analyzes must be carried out in accordance with standards such as ISO, DIN, ASTM,

- Occupational Safety and health rules must be followed, Laboratories must be kept clean,

- Staff and student training must be done,

- Laboratories should be managed by establishing a LIMS system,

- Sample acceptance system must be clearly declared and sample return/disposal system should be established after the process,

- Laboratory accreditations should be done,

- Academic Laboratories should be able to serve not only the current staff but also their graduates at advantageous prices to support Alumni,

- High-quality service should be provided to external partners,

- With financial management, equipment should be constantly renewed,

- Active participation in academic studies should be possible.

Acknowledgement

This paper is a short outline about Laboratory Management basing on 23 years of Lab Management Experience.

References

[1] Ceballos, F., Olalla, C., Jiménez, R., 2014. Relationship between RMRb and GSI based on in situ data. In Alejano, Perucho, Olalla & Jiménez (Eds) Rock Engineering and Rock Mechanics: Structures in and on Rock Masses, Taylor & Francis Group, London, 978-1-138-00149-7

[2] Clark,G.B., 1995. Eight Principales of Laboratory Management. Laboratory Medecine, 26/11, 713-714.

[3] Coplen, T.B., (1998). A Manual for a Laboratory Information Management System (LIMS) for Light Stable Isotopes-Version 7.0. U.S. Geological Survey Open-File Report 98-284 Revision of Open-File Report 97-812.

[4] Çubukcu, H.E., Ersoy, O., Aydar, E., Cakir, U., 2008. WDS versus silicon drift detector EDS: A case report for the comparison of quantitative chemical analyses of natural silicate minerals. Micron, 39, 88-94.

[5] Earle, S. (2015). *Physical Geology*. Victoria, B.C.: BCcampus. Ebook ISBN 978-1-989623-71-8 Retrieved from https://opentextbc.ca/geology/

[6] Kalinski, M.E., 2011. Soil Mechanics Lab Manual. John Wiley & Sons, Second Edition. 193p. ISBN-13 978-0-470-55683-2

[7] McComas, W.F., 2014. Laboratory and Science Teaching. In: McComas W.F. (eds). The Language of Science Education. SensePublishers, Rotterdam. https://doi.org/10.1007/978-94-6209-497-0_50

[8] Pain. E., 2012. Laboratory Management. Science. DOI:10.1126/science.caredit.a1200060

[9] Riecker, R.E., 1984. Rock mechanics. In: Finkl C. (eds) Applied Geology. Encyclopedia of Earth Sciences Series, vol 3. Springer, Boston, MA. https://doi.org/10.1007/0-387-30842-3_57

[10] Sandquist, E., 2013. How to become a good lab manager. ASBMBToday, 23.Septembre.2013. https://www.asbmb.org/asbmb-today/careers/092313/how-to-become-a-good-lab-manager

[11] Thomas, S.M., 2015. Infrared and Raman Spectroscopy. https://serc.carleton.edu/NAGTWorkshops/mineralogy/mineral_physics/raman_ir.html#rama

[12] VA Design guide, 1995. Research Laboratory Design Guide. Department of Veterans Affairs Veterans Health Administration Office of Research & Development Office of Facilities Management Facilities Quality Office Standards Service. 98p.

[13] WHO, 2011. Laboratory Quality Management System Handbook. 248p. ISBN 978 92 4 154827 4