

Soil Evaluation Research for Salton Sea-A Survey of Available Salton Sea Soil and Sediment Evaluation Research Literature

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ABSTRACT

The Salton Sea, a saline lake in California, is becoming an environmental disaster. With a receding lakeshore, severe dust emission, and toxic water and soil, Salton Sea ecosystem is on a continuous decline for a long time. Many studies and research have been performed to understand the characteristics of soil and sediments present in Salton Sea region to find the root-cause of the environmental degradation and to provide a mechanism to reverse its affects. This survey aims at providing a detailed analysis of the available research literature on Salton Sea soil evaluation and to identify some of the prevalent methods and practices used by researchers. This survey will provide common soil evaluation parameters, collection and analysis methods used by researchers throughout a long duration of continuous research. Finally, this paper will survey some semi-automatic methods for soil analysis and some AI and ML algorithms which are being applied for general soil evaluation.

Keywords: Soil evaluation, Pesticides, Severity level, Chromatography, Spectroscopy, Machine learning, Artificial intelligence, Support vector machine, Regression

INTRODUCTION

Salton Sea is a 25 x 55 km wide, shrinking saline lake located in southern California. It is surrounded by the agricultural plains of the Imperial Valley in the south, by the Anza-Borrego Desert State Park in the west and by the Coachella Valley on the north. Salton Sea could be categorized as a man-made lake formed during 1905-1907 due to inflows from Colorado river. For a long time, it was the water source and sink for nearby areas. It supported a huge variety of flora and fauna and was also a favorite tourist spot. However, A constant inflow of polluted water from nearby agricultural lands, no drainage outlet and meagre rainfall have converted the lake into an environmental disaster. Now, the beaches are deserted, flora and fauna are nearly extinct, and the odor and insect problems are affecting the nearby areas. Moreover, dust emission from the receding lakebed is contributing to the health problems of local community. The ecology and environment of Salton Sea is under pressure from a long time and there is a need for sustainable solution [1]. Various public and private organizations have performed research and analysis to determine the causes and effects of environmental degradation. Many institutions and agencies have been publishing the research findings even before

1970. The research activities are mostly based on assessing either a specific environmental parameter such as air, water or soil etc. or a combination of these parameters. The conventional evaluation models are based on collecting samples from specific locations, analyzing the samples, and producing results or general findings, to determine the root-cause of the environmental degradation [2]. Physical map of Salton Sea is shown in **Figure 1**.

Soil is an important parameter which provides a variety of useful information about the environmental condition of any region. Soil quality evaluation is particularly important in case of Salton Sea because the future of adjacent agricultural regions depends fundamentally on a healthy and nutritious soil. However, soil evaluation is complex in nature and wide

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in scope. For example, Studying the pesticide contents of the soil to understand the effects of agricultural drainage [4] and identifying the physical composition of soil to study erosion [5] employ completely different soil evaluation techniques. Soil can be evaluated using different criteria and methodologies, and a lot of research has already been performed on soil evaluation methods and techniques [6]. Salton Sea soil and sediment evaluation has been performed

by different research groups using conventional procedures and techniques. This paper surveys the available research literature to obtain the methods and techniques used for the soil evaluation of Salton Sea region over the period of last fifty years. It is important to note that “soil” is a generic term which also includes variants like sediments, playa etc. and this paper would use these terms interchangeably unless specified otherwise.

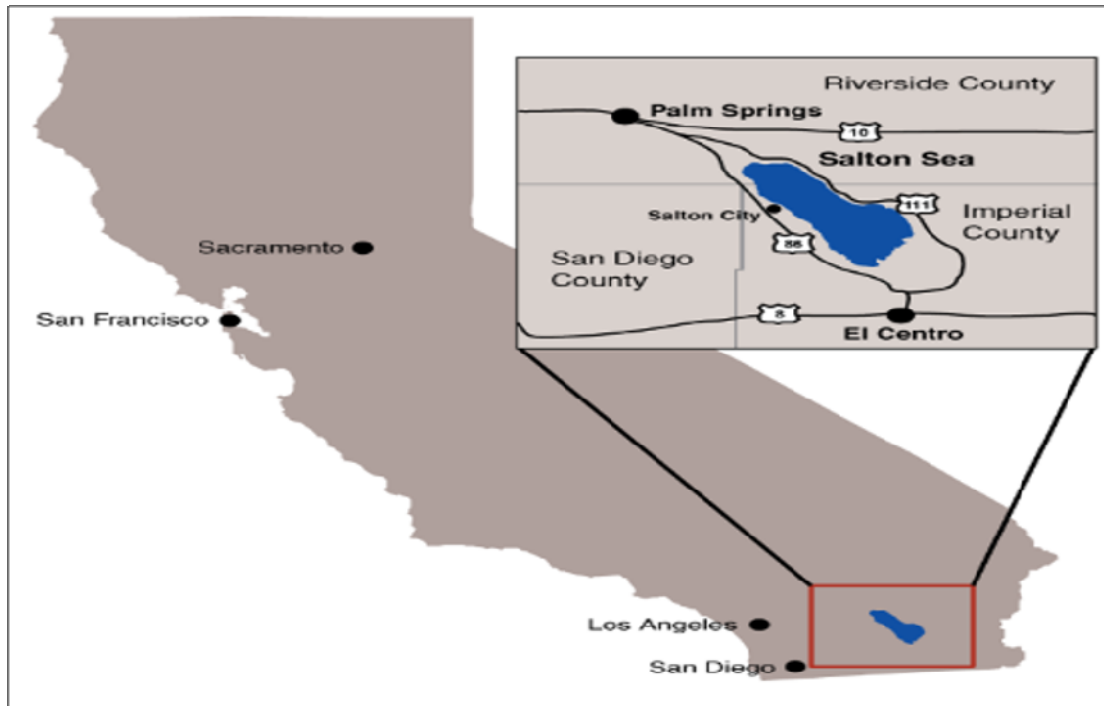


Figure 1. Physical map of Salton Sea [3].

Soil can be evaluated using different parameters. Section II will categorize the parameters used by different research papers for Salton Sea soil evaluation. These primary (Level-I) evaluation parameters or indices will be further classified into more complex secondary (Level-II) parameters which are direct indicators of the soil health of any region. This section will also list Salton Sea soil data, for some of the secondary parameters, collected by different researchers. Section III will provide a general survey of data or sample collection methods used for Salton Sea soil evaluation. Section IV will review and compare various sample analysis and detection methods employed by the researchers. Note that Section II, III and IV are specific to Salton Sea soil evaluation and these sections are derived from the Salton Sea based research papers only. Section V will list some industrial equipment which could be used for semi-automatic soil evaluation. It will also provide a table of Artificial Intelligence (AI) and Machine Learning (ML) based algorithms and techniques which are currently used for evaluation of soil throughout the world. It is a general section and it is not limited to Salton Sea. Section V summarizes the findings of this survey and underlines the

challenges in moving forward. This survey will end with concluding Section VII.

PARAMETERS FOR SALTON SEA SOIL EVALUATION

Soil evaluation is generally performed by identifying primary parameters and dividing these parameters into secondary parameters. Secondary parameters are directly measured by analysis of the soil sample using a chemical, optical or other type of method. Any primary parameter, however, is calculated indirectly by considering a combination of secondary parameters. Secondary parameters have specific ranges or tolerance limits criteria which are generally established by environmental agencies. For Example, the US EPA (Environmental Protection Agency) determines the heavy metal concentration limits in USA [7]. On the other hand, the primary parameters are just an aggregation of secondary parameters and there are no tolerable numerical limits for primary parameters. Majority of research papers on soil evaluation for Salton Sea use the parameters described in **Table 1**.

Table 1. Parameters for Soil Evaluation.

Primary Parameters for Soil Evaluation	Secondary parameters
Soil Crust	Physical, Biological and Chemical
Soil Nutrients and Minerals	Nitrate (NOx), Phosphorous, Nitrogen, Ca, Mg, K, organic C etc.
Heavy Metal and Non-Metal content	Al, Sb, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Hg, Mn, Mo, Ni, Se, Ag, Th, Ti, V, Zn etc.
Pesticides	Insecticides, herbicides etc.
Soil Biochemistry	Soil Moisture, pH, CEC, Organic Matter, SAR etc.

A. Soil Crust Evaluation

Soil crust consists of surface layers of the soil which are constantly evolving due to various environmental factors such as rain, storms etc. Soil crust can be divided into three categories [8]:

- Physical crust: - Sand, Silt, Clay
- Biological crust: - Organic matter, micro-organisms etc.

- Chemical crust: - Salt Mineralogy

For Salton Sea region, study of physical crust provides important information about agricultural suitability such as seed germination, soil moisture content, temperature etc. [9] (**Table 2**).

Biological crust is made up of organic matter and microorganisms which contributes to the productivity of soil. Chemical crust study provides a deeper understanding of soil erosion and therefore dust emission [5].

Table 2. Physical Soil Crust Evaluation for Salton Sea [9].

Analyte	Fall 2006	Fall 2007	Fall 2008
Sand (%)	20.0	32.7	43.3
Silt (%)	50.3	35.7	30.7
Clay (%)	29.7	31.7	26.0

B. Nutrients and Minerals Evaluation

Soil consists of a variety of nutrients and minerals which contribute significantly to the health and wellbeing of the soil and environment. A balance of various nutrients like N,

P, K are essential for soil fertility and plant growth. A couple of research activities have been performed at different times to access the nutrients and minerals in the soil of Salton Sea region. **Table 3** lists some of the nutrients found in the Salton Sea soil [9-13].

Table 3. Nutrients and Minerals Evaluation for Salton Sea.

Parameter	Concentration (Salton Sea)
Nitrate as NO ₃	3 to 27 mg/kg (NO ₂ + NO ₃)
Nitrate as NO ₂	3 to 27 mg/kg (NO ₂ + NO ₃)
Phosphorus	320 to 1600 mg/kg
Nitrogen	23 to 1700 mg/kg (N Organic)
Sulphur	2.25 mg/kg
Chloride	4600-12000 mg/kg
Calcium	36000-62000 mg/kg
Magnesium	7500-11000 mg/kg
Potassium	2000-5900 mg/kg
Sodium	4600-18000 mg/kg
Organic Matter	0.80-2.3 %

C. Soil Biochemistry Evaluation

Soil Biochemistry is a measure of chemical properties of the soil. It could be roughly categorized as a study of chemical reactions and phenomenon in soil. However, a majority of soil biochemistry deals with organic matter content of the soil. Moreover, some studies classify organic matter content as a primary parameter. A limited dataset is available for Salton Sea soil biochemistry analysis (Table 4). Note that there are some other bio-chemistry related parameters, such

as Cation Exchange Capacity (CEC), Sodium Absorption Ration (SAR) which are not listed in **Table 4**. However, the data related to these parameters is not available for Salton Sea.

Note that organic matter concentration and soil moisture changes from one location to another which indicates the differences in regions surrounding the Salton Sea. Also note the high salt content for Salto Sea region [13].

Table 4. Salton Sea Soil Biochemistry Evaluation [13,14].

Parameter	Concentration
CaCO ₃	2.78 to 35.98 %
Soil Moisture	0.3 to 62.8 %
Organic Matter	0.20 to 16.02 %
Reactivity (pH)	6.77-8.90
Salt Content	242 to 585969 mg/kg

D. Evaluation for Pesticides

The parameters discussed above are responsible for soil health and productivity. Now, let us move towards parameters which contribute towards soil toxicity.

One of the most important criteria for soil toxicity evaluation is determining pesticides content in soil. Pesticides are found in almost every landmass adjoining a water body. This is mostly due to the irrigation inflow from nearby agricultural lands. Salton Sea has huge inflow from the irrigation channels of nearby imperial valley and therefore the soil in Salton Sea region contains a variety of pesticides. Pesticides are complex organic and inorganic molecules which have a long and at times complex movement and decomposition cycle. A large quantity of research material is available on Salton Sea soil evaluation for pesticides [10,15,16].

Pesticides can further be divided into various categories depending on the “pest” or “agent.” Some of the categories are:

- Algicide
- Biopesticides
- Fungicides
- Herbicides
- Insecticides
- Rodenticides

Agricultural community use insecticides in large quantities and **Table 5** lists some of the insecticides present in Salton Sea soil.

Table 5. Different Types of Insecticides in Salton Sea Soil.

Group	Insecticide
Organochlorides	Aldrin, Chlordane, DDT, DDD, DDE, Dieldrin, Endosulfan, Endrin, Heptachlor, Hexachlorobenzene, Lindane,
Organophosphates	Chlorpyrifos, Diazinon, Dimethoate, Malathion, Methidathion
Carbamates	Carbofuran, Carbaryl
Pyrethroids	cyhalothrin, Cypermethrin, Cyfluthrin, Permethrin

Salton Sea sediments are extensively evaluated for pesticides. It is a definite conclusion that the number of different pesticides is high in the Salton Sea region. **Figure 2**

provides a chart of p,p'-DDT in sediments collected from various Salton Sea regions over the years as an example [9,15-19].

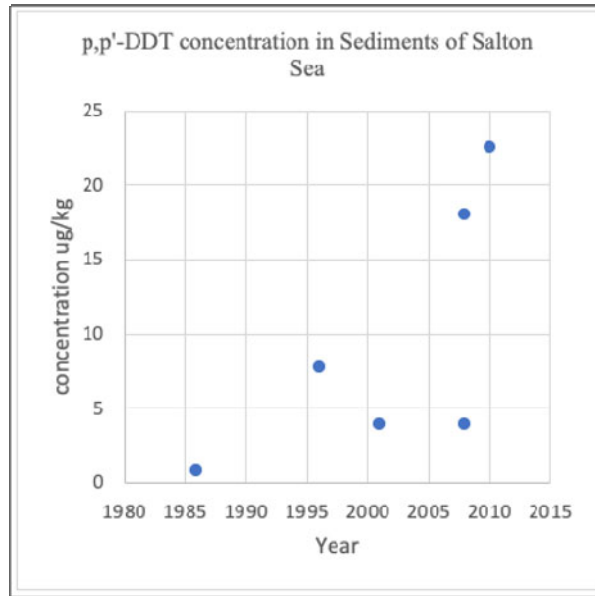


Figure 2. p,p'-DDT concentration chart Salton Sea soil evaluation.

E. Heavy metal and non-metal content

Heavy metals and non-metals also contribute greatly towards soil toxicity. The presence of various heavy metals and non-metals in high quantity is a definite indicator of poisonous soil. This parameter is also largely responsible for making soil barren for any kind of flora and fauna. Salton Sea soil evaluation for heavy metals and non-metals results in very high levels of Selenium and other poisonous metals [20].

Some of the heavy metals and non-metals found in Salton Sea soil are: - Aluminum (Al), Arsenic (As), Barium (Ba), Cadmium (Cd), Cerium (Ce), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lanthanum (La), Lead (Pb), Lithium (Li), Manganese (Mn), Molybdenum (Mo), Neodymium (Nd), Nickel (Ni), Niobium (Nb), Selenium (Se), Silver (Ag), Strontium (Sr), Thallium (Tl), Thorium (Th), Titanium (Ti), Uranium (U), Vanadium (V), Zinc (Zn) (Table 6).

Table 6. Severity Levels for Some Contaminants.

Contaminants	US EPA (TR= 1E-06, THQ = 0.1)		CTSE (Non-Cancer Endpoint)	
	Residential Soil(mg/kg)	Industrial Soil(mg/kg)	Residential Soil(mg/kg)	Industrial Soil(mg/kg)
Aldrin	3.9E-02 c**	1.8E-01 c*	Same as USEPA	3.4E+01
DDT	1.9E+00 c**	8.5E+00 c**	3.7E+01 (4,4' DDT)	4.3E+02 (4,4' DDT)
Chlorpyrifos	6.3E+00 n	8.2E+01 n	6.3E+01	5.3E+02
Carbaryl	6.3E+02 n	8.2E+03 n	6.3E+03	5.3E+04
Permethrin	3.2E+02 n	4.1E+03 n	3.2E+03	2.6E+04
Arsenic, Inorganic	6.8E-01 c**R	3.0E+00 c*R	4.1E-01	4.2E+00
Barium	1.5E+03 n	2.2E+04 n	-	-
Chromium (VI)	3.0E-01 c*	6.3E+00 c*	2.3E+02	3.5E+03
Cobalt	2.3E+00 n	3.5E+01 n	-	-
Copper	3.1E+02 n	4.7E+03 n	-	-
Lead and compounds	4.0E+02	0E+02 L	8.0E+01	3.2E+02
Manganese (Non-Diet)	1.8E+02 n	2.6E+03 n	-	-
Mercury (Elemental)	1.1E+00 n	4.6E+00 ns	1.0E+01	4.4E+00
Molybdenum	3.9E+01 n	5.8E+02 n	-	-
Selenium	3.9E+01 n	5.8E+02 n	-	-
Silver	3.9E+01 n	5.8E+02 n	-	-

c = cancer; n = noncancer; * = where: n SL < 100X c SL; ** = where n SL < 10X c SL, R = RBA applied

United States Environmental Protection Agency (US EPA) provides guidance about screening levels (Regional Screening Levels) of various chemical contaminants in the soil from cancer and non-cancer end points. It provides the generic RSL tables and guidance about equations to calculate the various types of chemical risks associated with a chemical contaminant to various entities like residents, workers etc. [7]. California EPA and DTSC (Department of Toxic Substance Control) also provides the screening levels of various chemical contaminants from cancer and non-cancer end points [21]. These two datasets are often used for identifying the maximum limits for soil contaminant

evaluation. **Table 6** provides generic RSLs for some of the toxic soil parameters.

METHODS USED FOR SOIL SAMPLE COLLECTION

A major aspect of soil evaluation is sample collection. It is difficult to perform soil evaluation using remote sensing techniques. However, there are some remote sensing techniques to predict limited soil parameters such as soil moisture [22]. For Salton Sea, majority of sample collection methods were manual in nature. **Table 7** summarizes the details of methods used for sample collection by different researchers for soil evaluation.

Table 7. Methods of Data Collection for Salton Sea Soil Evaluation.

Reference	Timeline	No. of Sites	Frequency	Type	Instruments Used
HydroGeo Consultants [23]	Phase 1: December 15-22, 1998 Phase 2: January 1-22, 1999	Phase 1: 42 + 6 Phase 2: 15 + 10	Not Mentioned	Manual	stainless-steel modified Birge-Ekman-style box sediment sampler AMS stainless-steel soft sediment sampler
Roy A Schroeder [4]	1995-1996: NA 1996: May 31, 1996 1998: July 20-22, 1998 1999: April 25-27, 1999 2001: October 23-28, 2001	1995-1996 : 6 Sites 1996 : 1 Site 1998 : 11 Sites 1999 : 2 Sites 2001 : 9 Sites	Once only	Manual	Ekman dredge Ekman dredge
King [13]	September 21–30, 2005 January 24–27, 2006 (JA06) March 20–24, 2006 (MR06) February 8–11, 2007 (FE07)	14 + 3 + 2	4 times	Manual	NA
LeBlanc [16]	October 20-29, 2001 March 14-22, 2002 April 16-18, 2002 September 16-25, 2002	9	Once each time each site	Manual	23-cm Ekman grab sampler, 5-cm diameter, Teflon-barreled hand corer + Ekman dredge
Sapozhnikova [15]	May 2000	6	NA	Manual	Ponar grab sampler
Hultgren - Tillis Engineers [11]	9/29/2010	6	One time	Manual	Hand auger
Radtke [10]	NA	15	One time	Manual	BMH-53 hand-operated piston-type corer.
Buck [5]	February 9-11, 2007	12	One time	Manual	NA

METHODS FOR SAMPLE ANALYSIS

The final aspect of soil evaluation is the analysis of soil sample collected in the field. Analysis of sample to determine the concentration of different parameters is normally performed by using one of the standard chemical analysis methods listed here.

1. Ion Chromatography (IC)

Ion Chromatography is a prevalent chemical analysis method which is capable of detecting almost any charged molecule including large proteins, small nucleotides, and amino acids. It works via separation and quantitative analysis of anions and cations in an ionic solution using the ion exchange method of liquid chromatography (LC).

2. Gas Chromatography (GC)

Chemical analysis method which is applicable to any compound that can be vaporized without decomposition (like NO₃, NO₂, P, N etc.). The components of a sample are dissolved in a solvent and vaporized in order to separate the analytes by distributing the sample between two phases: a stationary phase and a mobile phase. The mobile phase is a chemically inert gas that serves to carry the molecules of the analyte through the heated column.

3. Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)

ICP-AES is a chemical analysis method used for determining trace elements, including metals, in solutions. All matrices including ground water, aqueous samples, TCLP and EP extracts, industrial and organic wastes, soils, sludges, sediments, and other solid wastes, require digestion prior to analysis. The ICP-AES is composed of two parts: the ICP and the optical spectrometer. Every ICP has a source, or plasma, optics to split the light into its various wavelengths, and a detector to measure each specific wavelength and its intensity. The position of the light on the detector determines its wavelength and the intensity is proportional to concentration.

4. Inductively Coupled Plasma Mass Spectroscopy (ICP-MS)

ICP-MS is a chemical Analysis method used for metals and non-metals detections. It can also detect isotopes. It works via atomizing the sample and creating atomic and small polyatomic ions, which are then detected.

5. Energy Dispersive X-Ray Fluorescence Spectroscopy (ED-XRF)

It is an X-Ray based analysis method capable of detecting all the elements. This type of XRF instrumentation separates the characteristic x-rays of different elements into a complete fluorescence energy spectrum which is then processed for qualitative or quantitative analysis (Table 8).

Table 8. Methods of Sample Analysis for Salton Sea Soil Evaluation.

Method	EPA Standard	Primary Parameters	Secondary Parameters	Advantages	Disadvantages
Ion Chromatography [24,25]	EPA 0007C, EPA 300	Soil Nutrients and Minerals	Nitrogen Oxide. Chloride, Fluoride, Bromide. Other Inorganic Anions, Nitrate, Nitrite	Highly Selective. Used at all scales and stages of purification. Resolve molecules with small charge differences.	Expensive Equipment. Turbidity Requirement < 10 ppm.
Gas chromatography [24,26-28]	EPA 0007C, EPA 0016B, EPA 8081 EPA 8141	Soil Nutrients and Minerals Pesticides	Organic Compounds Sulfur Organohalide Pesticides and PCBs Other Pesticides	High sensitivity. Accurate and precise. Small sample is required for analysis.	Non-responsiveness to column inorganic compounds. Mobile phase impurities are not detected
ICP-AES [29]	EPA 6010B	Heavy metals and Non-metals	Al, Sb, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Hg, Mn, Mo, Ni, Se, Ag, Th, Ti, V, Zn	Excellent dynamic range and limit of detection. Low-chemical interference and multi-element capability. Stable and reproducible signal.	Huge cost of infrastructure maintenance and operation. Sample should be dissolved in the solutions before analysis.
ICP-MS [30-32]	EPA 200.8, EPA 6020A, EPA 6020B	Heavy metals and Non-metals	All elements from atomic number 7 to 250	Greater speed, precision, and sensitivity than ICP-AES.	Techniques like TIMS and GD-MS are superior.
ED-XRF [30-32]	EPA 200.8, EPA 6020A, EPA 6020B	Heavy metals and Non-metals	All elements from atomic number 7 to 250	Simple operation, compact, low price. Flexibility in specimen shape	Suffers from low resolution (overlapped peaks) and requires cooling mechanism requiring liquid nitrogen or the like

6. Other methods

These are some other methods found in the research literature for Salton Sea soil sample analysis. These methods

are specially used for soil crust and biochemistry evaluation (Table 9).

Table 9. Other Analysis Methods for Some Parameters.

Parameter	Method
Soil crust Evaluation [5]	X-Ray Diffractometry (XRD) and Scanning electron Microscopy-Energy dispersive X-Ray Spectrometry (SEM-EDS)
Soil pH [33]	1:1 soil-aqueous matrix suspension method
Soil Moisture	Weight based sample measurement
Organic Matter [34]	“Loss on ignition” Method
CEC [35]	Ammonium Saturation Method

Automatic Approaches for Soil Evaluation

This section provides a general description about some “automatic” approaches which could be used to automate the soil evaluation process. These approaches are not taken from research literature for Salton Sea soil evaluation. This is an exploratory section which is applicable to any kind of soil evaluation including Salton Sea soil evaluation. The data and

methods described in this section are general in nature and these approaches could be used to partly automate the soil evaluation practices.

1. Automatic parameter evaluation instruments

There are some commercially available instruments which could be used to evaluate some of the parameters of the soil. Table 10 provides a list of some such instruments.

Table 10. Instruments for evaluating soil parameters.

Primary parameters	Secondary Parameters	Product Name(s)	Company	Specifications
Biochemistry	Soil Moisture, pH	AWZSDF Soil Water Moisture Light PH Meter	AWZSDF	pH Range: 3-8 Moisture Range: 1-8
Minerals and Nutrients	N, nitrate, ammonium, P, available potassium, organic matter, total N, total P, total K	NPY-6A, NPK, Organic matter, pH, Salinity test automatic Soil Nutrient Tester. NB-Q Series	Zhengzhou Nanbei Instrument Equipment Co. Ltd. China	pH Range: 1-14 Salinity Range: 0.01% - 1.00% Moisture Range 0-100%
Pesticides	Organophosphate and carbamate pesticides	CNH-81 series quick bio pesticide residue test, NB-C16 PESTICIDE RESIDUE TESTER	Hangzhou West Tune Trading Co., Limited, China Zhengzhou Nanbei Instrument Equipment Co. Ltd. China	detection limit :0.1~3 .0 mg / L (organic phosphorus and carbamate)
	Organochlorine pesticides	Multi Parameter Pesticide Residue Tester	Zhengzhou Nanbei Instrument Equipment Co. Ltd. China	Organophosphorus range: 0.03-20 mg/kg Carbamate range: 0.03-20 mg/kg Esbiothrin range: 0.10-30 mg/kg Organochlorine range: 0.10-10 mg/kg
Heavy metals and Non-metals	Pb, Cr, Cd, As, Hg	NB-Q10	Zhengzhou Nanbei Instrument Equipment Co. Ltd. China	Measuring range: 0.001 - 9999%
	B, Mn, Fe, Cu, Ca, Mg, S, Cl, Zn, Si	NB-Q10	Zhengzhou Nanbei Instrument Equipment Co. Ltd. China	Measuring range: 0.001 - 9999%

2. Machine Learning based evaluation Methods

Most of the research literature for general soil evaluation follow traditional methods as described earlier. However, to some extent, some Machine learning and artificial

intelligence algorithms could be successfully applied to automate the process of soil evaluation. It is important to note that soil evaluation using AI and ML techniques is still an active area of research. In fact, one of the interesting

findings of this survey is that no AI and ML based technique is applied on Salton Sea soil evaluation.

analysis. In all cases, AI and ML algorithms are used with an existing method to obtain tangible results.

Table 11 is compiled from the study of available soil evolution research which use AI and ML for soil sample

Table 11. AI and ML based approaches for soil evaluation.

Parameters	Method Type	Chemical Method Type	ML method Type	Parameters identified	Location
Soil Crust [36,37]	Chemical + ML	NIRS	PRL	Clay, Silt, Sand (r2>0.80)	Multiple locations, USA
	Chemical + ML	Reflectance Spectroscopy (Near-infrared, short-waved infrared)	MBL, PLSR, SVMR, BRT	Clay, Silt, Sand	Czech Republic
Nutrients and Minerals [36,38]	Chemical + ML	Kjeldahl Method (Total N) Alkaline hydrolysis diffusion method (Available N) Olsen method (Available P) Ammonium acetate method (Available K) Heating potassium dichromate in an oil bath (Organic Matter) pH meter (pH)	SQ-SVM Model	(pH, Total N, Organic Matter, Absorbed N, P, K)	Taiyuan city, Shanxi, China
	Chemical + ML	NIRS	PRL	Total C, Total N, Biomass C, Sodium (r2>0.80) Ca, Mg, K : - Less accurate (r2 = 0.50-0.80)	Multiple locations, USA
Biochemistry [36]	Chemical + ML	NIRS	PRL	CEC, Soil Moisture (r2 > 0.80) pH: - Less Accurate (r2 = 0.50-0.80)	Multiple locations, USA
	None	No direct paper found	No direct paper found	(Salt content, CaCO3, SAR)	-
Pesticides [40]	None	No direct paper found	No direct paper found	All Pesticides	-
	Chemical + ML	Gas Chromatography - Mass Spectrometry	MLP, RBF, SVR, MSP, MSR, LR	PAH compounds	UK
Heavy metals and Non-metals [36,38,39,41]	Chemical + ML	VisNIR	PLSR, SVM, BPN	Pb, Zn	Sarcheshmeh mine, Iran
	Chemical + ML	Atomic Fluorescence Spectrometry (Hg) Graphite furnace atomic absorption spectroscopy (Cd) Flame atomic absorption spectroscopy (Pb, Cr, Cu, Zn, Ni)	SQ-SVM Model	(Cu, Zn, Ni, Cr, Pb, Cd, Hg, As)	Taiyuan city, Shanxi, China
	Chemical + ML	XRF (Trace Metals) Atomic Absorption spectrometer (Hg, As)	MLR, ANN	(As, Cd, Cu, Fe, Hg, Pb, S, Sb, Zn) (Results for Cd, Cu, Zn were not accurate)	Aznalco'llar Mine, Spain
	Chemical + ML	NIRS	PRL	Ca, Cu, Fe, K, Mg, Mn, P, Zn: - Less accurate (r2 = 0.50-0.80 to r2 < 0.50)	Multiple locations USA

*PRL stands for Principle Component Regression, MBL for Memory Based Learning, PLSR for Partial Least Square Regression, SVMR for Support Vector Machine Regression, BRT for Boosted Regression Tree, MLR for stepwise Multiple Linear Regression analysis, ANN for Artificial Neural Network, MLP for Multi-Level Perceptron, RBF for Radial Basis Function, SVR for Support Vector Regression, MSP for M5 Model Tree, MSR for M5 Rule, LR for Linear Regression, NIRS for Near-Infrared Reflectance Spectroscopy, VisNIR for Visible and near-infrared and shortwave infrared reflectance spectroscopy

ISSUES, NEEDS AND CHALLENGES

Some of the issues discovered by this survey and the respective needs are listed below.

- Issue#1: Most of the traditional methods used for soil evaluation of Salton Sea are manual in nature. Traditionally, soil evaluation is a laborious task which is highly dependent on manual efforts such as sample collection, laboratory test etc. All these factors make soil evaluation an arduous, time consuming task.
- Need#1: Transition towards semi-automatic and automatic methods for analysis. There is a strong need to perform soil analysis using modern automatic analysis techniques which will reduce the time and produce results swiftly.
- Finding#2: High reliance on chemical analysis is observed. There are limited evaluation methods which could be used as an alternative. One exception was soil moisture evaluation where satellite-based methods are used for Salton Sea [22].
- Need#2: Alternative approaches should be used for some parameters. Though it is difficult to analyze soil without using chemical methods, yet it is important to employ alternative methods for the analysis of several simple parameters like soil moisture. It is also desirable to derive some alternate methods based on modern AI and ML techniques which could simplify the process.
- Finding#3: There is a high degree of variance between different research data. Various researchers have collected the data using different techniques and methods over a large period of time. Therefore, big differences are observed for some parameter's values in different studies.
- Need#3: There is a need for comprehensive model which could be used uniformly and provide low variance. A standardized framework will provide options to collect data in a uniform manner. It will also allow reuse of the data for a variety of analysis.
- Finding#4: Limited use of AI and ML techniques for Soil evaluation of Salton Sea. No research literature mentions applying AI and ML techniques to Salton Sea soil evaluation.
- Need#4: AI and ML based techniques should be implemented for soil evaluation of Salton Sea. This will result in a major improvement over almost all the aspects of traditional soil evaluation. It will reduce the time and effort and will also enable researchers to perform predictive analysis to identify the fragile parameters in Salton Sea soil.

Soil evaluation is a challenging subject. Most of the process is manual which makes soil evaluation even less feasible

than evaluation of other environmental parameters. It could be concluded that the overall process cannot be transformed into a totally automatic one, at least without significant research and development. There are some major repercussions of this limitation. Being manual, the process is time consuming, and as a result, it could not be performed repeatedly without considerable efforts. This results in either non-availability of data or obsolete data for comparative analysis. Other challenge is managing the financial aspect of the process. The instruments which can perform the tests are expensive and usually require expert support. As discussed throughout the paper, soil analysis can be performed using different instruments and techniques. A subtler challenge is to convince the researchers to follow a standard set of procedures and techniques to make data more reusable.

CONCLUSION

Salton Sea is California's largest lake. It has been a lifeline of local communities and a wide variety of flora and fauna for more than 100 years. Its survival is crucial for the success and prosperity of the region. Therefore, an improved and focused approach is required to reverse environmental degradation of the Salton Sea. A better understanding of various environmental parameters is essential to fulfill this mission. This work has identified the traditional methods of evaluation of one such environmental parameter – soil. This paper has surveyed the available research literature to obtain a comprehensive understanding of methods and techniques used for Salton Sea soil and sediment evaluation. Most importantly, it has retrieved a general set of primary and secondary parameters used for Salton Sea soil evaluation by various researchers. This paper has also provided a comprehensive set of data collection and data analysis methods used for Salton Sea soil evaluation. Finally, modern soil evaluation methods using AI and ML, which attempt to solve the problem using a completely different approach, are presented. Major findings and challenges are also highlighted separately.

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