TEXAS NATURAL RESOURCE CONSERVATION COMMISSION (TNRCC)

On behalf of the

TEXAS ON-SITE WASTEWATER TREATMENT RESEARCH COUNCIL (MC-178)

"CALICHE SOILS AS A FILTER MEDIUM FOR TREATMENT AND DISPOSAL OF WASTEWATER" FINAL REPORT

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EXECUTIVE SUMMARY

Caliche Soils as a Filter Medium for Treatment and Disposal of Wastewater

Through support from the Texas On-Site Wastewater Treatment Research Council, a project to search the literature relative to caliche materials as a medium for treatment and disposal of wastewater has been conducted. It was hypothesized before undertaking this effort that there would be a dearth of published and unpublished information on this subject. Specifically, the goals of the project were to:

- Provide a working definition of "caliche" in relation to treatment of wastewater.
- Perform a comprehensive literature review on the effectiveness of caliche soils as a bioremediation filter media in the treatment and disposal of wastewater.
- Develop recommendations for future research that would address issues identified above.

Definition of Caliche:

The term "caliche" is a very broad, ambiguous and sometimes a misleading term. It has both geological and pedological contexts and stems from the Latin root *cal* meaning lime. The working definition of caliche is "*a pedogenically altered limy material that contains more than 40% calcium carbonate equivalent and has sufficient accumulation of pedogenic carbonates to meet the minimum requirements of a calcic or petrocalcic horizon"* as defined in Soil Taxonomy.

The definition clearly restricts caliche *to weathered soil materials*. This distinction is important because pedogenic materials contain higher levels of organic matter and porosity that directly influence the bioremediation quality of caliche materials.

Virtually the entire extent of presumed geologic/geographic environments conducive to caliche soils in Texas lies west of the 98th Meridian (which roughly coincides with the 30-inch isohyet). Notable areas having widespread caliche soils include the Hill Country carbonate-rock terrain, the Reynosa Plateau of South Texas, and alluvial plains occurring in various geologic/geographic provinces. Soil survey data of Texas suggests that over 15 million acres or 9 % of the State are caliche soils meeting the above definition. This emphasizes the importance of caliche as a soil resource for on-site wastewater systems in Texas. In some areas of the State the soils are not carbonatic but still have lower soil profiles, which meet the definition of caliche, hence the above estimate might underestimate significant extents of caliche conditions in Texas.

The literature review was conducted using the traditional searches with library computer search engines. Keyword combinations were used with each search engine to narrow the list of possible citations. Keyword combinations were developed from the following words: pH, caliche, carbonate, calcium carbonate, calcic, petrocalcic, limestone in combination with filter field, septic systems, effluent, sewage, septic systems, wastewater. In addition, letters were sent to professionals most likely conducting research or having experience with this topic.

Literature Search:

Of the 205 different combinations and search engines used within the traditional literature, there were a total of 3608 keyword citation matches. Over 90% of the citations dealt with pH keyword combinations with effluent, wastewater, sewage, septic systems, and filter fields. Most of these were specific to municipal wastewater systems, reclamation of acid mine drainage, and land farming of sewage wastes. Likewise, most of the wastewater keyword combinations with limestone, calcium carbonate, and calcareous (and those associated with calcium carbonate and carbonate coupled with effluent and sewage) were directed to municipal wastewater issues. Of the remainder citations only 71 (about 2%) appeared to be of possible interest. Further scrutiny indicated that only 35 contained information of general interest to the search at hand, and only 3 dealt specifically with wastewater treatment in caliche soils, *per se*.

The most pertinent literature directly germane to the effectiveness of caliche soils as a bioremediation filter media indicated that caliche:

- was effective in removing P and heavy metals from domestic wastewaters,
- had high efficiencies for removal of total organic carbon from effluents (97%),
- had high oxidation rates with rapid decay of BOD materials over short transport distances,
- was well buffered in the alkaline pH range because of calcium carbonate,
- generally had low nitrate levels under field study conditions due to plant uptake, nitrification/denitrification, or immobilization in upper soil/limestone layers but sometimes indicated elevated nitrate dispersal,
- had immobilized most heavy metals in upper soil horizons,
- had minimal transport of the of the septic effluent into lower soil layers because high evapo-transpiration rates (except during significant storm events), and
- indicated possible transport of fecal coliform in surface and subsurface flow through macropore conduits such fissures and fractures in the soil/limestone.

There was no information directly germane to the viability of viruses in caliche soils though from previous work some general hypotheses may be formulated relative to their viability and these are noted in the report.

There were 71 citations (about 2%) that appeared initially to be of possible interest, but upon further scrutiny only 35 contained information of general interest to the search at hand, and only 3 dealt specifically with wastewater treatment in caliche soils, per se.

The contact with individuals to assess gray literature of a non-refereed nature was in general not very productive. However, several contacts, and specifically on-site wastewater specialists in Florida Department of Health, were most helpful. They noted several concerns about dissolution and reprecipitation of caliche materials yielding a subsequent medium that was cemented like limestone or concrete.

Recommendations:

The following recommendations are made to the Texas On-Site Wastewater Treatment Research Council for there consideration:

These are critical future research needs if caliche materials are going to be broadly utilized in Texas as filter media for on-site wastewater treatment:

- in-situ research on caliche materials conducted under field conditions rather than with laboratory column studies—the former cannot be adequately simulated in the laboratory because scaling limitations that do not adequately represent spatial diversity of caliche soils in the field;
- establish specific pathways (soil structure, fissures, fractures, biovoids, etc.) of water transport in different types of caliche soils using anionic dye-staining techniques to assess risks for rapid discharge of wastewater into shallow ground water aquifers;
- document on-site hydrology of representative caliche soils to verify infiltration rates, depths and durations of saturation/reduction, presence of restrictive aquitards, water retention capacities, surface and subsurface discharge, and water balance models;

- establish risk assessments of nitrate, phosphorous, heavy metal and pathogen transport to subsurface aquifers when caliche soils are subjected to high rates of wastewater loading;
- develop models for calculating loading rates specific to caliche soil attributes; and
- determine hydraulic changes in caliche soils subjected to high loading rates of domestic

wastes, especially evidence for dissolution of carbonates, formation of macroporosity, increased saturated hydraulic conductivity, and greater channel flow.

INTRODUCTION

Through a grant from the Texas On-Site Wastewater Treatment Research Council, Contract Number_________________a literature relative to caliche materials as a medium for treatment and disposal of wastewater was performed. It was hypothesized before undertaking this effort that there would be a dearth of published and unpublished information on this subject. The project was initiated November 1, 2000 and is to be completed by March 31, 2001. Specifically, the tasks of the project were to:

- Provide a working definition of “caliche” in relation to treatment of wastewater.
- Perform a comprehensive literature review on the effectiveness of caliche soils as a bioremediation filter media in the treatment and disposal of wastes.
- Develop a bibliography of all references on the subject with a brief summary or abstract of contents.
- Summarize findings on the effectiveness of caliche to treat and dispose of wastewater from subsurface disposal systems based on what has already been researched.
- Develop recommendations for future research that would address issues identified above.

HOW WAS THE LITERATURE REVIEW CONDUCTED?

The literature review was conducted initially by using the traditional searches with library computer search engines (Table 1). There are other search engines available besides the ones that were used; however, each search engine uses one of the few main database sources for abstracts. Two engines that use the same database source reap the same abstracts. For each of the keyword combinations, we used one search engine per database source. We believe those engines searched to date have reaped the major responses. Listed below in Table 1 are the search engines used and the source of the database.

Table 1. Search Engines used and the source of the database.

GeoRef SilverPlatter and Web Spirs

AgricolaNational Agricultural Library's (NAL)

Web of Science Institute for Science Information (ISI)

First Search Article First, UnionLists and Paper First.

CAB Abstracts Ovid

Water Resources Abstracts Cambridge Scientific Abstracts (CSA)

Applied Science & Tech Abstracts Wilson Web

Compendex Engineering Information (Ei)

Listed below are the keyword combinations used within each search engine query to narrow citations most appropriate for this literature search:

pH + filter field, pH + septic systems, pH + effluents, pH + sewage, carbonate + filter field, carbonate + septic systems, carbonate + effluent, carbonate + sewage, petrocalcic + filter field, petrocalcic + septic systems, petrocalcic + effluent, petrocalcic + sewage, calcium carbonate + filter field, calcium carbonate + septic system, calcium carbonate + effluent, calcium carbonate + sewage, caliche + filter field, caliche + septic systems, caliche + effluent, caliche + sewage, , wastewater + pH, wastewater + calcareous, wastewater + calcium carbonate, wastewater, wastewater + petrocalcic, wastewater + caliche, and wastewater + limestone.

Because the results from the traditional literature were limited, an overall search through non-scientific search engines was conducted. The search engines were Yahoo, HotBot, Alta Vista, Excite and Dogpile. There was no usable information gathered using these sources. Most of the information found was either too general or was advertisements for consulting companies.

In addition to literature searches, 102 letters were sent to professionals in the western states working for state and federal government agencies. The professionals included pedologists, engineers, chemists and geologists. Letters were sent to TNRCC employees in the counties of Texas that contains caliche soils. These responses should yield additional information on gray literature (that not found in the traditional literature citations). To date few responses were received from this source of information. Those received will be identified in the report.

WHAT IS CALICHE?

Geological Concepts:

The term *caliche* is highly ambiguous. It has multiple definitions depending on the context and professional disciplines involved. It is derived from the Latin root *cal* meaning lime. However, in the Glossary of Geology (Jackson,1997) the term carries two sets of definitions, one from the sub discipline of economic geology [eco-geol], and the other from a pedologic definition [soil]. The former implies: gravel, rock, soil, or alluvium cemented with soluble salts of sodium in nitrate deposits of deserts in northern Chile and Peru; thin layer of clayey soil capping a gold vein (Peru); whitish clay in veins along a fault zone (Chile); feldspar, white clay, or compact transition *limestone* (Mexico); and a mineral vein recently discovered or a bank composed of clay, sand, and gravel in placer mining (Columbia). At the extreme caliche has been compared to loess deposits (Reeves, 1970 and Brown, 1956), bog iron ore by Price (1933), and bauxites (Swineford et al.,1958).

Hence, the geologic perspective on caliche consists of a confusing amalgam of rock/mineral associations, and modes of origin. Astonishingly—given the prefix of the word (cal), and its apparent root in the Latin word for lime—*The American Heritage Dictionary of the English Language* bases its definition of caliche solely on that stemming from economic geology: “A crude sodium nitrate occurring naturally in Chile, Peru, and the southwest United States, used as fertilizer. b. See sodium nitrate. 2. See hardpan.” Other words, besides hardpan, that may be synonyms for caliche, include duricrust, calcrete, kankar (India), and tepetate. As noted in the AGI Glossary, the etymology of the word is rooted in American Spanish, from references to almost any porous material cemented by calcium carbonate. The apparent original use of the word was for small stones burned with the clay mass when brick or tile was made, or the crust of lime or mortar flaking from a wall. This application still has currency today with the word, calx, which is defined as “the crumbly residue left after a mineral or metal has been calcined or roasted” (*The American Heritage Dictionary of the English Language*). In Texas and other southwestern states, caliche is often used to describe limestone, marl, petrocalcic horizons, tuffaceous material (Alan Cherepon, 2001), and any light colored soil or sediment.

So the geologic literature is littered with references to caliche that refer not just to secondary limy deposits at or near the ground surface, but to an ungainly array of materials: kaolinite, feldspar, quartzite, bauxite, and others. Not surprisingly, a diversity of processes has been evoked in the formation of caliche: precipitation from shallow lakes and from streams, precipitation by groundwater and by capillary movement along the upper fringes of the water table, by evaporation (as in a playa lake), in-situ weathering of bedrock, and pedologic processes. At least most geologists currently studying near-surface processes adhere to the pedologic origin of caliche or to some variation thereof. Geologists, given their attempts at reconstructing past environments, pay considerable attention to caliche deposits in the rock record and to the ancient environments that formed them. It is an old problem for geology, the end product noted in the rock record may have been formed by a variety of convergent processes.

Pedological Concepts:
The Glossary of Geology (Jackson, 1997) gives the term caliche as a synonym for *calcrete.* It has been applied broadly in the Southwestern U.S. as the reddish-brown to buff or white calcareous material of secondary accumulation, commonly found in layers on or near the surface of stony soils of arid and subarid regions, but also occurring as subsoil deposit in subhumid climates. Sometimes caliche has been reserved for just the cement in calcareous and non-calcareous host gravels, sands, silts, and clays. Compositionally, it is mostly calcium carbonate but may include magnesium carbonate, silica or gypsum in various degrees of induration and in different morphological forms. Hard crusts, plates, nodules, soft porous masses, and massive strongly indurated zones are common. These distinctive materials have been called*: hardpan, calcareous duricrust, calcareous crust, croute calcaire, nari, sabach,* and *tepetate* in various parts of the world. In more recent pedological literature, calcic and *petrocalcic* are the terms commonly in vogue as substitutes for caliche (Soil Survey Staff, 1998). Caliche is considered obsolete by soil scientists because of its unrestricted usage (Wilding, et al., 1999).

Working Definition of Caliche*:*
Because of the common usage of the term caliche in engineering and wastewater practicing professional circles of Texas, the term caliche will be retained but its working definition will be restricted, and its usage limited to a pedological context. The working definition of caliche is "*a pedogenically altered limy material that contains more than 40% calcium carbonate equivalent and has sufficient accumulation of pedogenic carbonates to meet the minimum requirements of a calcic or petrocalcic horizon"* as defined in Soil Taxonomy (Soil Survey Staff, 1998). These materials may be either indurated (petrocalcic) or non-indurated (calcic); they have variable texture, morphology, thickness, and origin; however, they are differentiated from soft and hard limestones, or sediments derived therefrom, by sufficient weathering to form accumulations of pedogenic carbonates equivalent to at least 5% by volume identifiable forms (e.g. carbonate filaments, threads, soft masses, hard nodules, coatings, pedants, etc.). This is important because of enhanced organic matter and soil structure, which influence biotic activity, porosity and pathways of water movement.
The above definition clearly restricts caliche *to weathered soil materials*. This definition would exclude, for example, unweathered marls, chalks, soft limestones, hard limestones, and highly calcareous recent alluvial deposits. While some of these materials may be used as on-site wastewater treatment media, they are geologic materials and not caliche. This distinction is important because pedogenic materials contain higher levels of organic matter and porosity that directly influence the bioremediation quality of caliche materials. Higher organic matter contents favor higher microbial activity and oxidation rates of organic compounds under well drained conditions, and higher denitrification of nitrates under wet, anaerobic soil conditions. Enhanced porosity resulting from soil weathering increases microporosity and water retention. On the other hand, the formation of soil structure, biopores, and other types of macropores (fissures, cavities or fractures) may enhance flux of water and waste effluents through the soil without sufficient residence time for adequate bioremediation. Such effects could lead to increased losses of nitrates, phosphates, and other contaminants to ground waters, and thus decreased bioremediation quality of the caliche material. Lastly, pedogenic weathering of caliche materials can effectively translocate carbonates to lower soil layers and plug macropores such as bedrock joint planes, fissures and fractures so that these conduits are less effective in transmitting pollutants into and through water recharge vadose zones.

WHERE CAN CALICHE BE FOUND?

Regional distribution of caliche is mostly west of the 97th degree meridian in the U.S. (Machette, 1985, Fig. 1). However, this small-scale map likely omits large areas in south Texas and sections of the High Plains where caliche soils are known to occur.

Geological Inferences:
Geologic/physiographic regions in Texas favorable for the formation of caliche soils are given in Figure 2 (Bureau of Economic Geology, 1992 and Ferguson, 1986). The units shown on this state-wide map are chiefly drawn along geologic boundaries, although certain physiographic regions are also delimited without regard for geologic age and rock types contained within these regions (for example, the mountainous reaches of Trans Pecos Texas). Virtually the entire extent of presumed geologic/geographic environments conducive to caliche soils in Texas lies west of the 98th Meridian (which roughly coincides with the 30-inch isohyet). But included within the various map units are certain areas that do not typically include extensive caliche soils; for example, most of the Edwards Plateau is noted for its thin, rocky soils, and much of the mountainous terrain of Trans Pecos comprises rocky uplands without widespread caliche soils. Yet for both regions, local areas may be expected to exhibit caliche soils. Notable areas having widespread caliche soils include the Hill Country carbonate-rock terrain, the Reynosa Plateau of South Texas, and alluvial plains occurring in various geologic/geographic provinces—ranging from the extensive gravel plains off the edge of the Caprock Escarpment; Uvalde Gravels and related alluvial plains off the southern edge of the Balcones Escarpment; and the bolsons of the Trans Pecos Basin and Range Province. The Caprock Caliche, which makes up part of the Ogallala Formation, underlies the vast reaches of the High Plains; yet caliche soils may generally be restricted to local playas and stream incisions, owing to widespread cover by aeolian sand sheets. Because of scale of base maps used for this illustration, much allowance must be made for inclusions of materials that vary from the general descriptions of the various units.

Soil Survey Inferences:
A more comprehensive assessment of the distribution of caliche soil in Texas is illustrated in Figure 3. This information is based on detailed soil surveys (SURGO database) which has correlated acres of caliche soils. This database is available for most of the counties in Texas; where unavailable estimates of probable caliche soils are made from nearby counties. An asterisk is placed in those counties where such estimates were made. The database from SURGO suggests that 14 million acres (or about 8.4% of the State) are caliche soils. This is a conservative figure. When one considers all counties in the State (those with known and estimated caliche percentages), then the value will likely exceed 17 million acres, or over 10% of the State. This emphasizes the importance of caliche as a soil resource for on-site wastewater systems in Texas.

In general, there is a close relationship between the generalized geologic bedrock/physiographic regions in Texas with favorable conditions for caliche soils (Fig. 2) and actual percentages of counties with carbonatic (caliche) soil materials (Fig. 3). For example, many counties of the Hill Country, Lampasas Cut Plain, Alluvial Plains off Balcones Escarpment, and selected counties/or sectors thereof, in Southern Plateau Edge, Edwards Plateau and West Texas Bolsons have over 50% of the total area composed of caliche. It is noteworthy that incongruities also occur between the bedrock/physiographic map and soil databases, especially for the Rio Grande/Nueces Plain and Reynosa Plateau. Here soil surveys suggest either no caliche soils or percentages less than 10%. The reason for these disparities is not fully known but may represent in some cases caliche materials in soils that are below the depths considered for carbonatic mineralogy. In other cases, it may be due to soils that are developed from strongly calcareous materials but with insufficient carbonate contents to be carbonatic in mineralogy according to Soil Taxonomy (at least 40% calcium carbonate equivalent). In these cases areas of soil conditions that are caliche-*like* may be underestimated from soil maps.

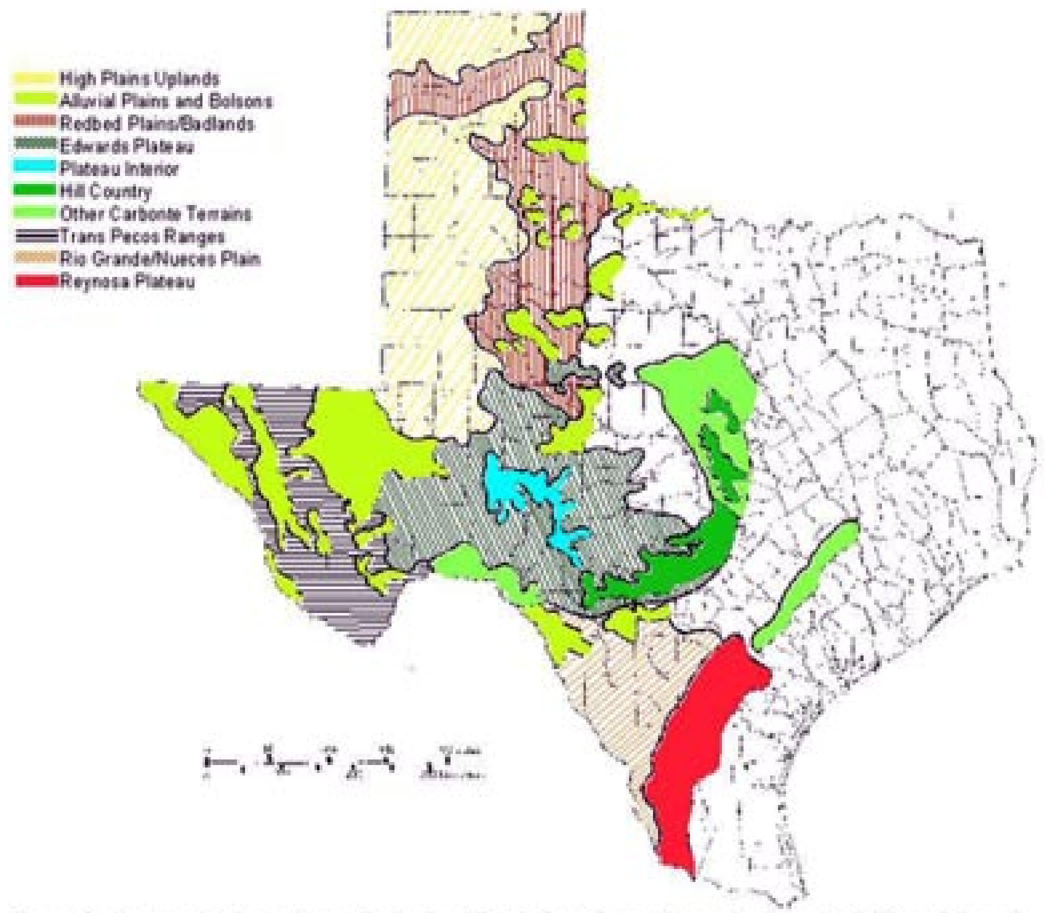


Figure 2. A generalized map illustrating bedbock/geologic regions of Texas having potential for caliche soils. (Modified from Bureau of Economic Geology 1992 and Ferguson, 1986).

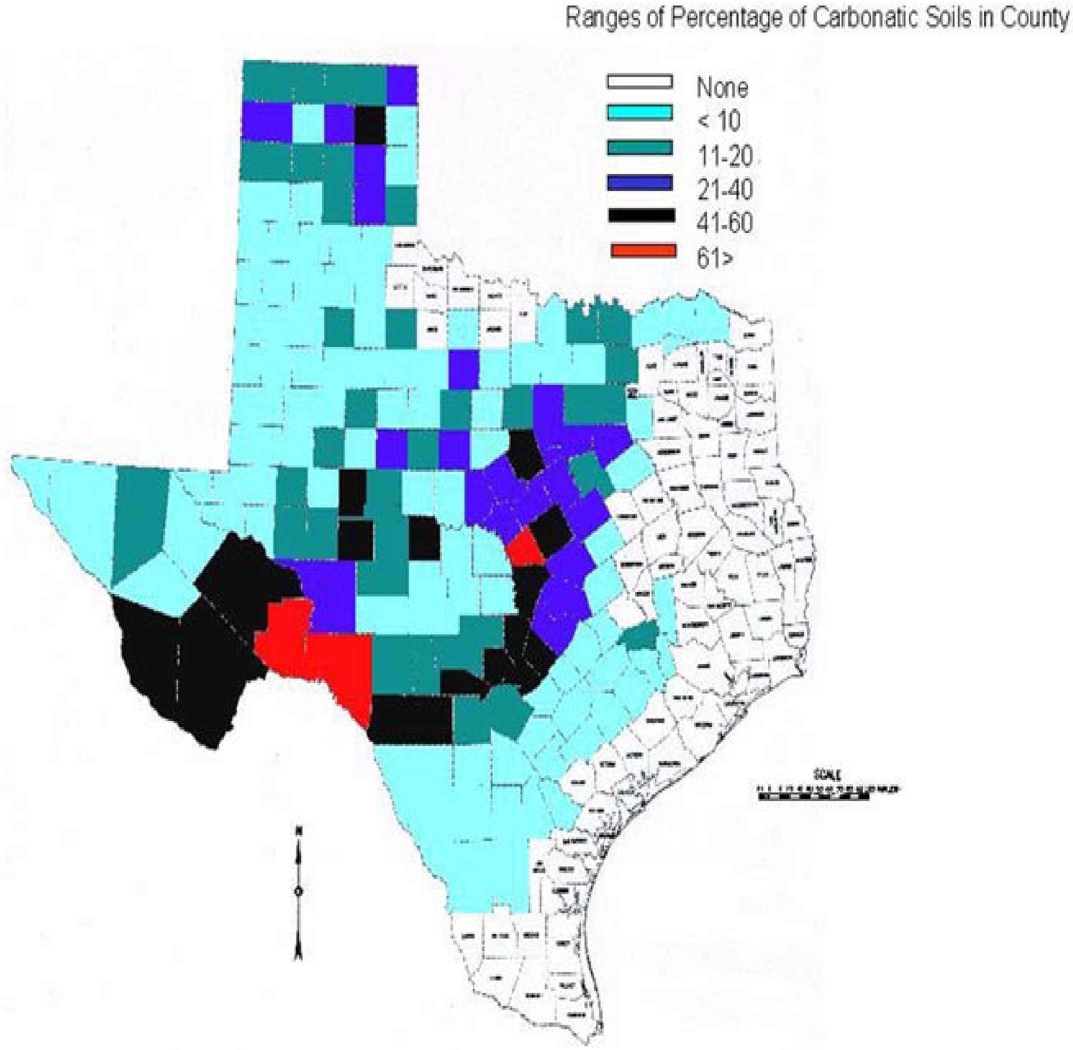


Figure 3B. Percentage of counties with caliche soils (Carbonatic mineralogy) according to Texas soil survey data. (Data courtesy of Wayne Grabriel, Soil Scientist, USDA-NRCS, Temple, TX.)

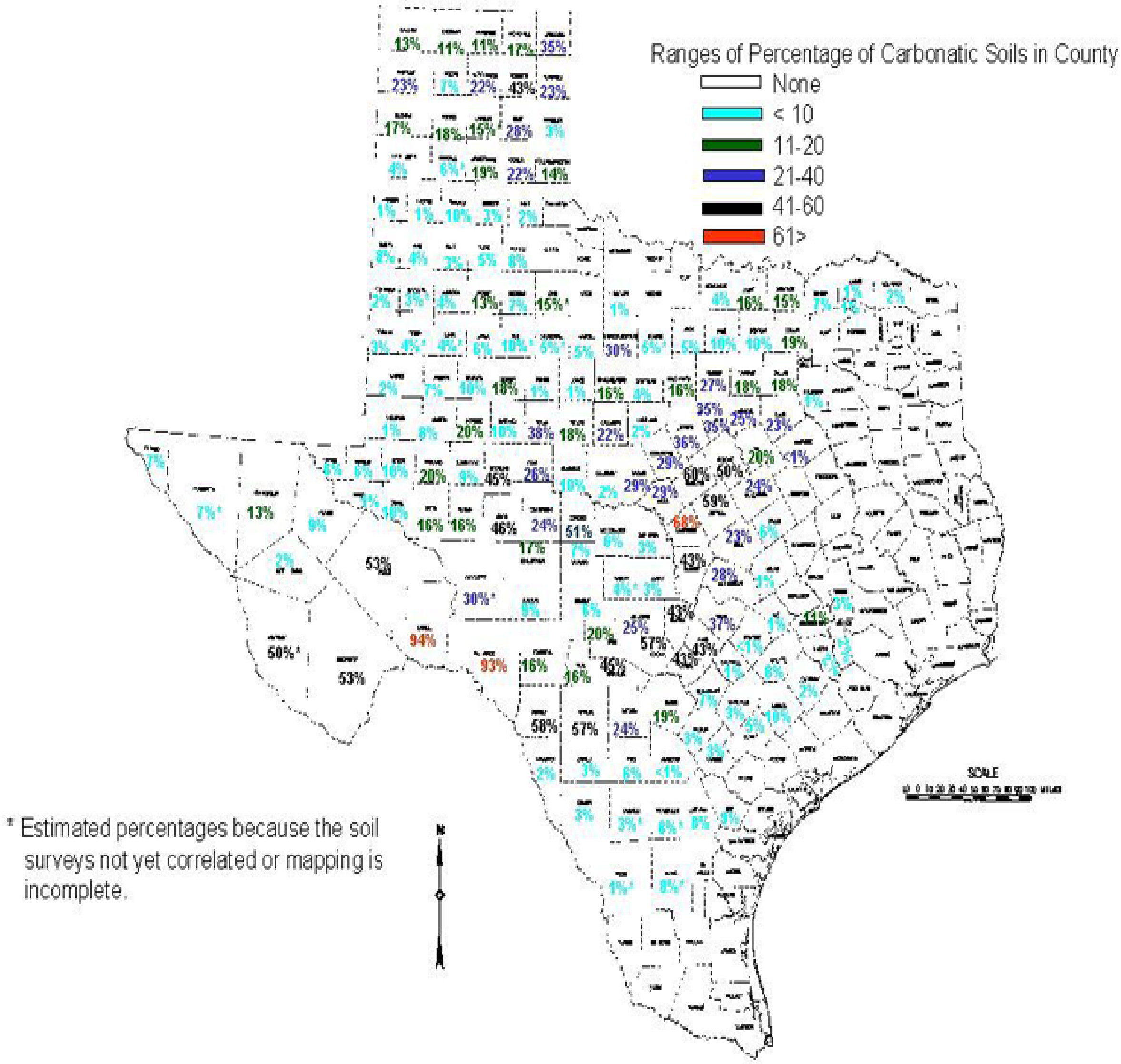
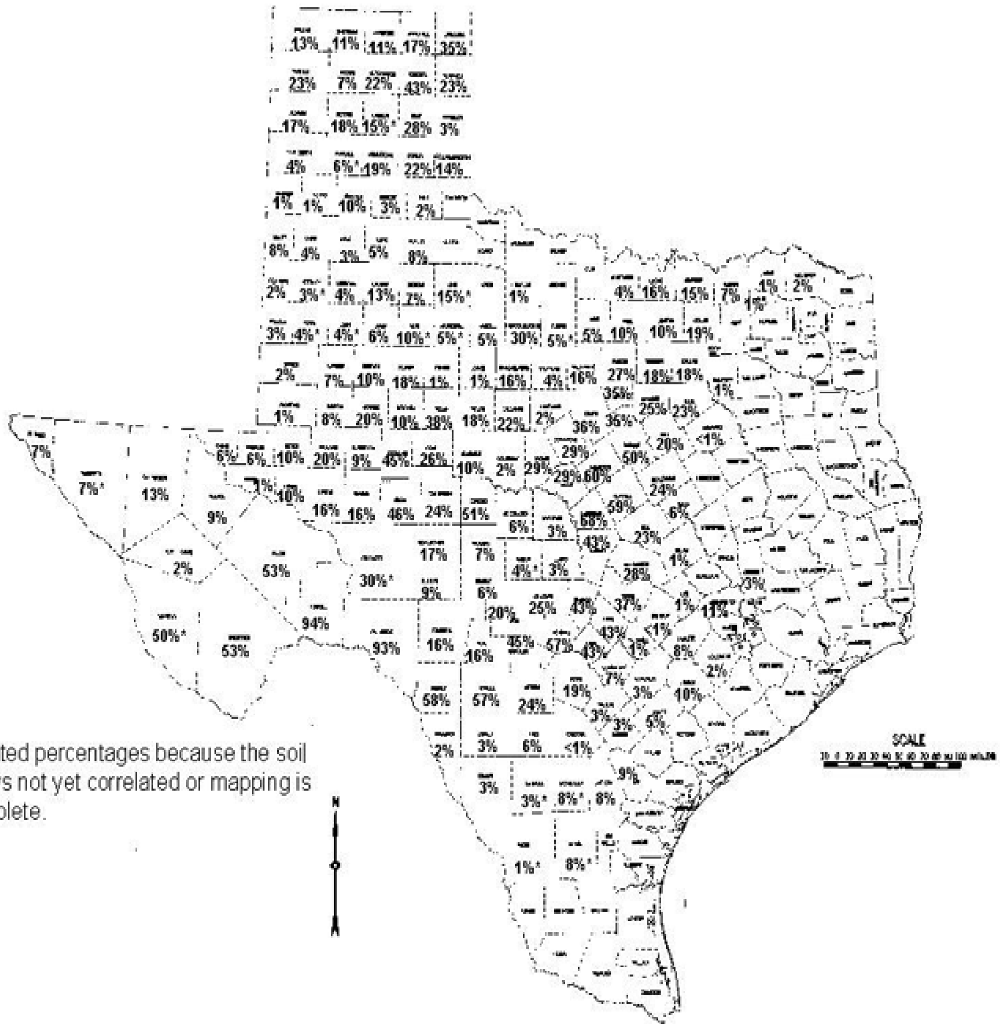


Figure 3. Percentage of counties with caliche soils (Carbonatic mineralogy) according to Texas soil survey data. (Data courtesy of Wayne Grabriel, Soil Scientist, USDA-NRCS, Temple, TX.)



* Estimated percentages because the soil surveys not yet correlated or mapping is incomplete.

Figure 3B. Percentage of counties with caliche soils (Carbonatic mineralogy) according to Texas soil survey data. (Data courtesy of Wayne Grabriel, Soil Scientist, USDA-NRCS, Temple, TX.)

WHAT ARE THE PROPERTIES AND ATTRIBUTES OF CALICHE?

Databases Available:

No attempt is made in this paper to identify comprehensively all of the attributes of soils with calcic and petrocalcic horizons that meet our working definition of caliche, but readers are referred to the extensive data base available for soils of Texas and other regions of the U.S. which are on line (http://www.statlab.iastate.edu/soils/soil/div/). These databases give physical, chemical, mineralogical, and biological attributes for over 10,000 pedons including pedon descriptions, soil interpretations, and engineering behavior. Suffice to say, this data base can be used as a critical source of information to obtain laboratory and field attributes for soil series that have calcic and petrocalcic horizons above 40% calcium carbonate equivalent.

Examples of soils that fit the above concept of caliche in Texas have been published for the Edwards Plateau and the Grande Prairie by Rabenhorst and Wilding (1986a,b), West et al (1988), West et al (1989a,b), Woodruff, et al (1992), Wilding and Woodruff (1993) and Wilding et al (1997). Selected chemical, mineralogical and physical attributes are considered below.

Chemical Attributes:

While attributes of carbonatic soils containing calcic and petrocalcic horizons are quite variable, several common relationships exist. These soils have high calcium carbonate equivalents (40-90%). The carbonate minerals are dominantly calcite and dolomite. Caliche soils have alkaline soil reactions buffered in pH ranges from 7.5-8.3. This means that many elements are sparingly soluble for plant uptake or subsequent soil leaching. In spite of commonly held misconceptions, the organic carbon (OC) contents of surface horizons are much higher than their colors would indicate (1-5%) and subsoils commonly contain 0.5-2% OC. In spite of their high carbonate content, these soils have moderately high to high chemical sorbtivity with cation exchange capacities of 10-30 meq/100g soil for surface horizons and 3-20 meq/100g soil for subsoils. This reflects the presence of OC and active clay minerals, both of which have high chemical sorption potential. Nutrient deficiencies in caliche materials are quite common, especially for plant available N, P, Fe, and trace elements.

Mineralogical Attributes:

The mineralogy of non-carbonate clays in caliche is predominantly smectite, regular and random mixed-layer assemblages (smectite-mica or vermiculite-mica), mica, quartz, and lesser amounts of kaolinite. Hence, the fine-earth component of these soils has appreciable shrink-swell potential in spite of their high carbonate content. The sand and silt fractions of caliche materials are primarily calcite and dolomite with secondary amounts of relatively unweathered and stable quartz, feldspars, pyroxenes, amphiboles, and heavy minerals. Hence, most of the coarse separates of caliche materials do not weather rapidly to yield plant-available nutrients, other than Ca and Mg. This is due in part to the highly buffered pH of these materials, which retards chemical weathering. It is due also to the fact that most of the non-carbonate detrital grains in limestone are stable minerals—the more weatherable forms have been weathered prior to depositional cycles associated with the genesis of the limestone bedrocks.

Physical Attributes:
Many caliche soils have loamy to clayey textures and are skeletal which means they contain more than 35% by volume of gravels, rocks, and stones; however, non-skeletal analogues also occur, especially in alluvial valleys. *Para* gravels, rocks and stones, which are weak to moderately cemented, are common in soils developed from soft limestones, marls, or alluvial deposits derived therefrom. These para fragments wet via macro pores in the rock fabric. This enhances the water retention potential for caliche materials and makes them less droughty than one might predict, and enhances bioremediation quality.

Soil drainage, soil thickness, water retention, and infiltration rates are highly variable among caliche materials—they are soil and site specific. They vary with nature of parent materials (origin and consolidation), vegetative cover, landform position, landform geometry, microtopography, slope gradient, stoniness, surface crusting, soil degradation, biological activity, and intensity of soil development processes.

A case example of soils with caliche is the stepped landforms of the Hill Country of central Texas (Woodruff, et al., 1992 and Wilding et al., 1997). The bedrock is interbedded hard and soft Glen Rose Limestone. In these stepped landscapes, at lateral intervals of 30 to 60 ft, the soils exhibit remarkable and unique spatial diversity corresponding to steep “risers” and gently sloping “treads”. For example, they have the following short-range attributes: (1) soil thickness that varies from less than 1 foot to over 5 feet; (2) slope gradients that range from 1 to 40%; (3) infiltration rates that vary from less than 1 to over 6 inches/hr; (4) average cumulative runoff which ranges from 1% of the annual rainfall to 28%; (5) erosion rates that range from nil to 1.5 tons/A/yr; (6) water retentions that range from 0.3 to 7 inches; and (7) stone contents that range from 25 to 70%. In general, from risers to treads the trends are as follows: decreasing soil thickness, decreasing biological activity, decreasing soil permeability, decreasing water storage, increasing runoff and sediment transport, increasing hydrological curve numbers (less infiltration and higher runoff from storm events) and decreasing remediation quality.

Hydrological Attributes:
Hydrology of caliche soils is critical to their functioning as filter field media for wastewater treatment systems. Unfortunately, little is known about the effective pathways of water transport, mean residence time of fluids in transport, density flux distributions, and convergence of flow pathways with depth in these systems through biopores, structural interfaces, fissures and fractures. Likewise, recharge through soils to near-surface ground water aquifers is poorly understood, in part because water balance models are only approximate or undeveloped for areas of caliche occurrence. The hydrology of these soils on a site-specific basis has not been researched comprehensively, even though such knowledge is prerequisite to understanding water balance and wastewater loading rates in caliche soils. It is probable that

such information will need to be gained if these soils are to be used for on-site treatment systems in regions of high environmental sensitivity, such as in limestone bedrock regions, near urbanizing communities, and wherever aquifers are subject to contamination from vadose zone inputs. This is particularly acute in the contributing zones to the Edwards aquifer along the Balcones Escarpment of Central Texas, but also germane to other regions of the State where urbanization has placed stress on establishment of central sewer systems to dispose of on-site wastes.

A case study of caliche hydrology in the Central Hill Country of Texas was reported by Wilding and Woodruff (1996). This involved a 3-year monitoring study from 1993-1995 at multiple sites within 3 small subbasins of the Barton Creek Watershed near Austin, Texas. Hydrological parameters were ascertained using infiltrometer, piezometer, tensiometer, shallow access wells, soil morphology, microfabric porosity, and microwatershed responses. This work demonstrated that the riser/tread microforms were essentially independent hydrological units. Ephemeral multiple water tables were perched within and among marly strata that exhibit limited interconnectivity. Locally, the risers served as recharge zones and the treads as interflow or discharge zones within given microform couplets. The cascading processes of water flow through multiple steps would retard discharge of incident water to downslope positions. In these caliche landscapes no systematic upslope to downslope trend in hydrology is apparent. Compartmental distribution flow processes replace Hortonian hydrological concepts in these landscapes. Vadose-zone hydrology is complex, temporal and local in scale.

WHAT IS KNOWN IN THE LITERATURE ABOUT CALICHE SOILS AND WASTEWATER TREATMENT?

Of the 205 different combinations and search engines used within the traditional literature, there were a total of 3608 keyword citation matches (Table 2). The percentage of keyword combinations obtained from this search is given in Table 3. Over 90% of the citations dealt with pH keyword combinations with effluent, wastewater, sewage, septic systems, and filter fields. Most of these were specific to municipal wastewater systems, reclamation of acid mine drainage, and land farming of sewage wastes. Likewise, most of the wastewater keyword combinations with limestone, calcium carbonate, and calcareous (and those associated with calcium carbonate and carbonate coupled with effluent and sewage) were directed to municipal wastewater issues. Aggregating all of the above results together accounted for nearly 98% of the keyword combinations. There were 71 citations (about 2%) that appeared initially to be of possible interest. Upon further scrutiny of the titles and abstracts, only 35 contained information of general interest to the search at hand, and only 3 dealt specifically with wastewater treatment in caliche soils, per se. Several citations were duplicated in the initial search; however, they were not double counted in number of applicable abstracts reported above.

Table 2. List of keyword combinations and the number of results for each search engines used.

Search Engine		
GeoRef	pH + Effluent	5
Agricola	Wastewater + pH	2
Agricola	pH + Effluent	9
Web of Science	Wastewater + pH	13
Web of Science	Carbonate + Effluent	1
Web of Science	pH + Sewage	2
Web of Science	pH + Effluent	1
First Search	Wastewater + Limestone	4
First Search	Wastewater + Caliche	2

Table 2 (Continued). List of keyword combinations and the number of results for each search engines used.

Search Engine		
First Search	Wastewater + Calcium Carbonate	2
First Search	Wastewater + Calcareous	2
First Search	Wastewater + pH	52
First Search	Calcium Carbonate + Sewage	4
First Search	Carbonate + Sewage	5
First Search	Carbonate + Effluent	1
First Search	pH + Sewage	14
First Search	pH + Effluent	23
CAB Abstracts	Wastewater + Calcareous	2
CAB Abstracts	Wastewater + pH	7
CAB Abstracts	Carbonate+ Effluent	1
CAB Abstracts	pH + Sewage	4
CAB Abstracts	pH + Effluent	31
Water Resources Abstracts	Wastewater + pH	19
Water Resources Abstracts	Carbonate + Effluent	3
Water Resources Abstracts	pH + Sewage	8
Water Resources Abstracts	pH + Effluent	23
Applied Sci. & Tech Abstracts	Wastewater + pH	11
Applied Sci. & Tech Abstracts	pH + Effluent	19
Compendex	Wastewater + Limestone	43
Compendex	Wastewater + Caliche	1

Table 2 (Continued). List of keyword combinations and the number of results for each search engines used.

Search Engine		
Compendex	Wastewater + Calcium Carbonate	36
Compendex	Wastewater + Calcareous	36
Compendex	Wastewater + pH	1427
Compendex	Caliche + Effluent	1
Compendex	Calcium Carbonate + Sewage	19
Compendex	Calcium Carbonate + Effluent	33
Compendex	Calcium Carbonate + Septic System	1
Compendex	Calcium Carbonate + Filter Field	5
Compendex	Carbonate + Sewage	43
Compendex	Carbonate + Effluent	93
Compendex	Carbonate + Septic Systems	1
Compendex	Carbonate + Filter Field	12
Compendex	pH + Sewage	620
Compendex	pH + Effluent	923
Compendex	pH + Septic Systems	8
Compendex	pH + Filter Field	30

Table 3. Percentage of the keyword combinations obtained from the search.

pH + Effluent	1035	28.6
pH + Wastewater	1535	42.5
pH + Sewage	648	18.0
pH + Septic Systems	8	0.2
Total	**3256**	**90.2**
Keyword	**Results**	**Percent (%)**
Wastewater + Limestone	47	1.3
Wastewater + Caliche	3	<0.1
Wastewater + Calcium Carbonate	38	1.1
Wastewater + Calcareous	40	1.1
Total	**128**	**3.5**
Keyword	**Results**	**Percent (%)**
Calcium Carbonate + Sewage	23	0.6
Calcium Carbonate + Effluent	34	0.9
Calcium Carbonate + Septic System	1	<0.1
Calcium Carbonate + Filter Field	5	0.1
Total	**63**	**1.7**
Keyword	**Results**	**Percent (%)**
Carbonate + Sewage	48	1.3

Table 3 (Continued). Percentage of the keyword combinations obtained from the search.

Carbonate + Septic System	1	<0.1
Carbonate + Filter Field	12	0.3
Carbonate + Effluent	99	2.7
Total	**160**	**4.4**
Keyword	**Results**	**Percent (%)**
Caliche + Effluent	1	<0.1
GrandTotal	**3608**	**100.0**

Many of the publications dealt with:

- the use of crushed limestone or calcareous gravels as a sealant/liner in organic wastewater storage facilities and wetlands;
- efficacy in using calcareous media to immobilize various heavy metals;
- effects of effluent waste pH and dissolved organic carbon on flocculation of suspended solids oxidation/reduction reactions;
- ability of calcareous soil systems to buffer soil pH;
- hydraulic and loading parameters that determine P mobility in calcareous soil systems;
- soil physical and chemical changes from applying wastewater and sewage sludge to calcareous soils;
- optimal pH range for bacterial populations in soil systems;
- treatment of animal and biowastes in land application systems;
- influence of limestone geology on dispersal of nitrates and microbial pathogens;
- denitrification of domestic wastewater prior to a soil absorption system;
- temperature logging to detect sewage-polluted suface water infiltrating into fractured
- limestone rock.

The most pertinent literature directly germane to the effectiveness of caliche soils as a bioremediation filter media was that done by Liljestrand and Parten (1993), Parten and Liljestrand (1995), and Wilding and Woodruff, Jr. (1993). This research was done with caliche soils proximal to Austin, TX. Levine et al (1980) also conducted some valuable research to define long-term soil chemical changes resulting from the application of wastewater to calcareous soils in California. It was not clear from this work whether the soils used in this study would meet the working definition of caliche soils stated later.

In studies by Liljestrand and Partren, under both field and laboratory conditions, caliche soils:

- were effective in removing P and heavy metals from domestic wastewaters,
- had high efficiencies for removal of total organic carbon from effluents (97%),
- had high oxidation rates with rapid decay of BOD materials over short transport distances,
- were well buffered in the alkaline pH range because of calcium carbonate,
- had nitrate concentrations in the soils significantly higher than background or control cases for column studies,
- had low nitrate levels under field study conditions either due to plant uptake, nitrification/ denitrification processes, or immobilization in upper soil/limestone layers,
- demonstrated minimal transport of the of the septic effluent into lower soil layers because high evapo-transpiration rates, except during significant storm events, and
- indicated possible transport of fecal coliform in surface runoff and subsurface flow through macropore conduits such fissures and fractures in the soil/limestone.

As alluded to by above studies, caliche materials are highly diverse physically, chemically, biologically and hydrologically. Laboratory studies of these materials are often misleading because it is difficult to scale up results to field sites. In situ monitoring of filter field systems for their efficiency in bioremediation of wastewater is in order and strongly justified.

The work of Levine et al (1980) is particularly interesting in that it illustrates some of the important long-term (30 years) physical and chemical changes that could occur with caliche soils under high hydrological loading rates of wastewater. These are identified as follows:

- soil pH decreases because of calcium carbonate depletion with possible nitrification and acidity,
- increase in total dissolved salts,
- stable organic carbon levels,
- very little total N accumulation within the soil (less than 2% over a 30-yr period), probably due to denitrification,
- continued soil capability to adsorb P but only 30% of total applied P could be accounted for in the upper 3m of the soil (possibly due to transport of P to underlying groundwater aquifer),
- soil CEC and exchangeable Na, Mg, and K increased, and
- soil metals generally increased (slight evidence that Fe, Mn, Ni, Co, Bo and Zn slightly

mobile in upper soil.

It is not clear whether these results are directly transferable to caliche soils of Texas but the relationships observed in this study are worth considering in terms of long-term effects of the bioremediation quality of caliche.

Many of the results of the above two studies could have been predicted by a comprehensive knowledge of caliche soil attributes Wilding and Woodruff (1993). General physicochemical and hydrological functions of caliche materials pertinent to on-site wastewater treatment are:

- Moderately high to high organic carbon contents
- High surface reactivity due to reactive clays and organic carbon
- Chemisorption of P, Fe, Mg, Zn, Co, Cu, Pb, Sr, etc
- Buffered soil reactions above pH of 7.5
- Increased soil strength due to carbonate cements
- Limited root growth and water movement into soil matrix, especially petrocalcic and para rocks

Petrocalcic horizons or other subsurface restrictive layers such as lithic or paralithic bedrock contacts, restrict the biologically active soil zone for on-site remediation to the thickness of overlying horizons. Hence, the ability to identify a petrocalcic horizon and other probable restrictive layers is critical to knowledge about how a soil will function for on-site waste management, especially loading rates and residence times for remediation.

Petrocalcic horizons (or weakly fractured, carbonate plugged, subjacent hard limestones) function as aquitards (water restrictive layers) and may induce short-term reducing environments and increase the mean residence times of effluents for remediation. This would enhance anaerobic denitrification of NO_3 thus decreasing environmental hazards of $N0_3$ transport from the waste effluents to aquifers. However, it would negatively impact the site if it was overloaded with wastes and the effluents surfaced either on-site or off-site. For safe and effective utilization of caliche materials for on-site waste disposal, a functional knowledge of the local and regional hydrology is prerequisite. Research on this topic is of high priority because Texas has over 17 million acres (over 10% of the State) of caliche soils. In these soils water balance, hydrology, and pathways of water movement are poorly understood (Woodruff, et al., 1992; Wilding and Woodruff, 1993).

EFFECTIVENESS OF CALICHE TO TREAT AND DISPOSE OF WASTEWATER

In summary, a soil knowledge base of caliche is germane to on-site wastewater treatment in the follow ways:

- Soils are highly variable in soil depth, slope, drainage, and porosity and thus require on-site investigation for evaluation.

- Plant cover is restricted by arid/subarid climates, limited soil water retention, and deficient plant nutrients.

- Plant nutrient deficiencies in P, N, and trace elements are due to chemisorption of these nutrients to carbonate minerals.

- Low phytocycling of trace elements by plants would be expected because of high soil pH

- Rapid infiltration and drainage in many caliche soils occurs because of high gravel content and abundant macropores.

- Low water retention of gravelly caliche will limit loading rates.

- Most upland caliche soils are well aerated and drained favoring oxidation of organic compounds in A and B horizons, but may exhibit periodic reducing conditions at the contact with less permeable soil or bedrock substrata.

- Major hazard in wastewater treatment in caliche soils is NO_3 loss to shallow aquifers.

- Petrocalcic horizons or carbonate-plugged rock substrata function to:

- limit soil depths and consequent load rates of wastes,

- limit soil drainage and recharge into aquifers,

- retard water flow above petrocalcic or joint-plugged bedrock yielding perched water tables,

- enhance reducing conditions, and

- restrict losses of NO_3 into aquifers.

Fate and Transport of Viruses

There was no literature involving virus behavior in caliche per se; however, there was some literature on virus behavior under different soil conditions. Therefore, the effects of caliche on virus survival can be inferred from the literature but only generally and with little site specific attributes. The following paragraphs on virus behavior are a summarization of a literature review of the fate and transport virus through porous media (Jin and Flury, 2001). This review focused on virus survival and virus transport.

The general statements for virus survival are that temperature appears to be the primary influential factor of viruses in the soil and groundwater. In general, higher temperatures create higher inactivation rates. In most cases, viruses survive longer in moist versus dry soil conditions. Studies have shown that viruses are removed and inactivated better under unsaturated conditions (dry or moist) rather than saturated conditions. The association with metals and metal oxide surfaces tend to enhance virus inactivation. Other factors such as UV radiation, dissolved oxygen level, organic matter content, pH, and the presence of other microorganisms have been found to influence virus survival.

General statements can be drawn from the literature regarding the important soil components needed for sorption and retardation of virus transport. The primary controlling factors of sorption and transport through soils and sediments are pH and virus hydrophobicitiy. Viruses have a wide range of isoelectric points which is one of the most important characteristics in evaluating virus sorption. Since viruses and soils both have pH dependent charge, an increase in pH increases the electrostatic repulsion between them, thus virus sorption is decreased. This was proven in column studies where higher pH effluents produced higher column outflow of viruses. Viruses also vary considerably in hydrophobicities. A hydrophobic virus will sorb to organic matter and will not sorb or minimally sorb to mineral particle surfaces. Organic matter may provide hydrophobic sorption sites for viruses, although organic matter in dissolved form competes with viruses for the available sorption sites. The sorption of viruses depends on the soil properties and the individual virus. For example, in a column study with poliovirus the percolates had higher virus concentrations with low cation exchange capacity, high organic carbon and high clay content. Some viruses (such as ϕX174) had high percolate concentrations with low soil organic carbon and residence time with either high soil pH or high clay content.

Ionic strength of the solution and pH were also found to be very important. Higher ionic strengths collapse the diffuse double layer, which allows the virus to come closer to the solid surfaces. This would enhance virus attachment to the surface thus retard transport. The composition of both cations and anions influence the sorption of virus retention and transport. Divalent cations were found to be more effective than monovalent cations in promoting adsorption to solid surfaces. Although the anions NO_3^-, SO_4^{2-} and $H_2PO_4^-$ were found to promote virus sorption to solid surfaces in the literature, there were no chemical or physical properties to described to account for this observation.

There was no similar literature found on the fate and transport of bacteria or other pathogens through porous media.

RECOMMENDATIONS

Based on above knowledge of caliche materials gleaned from the literature and from research activities of the authors, the following areas represent critical future research needs if caliche materials are going to be broadly utilized in Texas as filter media for on-site wastewater treatment:

- in-situ research on caliche materials conducted under field conditions rather than with laboratory column studies—the former cannot be adequately simulated in the laboratory because of changes in environmental and physical condition of packed columns compounded by scaling limitations that do not adequately represent spatial diversity of caliche soils in the field, even over a few tenths of an acre;

- establish specific pathways (soil structure, fissures, fractures, biovoids, etc.) of water transport in different types of caliche soils using anionic dye-staining techniques to assess risks for rapid discharge of wastewater into shallow ground water aquifers—use backhoe exposures to couple pathways of dye tracers with plant root distribution patterns, pedogenic carbonate translocation, and biological activity;
- document on-site hydrology of representative caliche soils to verify infiltration rates, depths and durations of saturation/reduction, presence of restrictive aquitards, water retention capacities, surface and subsurface discharge, and water balance models;
- establish risk assessments of nitrate, phosphorous, heavy metal and pathogen transport to subsurface aquifers when caliche soils are subjected to high rates of wastewater loading;
- develop models for calculating loading rates specific to caliche soil attributes; and
- determine hydraulic changes in caliche soils subjected to high loading rates of domestic wastes, especially evidence for dissolution of carbonates, formation of macroporosity, increased saturated hydraulic conductivity, and greater channel flow.

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Wilding, L.P., and C.M. Woodruff, Jr. 1996. Soils and microtopography of the central Texas Hill Country: Implications on vadose zone hydrology, GSA Abstracts No. 1666, Geol. Soc. Amer., South-Central Section, vol. 28, No. 1.

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Wilding, L.P., L.R. Drees, and C.M. Woodruff, Jr. 1997. Mineralogy and microfabrics of limestone soils on stepped landscapes in Central Texas. pp. 204-218. *In* S. Shoba, M. Gerasimova, and R. Miedema. (eds.) Soil Micromorphology: studies on soil diversity, diagnostics, and dynamics. Proc. of X Int. working meeting on soil micromorphology, Moscow, Russia. July, 1996.

ABSTRACTS

All references are from refereed sources unless noted by the following symbols:

* Unsure of Refereed Status

** Non Refereed Source

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Al-Wabel, M.I., A.M. Al-Omran, A.A. Shalaby, M.I. Choudhary. 1998. Effect of sewage sludge on some chemical properties of calcareous sandy soils. Communications in Soil Science & Plant Analysis, 29:17/18. p. 2713-2724.

Sewage sludge was applied to the surface layer (0-10 cm) of two sandy soils, slightly calcareous with 8.9% $CaCO_3$ and moderately calcareous with 26.7% $CaCO_3$, at rates of 0, 25, 50, 75, and 100 t/ha. The effects of sewage sludge and its rates on total soluble salts, pH of soils and concentration and movement of some heavy metals within soils were investigated. Soil samples were packed at bulk density of 1.5 g/cm^3 in PVC columns and incubated for 19 weeks. The results indicated that total soluble salts (EC) of the treated layer increased with increasing sewage sludge rates. Soluble salts also increased with an increase in soil depth for both soils. The pH values of treated layers in two soils decreased with increasing sewage sludge rates. With increasing sewage sludge rates, concentrations of heavy metals (Co, Ni, Cd, and leaf Pb) increased in the treated layers compared to the untreated layers and their mobility was restricted mostly to the upper 30-cm depth. Movement of Co and Pb in both the soils was predominantly limited up to a depth of 40 cm for Co and 5 cm for Pb below the treated soil layer. Nickel and Cd movement was mostly limited to a depth of 10 cm in slightly calcareous soil and 5 cm in moderately calcareous soil. Metal movement in the respective soils was ranked as Co > Ni = Cd > Pb and Co > Ni = Cd > Pb. The low concentrations of heavy metals and the restricted mobility with soil depth, suggest that this material may be used for agricultural crop production without any toxic effect on plants.

((Web of Science))

Barrington, S.F., S. Hengnirun. 1996. Limestone liners to protect groundwater quality against organic wastewater seepage. Water Air and Soil Pollution, 92:(3-4), p. 315-327.

Crushed limestone was tested as a sealing liner for organic wastewater storage facilities. This material was compacted in laboratory columns and exposed in quadruplet to three levels of wastewater total solids (TS of 0.6, 1.3 and 2.6%). A fourth set of quadruple columns was used to monitor the total nitrogen (TN) loading rate using 1.3% TS wastewater. The crushed limestone cores measured 310 mm in depth by 98 mm in diameter and were exposed to a typical wastewater depth of 290 mm. Wastewater TS and ambient temperatures had a marked effect on seepage and TN loading rates. If the wastewater contains at least 1.3% TS, the seepage and N loading rate can be limited to 2×10^{-8} m s^{-1} and 200 mg N m^{-2} d^{-1}, respectively. Ambient temperatures below 5 degrees C caused the TN loading rate to increase 7 fold, while those above 5 degrees C favoured nitrifying and denitrifying activity, thereby reducing seepage TN.

Ben-Hur, M., I. Shainberg, D. Bakker, R. Keren. 1985. Effect of soil texture $CaCo_3$ content on water infiltration in crusted soil as related to water salinity. Irrigation Science, v 6, n 4, p 281-294.

The effect of soil texture and CaCO//3 content on water infiltration rate in crusted soil was studied with the use of a rain simulator. Two types of soils with low exchangeable sodium percentage were studied: calcareous soils with a high silt-to-clay ratio from a region with less than 400 mm winter rain; and non-calcareous soils with a low silt-to-clay ratio from a region with greater than 400 mm winter rain. For both types of soils and for both types of applied water, soils with 20% clay were found to be the most sensitive to crust formation and have the lowest infiltration rate. With increasing percentage of clay, the soil structure was more stable and the formation of crust was diminished. Silt and CaCO//3 had no effect on the final infiltration rate for either type of applied water, whereas with saline water, increasing the silt content increased the rate of crust formation.

((NSFC Bibliographic Database))

* Boller, M., A. Schwager, J. Eugster, and V. Mottier. 1993. Dynamic behavior of intermittent buried filters: 2nd International Specialized Conference on Design and Operation of Small Wastewater Treatment Plants, Norway.

Buried filters were investigated in pilot and full scale and were operated by intermittent flushing which causes the water and the pollutant transport through the unsaturated media to be of highly dynamic nature. Various schemes of hydraulic flushing frequencies were found to be inversely proportional to loading. These findings were confirmed in a full scale plant through monitoring of the dynamic washout of inoxidized matter under different hydraulic loads. The moisture retention capacity of the filter media correlated to the grain size distribution was found to be an important parameter. COD removal and nitrification rates depend strongly on the oxygen supply to the media. In general, oxygen diffusion into the media and the air exchange, induced by intermittent flushing, is sufficient. However, when applying relatively large hydraulic loads to coarse filter grains, especially in the range above 1 mm, buried filters tend to larger breakthroughs of inoxidized matter due to short retention times and instantaneous lack of oxygen. Experiments on average treatment performance and showed that under optimized conditions even wastewaters containing relatively high ammonia contents can fully be nitrified when limestone type filter material is used.

Brown, Charles N. 1956. The origin of caliche on the northeastern Llano Estacado, Texas. Journal of Geology, v. 64, no. 1, p. 1-15.

Brown describes the extent of caliche at or beneath the surface as coincident with the expanse of the Llano Estacado. Thickness ranges from 4 ft to 150 ft, and the material occurs in single, double, or multiple sequences that typically comprise an indurated cap underlain by varying degrees of unindurated caliche. Reviews of three main hypotheses for caliche formation include chemical or biochemical deposition in surface water, deposition by groundwater, and deposition by accretion within the subsoil. Pedogenic origin, aided by eolian aggradation, is the favored hypothesis. Caliches in this region consist of approximately equal parts $CaCO_3$, SiO_2, and water- (air-?) filled voids. The indurated caprock represents periods of slower eolian aggradation and a more complete precipitation of minerals within the pore spaces. This is an excellent regional geologic synthesis, but some of the cited references do not appear in the bibliography at the end of the article.

((NSFC Bibliographic Database))

Burgan, M.A., and D.M. Sievers. 1994. On-site treatment of household sewage via septic tank and two-stage submerged bed wetland. On-Site Wastewater Treatment: Proceedings of the 7th Int'l Symposium on Individual & Small Community Sewage Systems.

A two cell vegetated submerged bed wetland was constructed on private property in central Missouri to treat domestic sewage from two homes. Wastewater is initially treated in a single septic tank. The first cell of the wetland contains limestone (5 cm dia) and is planted to Scirpus validus and Equisetum hyemale. The second cell contains coarse sand and is planted to Alisma plantago-aquatica. Total surface area of the wetland is 136 m2 and has a design retention time of 5.3 days. Over the first 16 months of operation (Sept. 92 - Dec. 93) BOD5 removal has averaged 85%. Effluent BOD5 and TSS concentrations have averaged 14 and 16 mg/l respectively, and consistently been below the state's discharge requirements. Ammonia nitrogen removal averaged 42% (two periods had negative reductions) with approximately half of the reductions occuring in each cell. Little nitrate or nitrite was detected. Removal of total phosphorus averaged 44%. Fecal coliform reduction averaged 98% for the wetland with the majority of reductions occurring in the first cell (80%). Based on water outflow measurements from the wetland, the wetland lost 74% of the inflow during the summer and 13% during the winter.

((Compendex))

Coniglio, M., S. Harrison, Rand. 1983. Holocene and pleistocene caliche from Big Pine Key, Florida. Bulletin of Canadian Petroleum Geology, 31:1, p. 3-13.

Caliche developed on the Holocene surface and at two Pleistocene horizons on Big Pine Key occurs primarily in two modes: distinctly laminated crusts and irregular, unlaminated alteration zones. Both fabrics are part of a spectrum of textures that result from subaerial exposure of carbonate sediments. Components of caliche include micrite, equant spar, fibrous Mg-calcite, random needle fibers, peloids, calcified filaments and microborings. The formation of distinctively laminated caliche crusts is a common phenomenon, but such horizons are not always developed or may subsequently be eroded. Consequently, it is important to recognize the more subtle, often thicker, underlying alteration zone.

((Compendex))

Dewalle, F.B., and R.M. Schaff. 1980. Ground-water pollution by septic tank drainfields. American Society of Civil Engineers, Journal of Environmental Engineering Divison. 106: 3, p. 631-646.

Analytical results from 386 ground-water samples were used to determine the effect of septic drainfield leaching on ground-water quality. The calcium carbonate type groundwater showed lower correlation coefficients between its main parameters in unsewered areas than in sewered areas. The negative correlation between calcium and sodium, the significant increase of calcium with time and with decreasing well depth points to a cation exchange in which sodium from sewage effluent is exchanged by calcium. The increase of calcium, chloride, and nitrate with time was most significant in unsewered areas served by septic tanks. Highest nitrate and coliform concentrations were noted in the winter during maximum infiltration.

Duley, James W. 1983. Geologic aspects of individual home liquid-waste disposal in missouri.

Engineering Geology Report, n 7, 1983, 78p plus 4 maps.

This report delineates areas in Missouri where various limitations for Search IndustrySpecs and septic-tank soil-absorption field placement can be anticipated with respect to Standards groundwater and surface-water contamination. The first section deals with general hydrology and geology as they pertain to on-site treatment systems; the second Search CRC Handbooks section, with case histories documenting past effects of on-site waste disposal on groundwater quality in Missouri.

((Springer LINK))

* Elmaleh, S., J. Yahim, J. Coma. 1998. Are flocculants required in a flocculant process? Environmental Engineering and Policy, v. 1 n. 2, p. 97-102.

The effectiveness of solids abatements by pH increase was investigated using the jar test procedure with a bentonite tap water suspension and an urban wastewater and an oxidation pond effluent. The results indicated that, depending on the suspended particles and on the dissolved ions, pH values between 9.5 and 12 induced extensive solids elimination without adding any other chemical than a base, i.e. sodium hydroxide or lime. The major effective reactions are then calcium carbonate precipitation and the magnesium hydroxide precipitation. Moreover, this process does not require a flocculation step but only a precipitation step where the particles are entrapped by sweep coagulation and adsorption-coagulation. A continuous reactor was operated with an oxidation pond effluent. A suspended solids concentration less than 30 mg/l was obtained by adjusting pH between 11 and 11.5 while the reactor was operated up to 20 m/h superficial upflow velocity corresponding to a residence time through the whole unit of only 5 minutes. The sludge settling velocity depends on pH and on the primary particles but a maximum settling velocity larger than 1 m/h is easily reached. The concentration factor is then about 100. Environmental policy implications of this technique are that it allows to significantly upgrade a stabilization pond effluent and can be used when a high pH situation is acceptable.

((ArticleFirst))

Gaebe, G., Frimmel, F. H., 1996, Reaction of sediments of different origin under oxidizing conditions in dependence of the pH: acta hydrochimica et hydrobiologica: zeitschrift fur wasser- und abwasser-forschung. Journal for Water and Wastewater Research, v. 24, no. 4, 161.

The release of heavy metals under oxidative conditions was investigated for sediments of different tributaries of the Elbe. In the first part of the experiments, the sediments were resuspended in demineralized water, and the changes in pH value and the electrical conductivity during the experiment were determined. The pH values in the suspensions varied between 3.3 and 7.8, and the electrical conductivity showed values between 54 and 1575 μS/cm. The amounts of released metals varied with the pH value in the suspension. With decreasing pH value, the concentration of the metals in solution increased. In addition, the influence of pretreatment steps prior to oxidation of the sediments was tested. The sediments were freeze-dried or treated with ultrasonic energy to decrease the mean particle size. These pretreatments caused changes in the rate of the reaction but in most cases, the yield of mobilized metals did not change. In the second part of the experiment, the pH value was kept constant during the oxidation. The mobilization was determined for the pH values 2, 3, 4, 5, 6, 7, and 9. In general, the mobility of the metals decreased with increased pH value. The amount of released metal was fairly independent on origin and composition of the sediment. The strong influence of the specific properties of the metals and their species on the mobilization suggests modelling as a powerful tool for the description of reactions.

((CAB Abstracts))

Genitse, R. G. 1993. Mobility of phosphate from wastewater in calcareous sands of Rottnest Island (W.A.). Australian Journal of Soil Research. 1993. 31: 3, 235-244.

Natural levels of inorganic phosphate in soils of Rottnest Island (Western Australia) were approx equal to 300 mg P/kg (equivalent to 4 t P per ha). In the calcareous soils investigated the mobility of P from wastewater was less than 2% at water infiltration rates of 0.5 and 1 cm/day. An equation was proposed providing a good estimate of P in a field situation. The equation showed the relationship between P mobility, dispersibility and adsorption parameters at high rates of flow. It was demonstrated that the mobility of P in soils increases rapidly with increasing infiltration rate and P concentration in wastewater. The long-term effects of disposal of wastewater from treated sewage on pH and structure of the mainly calcareous soils of the Island need further investigations in terms of mobilization of mineral P and changes in adsorption characteristics for added P.

((Compendex))

** Gray, J. F. 1979. Update on the land application of waste water project at Lubbock, Texas. Paper - American Society of Agricultural Engineers, Pap ASAE for Presentation at Jt ASAE and CSAE (Can Soc Agric Eng) Summer Meet, Jun 24-27 1979, 1979 ASAE, St. Joseph, Mich, Winnipeg, Can, Manit, p. 17.

Experience under the project so far indicates that by using crops that are high users of water and with the given climatic condition and geological formation, 4 to 6 acre-feet per acre per year can be used. Also, 75-100 acres per 1,000,000 gal daily flow is sufficient with forage and livestock farming. The Geological formation on the farm has a top soil of mixed loam that is moderately to highly permeable and is from 3 or 4 in. to 4 or 5 ft in depth. Under the top soil there is a layer of highly permeable caliche, then some clay, and then water bearing sands. After the aquifer is saturated, the underground water empties into the channel of the North fork of the Double Mountain fork of the Brazos River in the form of seeps or springs. The paper discusses the operation at Lubbock in detail, including the irrigation system.

((Compendex))

Gray, S., J. Kinross, J. Read, A. Marland. 2000. Nutrient assimilative capacity of maerl as a substrate in constructed wetland systems for waste treatment. Water Research v. 34, n. 8, p. 2183-2190.

This study evaluated the performance of maerl (calcified seaweed) as a substrate for artificial wetland waste treatment systems. Pilot scale artificial wetlands were set up in the laboratory; three planted with Phragmites australis and three unplanted, and fed with a synthetic sewage solution. The effluent from the tanks was monitored over a period of 9 weeks for chemical oxygen demand, total nitrogen, total phosphorus, ammonium-N, total oxidised nitrogen, soluble reactive phosphorus, dissolved oxygen, pH and temperature. The data were analysed using repeated measures ANOVA to look for significant differences between treatments, and within treatments, over time. A batch incubation experiment was also carried out to ascertain the maximum adsorption capacity of maerl for phosphorus. Results obtained were compared with those in the literature for other substrates. Variability within and between treatments was high, but it was found that maerl effectively removed total phosphorus (98%). Nitrogen removal was less effective, with the tanks producing ammonium-N. The low nitrogen removal shown in the tanks was a factor of the short duration of the experiment; but ammonification did decrease in the planted tanks over time. Performance at removing nitrogen was normal when compared with figures in the literature, but phosphorus removal by maerl was considerably higher than gravel bed wetlands, and comparable with the very best figures given for artificial wetlands based on novel substrates such as shales and slags. This trial showed that maerl has great potential as a constructed wetland substrate, due to its high phosphorus-adsorbing capacity.

((Compendex))

Harrison, R. S. 1977. Caliche profiles: indicators of near-surface subaerial diagenesis, barbados, west indies. Bulletin of Canadian Petroleum Geology v. 25, n. 1, p. 123-173.

Many of the subaerially exposed Pleistocene reef tracts on Barbados (West Indies) are mantled by secondary caliche profiles which range from thin, vaguely laminated surficial crusts to horizons two to three metres thick. On a regional scale there is a

gradual transition from relatively well developed, laterally continuous caliche profiles in the more arid areas to a more karst-like topography in the high-rainfall regions. Major components of the caliche profiles are examined and, taken together, used as criteria for the recognition of subaerial-exposure surfaces. It is concluded that the initiation, evolution and thickness of the caliche profiles is controlled by the factors of climate, soil cover, substrate and time.

Hart, Sherman W. 1997. Minimizing on-site septic system drain field size by combining absorbic and evaporative disposal methods. ASTM Special Technical Publication, Proceedings of the 1997 Symposium.

There are two well established methods for the disposal of septic tank effluent in soil. The most common method utilizes the natural absorbic capacity of soil to move the effluent, over time, into groundwater. The other method is utilized in geographical areas of low to moderate rainfall and is based on effluent removal through surface evaporation with some contribution from plant transpiration. It is possible to reduce the size of a septic tank drain field, for a given effluent flow rate, by combining the two disposal methods. The amount of reduction is proportional to the absorbic capacity of the soil and net surface evaporation rate for a given geographical area.

* Hawker, H.W., M. W. Beck, and R. E. Devereaux. 1927. Soil survey of Hidalgo County, Texas: U.S. Department of Agriculture, Bureau of Chemistry and Soils Bulletin 21.

((Compendex))

* Jacobson, G., C.J. Barnes, L.K. Fifield, R.G. Cresswell. 1994. Time factor in arid-zone groundwater recharge. National Conference Publication - Institution of Engineers, Australia, Proceedings of Water Down Under 1994 Conference. Part 2-B (of 3), Nov 21-25 1994, 1994, Adelaide, p. 471-478.

Sustainable development of the Australian arid-zone economy depends on the use of groundwater resources. In connection, the management of arid-zone groundwater systems depends on the nature and amount of groundwater recharge. Previously several studies have been carried out regarding water resources and salinity problems in the humid and semi-arid regions of the continent. The study presented in this note is an attempt to differentiate modern recharge from palaeorecharge, and to elucidate the time scale involved. This central Australian work is summarized through distinction of three main types of recharge in the arid-zone.

Jaynes, Russell S., and Henry S. Chafetz. 1997. A petrologic analysis of caliche within the Central Texas region: Gulf Coast Association of Geologic Societies Transactions, v. 47, p. 239-249.

This paper, based on the senior author's master's thesis at the University of Houston, examines caliches occurring on the eastern Edwards Plateau region. Host substrates of 62 sample sites include materials of Quaternary, Cretaceous, Pennsylvanian, Mississippian, Ordovician, Cambrian, and Precambrian age. Seven lithofacies are described among the various sample sites: gravels; calcareous shales/marls; siliclastic shales; resistant limestones; siliclastic sandstones; terra rossas; and schists. Each of the lithofacies are described in terms of host bedrock unit; degree of induration/calichification; description of vertical caliche profile; and macrofeatures present (both abiotic and biotic). Analyses of stable isotopes were conducted for carbon in the caliche profiles, and oxygen isotopes in the caliches compared to nearby surface water bodies.

Jin, Y. and M. Flury. 2001. Fate and transport of viruses in porous media. Advances in Agronomy. Vol. 72. (In Press)

The general statements for virus survival are that temperature appears to be the primary influential factor of viruses in the soil and groundwater. In general, higher temperatures create higher inactivation rates. In most cases, viruses survive longer in moist versus dry soil conditions. Studies have shown that viruses are removed and inactivated better under unsaturated conditions (dry or moist) rather than saturated conditions. The association with metals and metal oxide surfaces tend to enhance virus inactivation. Other factors such as UV radiation, dissolved oxygen level, organic matter content, pH, and the presence of other microorganisms have been found to influence virus survival. The primary controlling factors of sorption and transport through soils and sediments are pH and virus hydrophobicitiy. Viruses have a wide range of isoelectric points which is one of the most important characteristics in evaluating virus sorption. Since viruses and soils both have pH dependent charge, an increase in pH increases the electrostatic repulsion between them, thus virus sorption is decreased.. Viruses also vary considerably in hydrophobicities. A hydrophobic virus will sorb to organic matter and will not sorb or minimally sorb to mineral particle surfaces. Organic matter may provide hydrophobic sorption sites for viruses, although organic matter in dissolved form competes with viruses for the available sorption sites. The sorption of viruses depends on the soil properties and the individual virus. Ionic strength of the solution and pH were also found to be very important. Higher ionic strengths collapse the diffuse double layer, which allows the virus to come closer to the solid surfaces. The composition of both cations and anions influence the sorption of virus retention and transport.

((Compendex))

Jones, B. 1988. Influence of plants and micro-organisms on diagenesis in caliche: Example from the Pleistocene ironshore formation on Cayman Brac, British West Indies. Bulletin of Canadian Petroleum Geology v 36, n 2, Jun, p 191-201.

Study of a caliche unit in the Pleistocene Ironshore Formation on Cayman Brac, British West Indies, demonstrates that plant roots and their associated micro-organisms played an important role in its diagenesis. The root borings, which are up to 25 cm in diameter and at least 4 m long, provided avenues by which water and a diverse array of micro-organisms penetrated the caliche. Both the water and the micro-organisms played an important role in the diagenesis of the caliche. The chasmolithic, epilithic and endolithic algae, fungi and bacteria mediated destructive and constructive processes. Destructive process include boring, etching of substrates and micritization; constructive processes include calcification of micro-organisms, binding of detrital grains, and precipitation of cements. Constructive and destructive processes were also critical in the generation and destruction of porosity and permeability in the caliche.

((NSFC Bibliographic Database))

Khanbilvardi, R.M., and D.A. Long. 1985. Effect of soil depth on wastewater renovation. Journal of Environmental Health 47(4): 184-188.

A soil column study evaluated the renovation of settled wastewater at various depths in a limestone based soil. In the top foot of soil, aerobic conditions allowed ammonium oxidation to nitrite and nitrate. Beginning with the second foot of soil, anerobic conditions prevailed and denitrification occurred. With increasing soil depth, increased nitrogen gas was converted to organic nitrogen which was subsequently reduced to ammonia. Thus, ammonia in the effluent increased with soil depth. COD was insignificant after two feet of percolation. Alkalinity and pH were essentially unchanged at depths beyond two feet. (SWF)

((NSFC Bibliographic Database))

Lee, G.R., and T. Christoffel. 1990. Clarke County, Virginia's innovative response to groundwater protection. Journal of Soil & Water Conservation v. 45, n. 2.

A Virginia county was forced to increase goundwater protection measures. Petrochemical and nitrate contamination were found to be present in rural and private wells. The limestone geology of the county was known to contribute to the contamination problems. Septic tank related fecal coliform counts had been included among groundwater contamination sources. A strategy was implemented which included on-site wastewater treatment system management, sinkhole ordinance, underground storage tank requirements, community educational needs, and well standards. Importance of the strategy lies in the emphasis of direct local government land use policies designed to mitigate risks of groundwater contamination.

((CAB Abstacts))

Levine, P. E., R.W. Crites, J.V. Olson. 1980. Soil chemistry changes at rapid infiltration site. Journal of Environmental Engineering Division, A.S.C.E. 106: EE5, 869-883.

Soil chemistry changes resulting from the application of wastewater to a calcareous soil at a rapid infiltration facility included the following: (1) Soil pH decreased significantly as a result of calcium carbonate depletion and possible nitrification. (2) A significant increase in saturated extract conductivity was observed. (3) Soil organic matter did not increase significantly. (4) Nitrogen accumulation within the soil profile accounted for only 2% of the total nitrogen applied in a 30 yr period. Conversion of nitrogen to gaseous forms (denitrification) was believed responsible for nitrogen loss from the soil profile. (5) The soil maintained its ability to adsorb solution phosphorus after 30 yr of wastewater application. However, only 30% of the total wastewater-applied phosphorus could be accounted for within the upper 300 cm (118 in.) of soil. Phosphorus appeared to pass through the soil profile to the underlying groundwater aquifer. Longer vertical travel distances would be required to increase removal efficiency. (6) Soil boron increased preferentially within the surface of the soil profile. (7) Soil cation exchange capacity and exchangeable sodium, magnesium, and potassium increased. (8) Soil metal concentrations generally increased. It appears that iron, manganese, nickel, cobalt, and zinc were somewhat mobile within the upper soil profile.

((Compendex))

Liljestrand, H.M., S.M. Parten. 1993. Design of on-site treatment system in caliche soils. Water Science and Technology v 28, n 10 p. 83-87.

Caliche soils, weathered limestone soils of high calcium carbonate content and low organic content, are common in regions with limestone sedimentary geology and arid to semi-arid climate. Currently, there are no standards other than hydraulic soil properties for the design and construction of on-site wastewater treatment systems in caliche soils. Experimental studies were performed to investigate biological transformation rates for organic carbon to inorganic carbon and organic nitrogen to nitrate, using four different caliche soils and the range of recommended hydraulic loading rates. The experimental results indicate that oxygen demanding materials readily decay over short distances in caliche soils. Efficiency for removal of TOC was gt; 97%. However, in three of the four caliche soils, nitrate concentrations were significantly higher than the background and control cases. The high calcium carbonate content of the caliche soils leads to solutions well buffered with respect pH and alkalinity. Nitrification rates are very rapid in these soils which are buffered at the optimum pH range for Nitrosomonas growth. The low organic carbon content of caliche soils results in low denitrification rates. Nitrate in the effluent is the limiting pollutant in the determination of appropriate loading rates, drain field area, and land requirements. Phosphate and metal aqueous concentrations are acceptably low and are limited by the solubility control in the open system equilibrium model.

((NSFC Bibliographic Database))

** Liljestrand, H., and S. Parten. 1993. Design of on-site treatment systems in caliche soils. 2nd International Specialized Conference on Design and Operation of Small Wastewater Treatment Plants, Norway.

Currently, there are no standards other than hydraulic soil properties for the design and construction of on-site wastewater treatment systems in caliche soils. Experimental studies were performed to investigate biological transformation rates for organic carbon to inorganic carbon and nitrification, using four different caliche soils and the range of recommended hydraulic loading rates. The experimental results indicate that oxygen demanding materials readily decay with over short distances in caliche soils. Efficiency of removal for TOC was > 97%. However, in three of the four caliche soils, nitrate concentrations were significantly higher than the background and the control cases. The high calcium carbonate content of the caliche soils leads to solutions well buffered with respect to pH and alkalinity. Nitrification rates are very rapid in these soils which are buffered at the optimum pH range for Nitrosomonas growth. The low organic carbon content of caliche soils results in low denitrification rates. Nitrate in the effluent is the limiting pollutant in loading rate design and sizing. Phosphate and metal aqueous concentrations are acceptably low and are limited concentrations are limited by solubility control in the open system equilibrium model.

((ArticleFirst))

Lipp, P., G. Baldauf. 1996. Nanofiltration in combination with limestone filtration for treating a soft spring water containing high amounts of humic substances. Acta hydrochimica et hydrobiologica: Zeitschrift fur Wasser- und Abwasser-Forschung. Journal for Water and Wastewater Research, 24, no. 6, p. 267.

The paper presented here describes experiments with a nanofiltration pilot plant treating water which contains high amounts of humic substances. With this process, water components such as humic substances, iron, manganese, and aluminum may be very well removed. However, low pH value of the NF filtrate does not conform with the German standards of 9.5. With this treatment, a drinking water results which meets the German standards and has good chemical properties with respect to corrosion. The operation of the nanofiltration pilot plant for the treatment of the very soft spring water did not require the continuous addition of chemicals in order to prevent scaling. Although the spring water entered the NF without chemical pretreatment, there was no decrease in filtrate capacity observed over a period of six months. This is in contrast to other investigations involving colour reduction from very hard surface waters. When treating very hard waters by nanofiltration, the addition of complexing agents or acid is required in order to prevent scaling of the membranes. Such intricate pretreatment procedures cause doubt of the application of nanofiltration for the treatment of hard water in large plants. However, in the case presented here, the application of NF in combination with the hardening step is quite simple, so that the full-scale plant may be operated mainly automatically and will require only little maintenance.

Machette, M. N. 1985. Calcic soils of the southwestern United States. Special Paper, Geological Society of America, No. 203, 1-21.

Calcic soils are commonly developed in Quaternary sediments throughout the arid and semiarid parts of the southwestern United States. Inalluvial chronosquences, these soils have regional variations in their content of secondary calcium carbonate ($CaCO_3$) because of (1) the combined effects of the age of the soil, (2) the amount, seasonal distribution, and concentration of Ca^{2+} in the rainfall, and (3) the $CaCO_3$ content and net influx of airborne dust, silt, and sand. This study shows that the morphology and amount of secondary $CaCo_3$ (cS) are valuable correlaton tools that can also be used to date calcic soils. The structures in calcic soils are clues to their age and dissolution-precipitation history. Two additional stages of carbonate morphology, which are more advanced than the four stages previously described, are commonly formed in middle Pleistocene and older soils in southwestern United States. Stage V morphology includes thick laminae and incipient pisolites, whereas Stage VI morphology includes the products of multiple cycles of brecciation, pisolite formation, and wholesale relamination of breccia fragments. Calcic soils that have Stage VI morphology are associated with the late(?) Miocene constuctional surface of the Ogallala Formation of eatern New Mexico and western Texas and the early(?) Pliocene Mormon Mesa surface of the Muddy Creek formation east of Las Vegas, Nevada. Thus, calcic soils can represent millions of years of formation and, in many cases, provide evidence of climatic, sedimentologic, and geologic events not otherwise recorded. The whole-profile secondary $CaCO_3$ content (cS) is a powerful developmental index for calcic soils: cS is defined as the weight of $CaCO_3$ in a 1-cm vertical column through the soil (g/cm). This value is calculated from the thickness, $CaCO_3$ concentration, and bulk density of calcic horizons in the soil. (See Soil Survey Staff, 1975, p.456-46, for a complete defination of calcic horizon.) $CaCO_3$ precipitates in the soil through leaching of external Ca that is deposited on the surface and in the upper part of the soil, generally in the A and B horizons. The cS content, maximum stage of $CaCO_3$ morphology, and accumulation rate of $CaCO_3$ in calcic soils of equivalent age can vary over large regions of the southwestern United States in response to regional climatic patterns and the influx of Ca^{2+} dissolved in rainwater and solid $CaCO_3$. Preliminary uranium-trend ages and cS contents for relict soils of the Las Cruces, New Mexico, chronosequence show that 100,000- to 500,000-year-old soils have similar average rates of $CaCO_3$ accumulation. Conversely, soils formed during the past 50,000 years have accumulated $CaCO_3$ about twice as fast, probably because the amount of vegetative cover decreased in the Holocene and, hence, the potential supply of airborne Ca and $CaCO_3$ to the soil surface increased. The quantitative soil-development index cS can be used to estimate the age of calcic soils. This index can also be used to correlate soils formed in unconsolidated Quaternary sediments both locally and regionally, to compare rates of secondary $CaCO_3$ accumulation, and to study landscape evolution as it applies to problems such as earthquake hazards and siting of critical facilities.

((NSFC Bibliographic Database))

Malard, F., and R. Chapuis. 1995. Temperature logging to describe the movement of sewage-pollutant surface water infiltrating into a fractured rock aquifer. Journal of Hydrology i. November.

In 1992-1993, temperature logs were used to study the movement of sewage-polluted surface water infiltrating into the fractured limestone of an experimental site located in the south-eastern part of the Lez Basin (Southern France). The wells investigated were located on either side of a sewage-polluted stream and intersected water-bearing fractures characterised by large contrasts in hydraulic conductivity. From the results of temperature-depth profiles measured in four closely spaced wells of 60 m depth (W7, W8, W10 and W16) during the period February 1992-June 1993 and the findings of a previous and more extensive geothermal survey, we examined the spatial distribution and the temporal variability of ground-water temperature during periods influenced or not influenced by percolating sewage-polluted water. Results of this thermal survey, which were in good agreement with those of a physico-chemical and bacteriological survey simultaneously carried out at the site, provided a substantial amount of information on the distribution of contaminant flow pathways. Well W8, which showed high fluctuating ground-water temperature anomalies, intersected a solution-enlarged part of a bedding joint which seemed to carry much of the sewage-polluted infiltrating water. Ground water in this conductive opening also had a low physico-chemical and bacteriological ‘stability’ and the highest average contaminant concentrations. In contrast, Wells W10, W16 and, to a lesser extent, Well W7 displayed only low ground-water temperature anomalies during periods influenced by percolating sewage-polluted water. Ground water circulating through the thin and rather closed fissures intersected by these wells was less sensitive to pollution, as it had a greater thermal, physico-chemical and bacteriological ‘stability’ and the lowest average contaminant concentrations. Thus, we suggest that in advance focused monitoring programmes, temperature-depth profiles in wells could effectively be used to describe the effect of the structural features of fractured limestone aquifers on the movement of infiltrating contaminants.

((NSFC Bibliographic Database))

Mitchell L.K, and A.D. Karathanasis. 1995. Treatment of metal-chloride-enriched wastewater by simulated constructed wetlands. Environmental Geochemistry and Health v. 17, n. 3, September.

The ability of surface flow and subsurface flow simulated wetlands to remove heavy metals from a NaCl-enriched wastewater was examined, employing bulrush (Scirpus validus) and cattail (Typha angustifolia) plants, and two organically amended substrates (mixtures of mushroom compost and leaf litter, with topsoil) with a limestone liner. A simulated wastewater solution containing Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn as chloride salts was added to the wetlands at a rate of 0.3 l/hr. During 12 weeks of surface flow, Fe was retained most efficiently (74%), and Mn the least (24%). Most metal retention occurred in residual forms, primarily in the upper 5 cm of the substrate. A subsequent 10 week subsurface flow treatment exhibited greater removal efficiencies for all metals, probably due to increased contact with the highly buffered lower substrate. During both treatments, bioaccumulation occurred in plants, but accounted for a very small portion of the total metal removal. Plant species did not significantly influence wetland performance with respect to metal retention. Substrate type did not affect removal efficiency for most metals, but did influence the forms of the metals retained in the wetland.

((NSFC Bibliographic Database))

** Murphy, A., W. Robertson, and J. Cherry. 1993. Septic system-type tile bed treatment of landfill leachate. Waterloo Centre For Groundwater Research, Univ. of Waterloo problem Environments For Septic Systems And communal Treatment Options Conference.

A study was conducted to determine if septic type tile beds can be successfuly utilized as a passive treatment technology for landfill leachate. The aerobic unsaturated zone beneath septic system tile beds had already been found to be effective in reducing dissolved organic carbon and ammonium. The chemicals of concern in the landfill under study are dissolved organic carbon (DOC) ammonium, iron, and chloride. Two weeping tiles were placed two meters above the water table and a peat and a limestone layer were placed beneath one tile to enhance denitrification and to provide a buffer. DOC was biodegraded, ammonium and ferrousions were oxidated to nitrate and ferric hydroxide, respectively. Success of the system depended upon a oxygen-rich, unsaturated zone; sufficient residence time; and limited contaminants which could be oxidized or biodegraded in aerobic conditions.

((ArticleFirst))

Nguyen, L. M. 2000. Phosphate incorporation and transformation in surface sediments of a sewage-impacted wetland as influenced by sediment sites, sediment pH and added

phosphate concentration. Ecological Engineering 14, no. 1-2, (January 01, 2000): 139.

((NSFC Bibliographic Database))

Osesek, S., B. Shaw, and J. Graham. 1994. Design and optimization of two recirculating sand filter systems for nitrogen removal. On-Site Wastewater Treatment, Proceedings of the 7th Int'l Syposium on Individual & Small Community Sewage Systems.

Removal of nitrogen from domestic wastewater prior to discharge to a soil absorption system can help protect groundwater from exceeding the nitrate standard. This is becoming of increasing importance in Wisconsin and elsewhere, as rural development increases and people demand high quality drinking water. This study involved the design, installation, and evaluation of sand filter/denitrification systems on two private residences in Central Wisconsin. The recirculating sand filter design involves the use of 7,571 liter (2,000 gallon) septic tanks with wooden covers. To allow for easy access, the top of the cover is at the land surface. The systems have 5.1 cm (2 in) of insulation around the tanks and in the cover to help maintain heat during Wisconsin's cold winter. The filter is made up of 41 cm (16 in) of 2.5 to 3.8 cm (1 to 1.5 in) limestone overlain with 7.6 cm (3 in) of pea gravel and 61 cm (24 in) of coarse sand. Within the sand filter, a 61 cm (2 ft) slotted PVC pipe serves as a pump chamber to recirculate waste to the sand filter, pump back to the septic tank for denitrification, and pump to the soil absorption system. One of the sand filter systems was installed on a mound system, the other on a conventional gravity system. Samples from the septic tank, sand filter, dosing chamber, and monitoring wells adjacent to the drainfields are collected at least monthly, and analyzed for the nitrogen series, BOD, pH, and chlorides. Phosphorous and volatile organic chemicals are analyzed seasonally. A series of studies have been conducted, varying the recirculation rate to the sand filter and septic tank to optimize waste treatment during different seasons. Nitrogen removal of at least 60 to 70 percent can be achieved with systems of this design, with fairly simple pump and flow regulation equipment. Design problems and success along with flow optimization results are discussed.

((Compendex))

Parhad, N.M., and N.U. Rao. 1974. Effect of pH on survival of Escherichia coli. Journal Water Pollution Control Federation v. 46, n. 5, May, p. 980-986.

An attempt was made to delineate the factors affecting bacterial reduction using Escherichia coli as a representative of indicator bacteria. Laboratory studies involving the use of different algae and E. coli indicated that the increasing pH of wastewater resulting from algal growth was responsible for the gradual reduction and eventual elimination of E. Coli. These results supported the field observations on stabilization ponds.

((NSFC Bibliographic Database))

** Parrott, Ely, and Hurt, Consulting Engineers, Inc. 1981. Description of system design for the foundation run water district wastewater facilities consisting of: septic tanks, effluent sewer system and subsurface absorption systems. Parrott, Ely and Hurt, Lexington, KY 40522.

A small community (population 131) uses 5 decentralized subsurface disposal systems to treat a total design flow of 40,000 gallons per day. Includes determination of design flows and disposal site evaluations. Small diameter, septic tank collection systems convey waste to dosing tanks. Uses siphons for low pressure dosing of the limestone/sand trenches.

((CAB Abstracts))

Parveen, Z., A.C. Edwards, M.S. Cresser. 1994. Redistribution of zinc from sewage sludge applied to a range of contrasting soils. Science of the Total Environment 155: 2, p. 161-171.

An incubation study was performed to investigate the rates of redistribution of 65Zn from spiked sewage sludge into soil fractions. The labeled Zn in soils amended with sludge was fractionated by operationally defined procedures at 1, 7 and 30 days after incubation into exchangeable, organically bound, amorphous iron oxide-bound, crystalline iron oxide-bound and residual fractions. The rates of Zn redistribution from sewage sludge depended mainly on soil pH. In acid soils, 70-80% of sludge-derived Zn went to the exchangeable pools, where it was retained at high concn for more than or equal to 1 month. The timing of incorporation of the 65 Zn spike into sludge during digestion also significantly influenced zinc fractionation, but to a much lesser extent than soil pH. Sewage sludge improved available soil Zn only in the very short-term for near neutral soils; increased digestion times generally increased organically bound, amorphous and crystalline iron oxide-bound, manganese oxide-bound and residual fractions in soils, especially at low pH.

((NSFC Bibliographic Database))

** Pitt, W.A.J., H.C. Mattraw, H. Klein. 1975. Groundwater quality in selected areas serviced by septic tanks, Dade County, Florida. U.S. Dept. of the Interior - Geological Survey, Tallahassee, Florida, Open File Report 75-607.

From 1971-1974, wells at five selected areas in Dade County, Florida were monitored for chemical, physical, bacteriological and virological groundwater characteristics. Shallow wells were affected primarily by storm water runoff, with some indication of contamination by septic tank effluent. Wells deeper than twenty feet did not experience significant groundwater contamination due to dispersing dilution and chemical processes which prevented accumulation of septic effluent. Groundwater quality was influenced greatest by the compositon and hydraulic conductivity of the sand and limestone aquifers.

((Compendex))

Post, J. L. 1982. Strength characteristics of caliche soils of the Tucson area: ASTM Special Technical Publication, Geotechnical Properties, Behavior, and Performance of Calcareous Soils, 1982, Fort Lauderdale, FL, p. 483.

The physical and chemical composition of caliche soils of the Tuscon, Ariz. Area were investigated to determine the compressive strength of indurated and crushed calcisols. The results of stabilization of crushed calcisols with portland cement additive were determined and the soil-cement reaction products were investigated.

Soil minerals were identified by X-ray diffraction analysis. The calcisols were found to consist mainly of feldspar and randomly oriented microcrystalline calcite with lesser amounts of quartz and clay minerals. The strength of the calcisols was found to be inversely related to their clay content, with unconfined compressive strengths varying from less than 1.03 Mpa (150 psi) to more than 20.67 Mpa (300 psi). When the indurated caliche was crushed it behaved as an inert granular material with no immediate recementation when compacted. It was shown that a loss of compression strength generally occurred in the remolded soil-cement mixtures after 28 days of curing, the maximum 28-day compressive strength, using 10 percent portland cement, varying from 2.51 to 7.80 Mpa (364 to 1132 psi). The compressive strength was a function of the amount of portland cement added and of the combined feldspar-calcite content of the soil. The feldspars of the Tucson basin were found to consist mainly of intermediate microcline with lesser amounts of orthoclase and oligocase. The weak soil-cement bonding strengths appear to be due to the feldspars and the strength losses which occur are the result of the chemical interaction of the calcite and alkali feldspars with the portland cement in an aqueous environment. Portland cement is an unreliable additive for the effective stabilization of crushed calcisols.

Price, W. Armstrong. 1925. Caliche and pseudo-anticlines: American Association of Petroleum Geologists bulletin, v. 9, no. 6, p. 1009-1016.

Price reports on studies in Tamaulipas, Mexico, where strata have been deformed by the deposition of caliche in the subsoil/substrate. He notes dips of up to 17°, and uplift of strata for about 15 ft along a lateral extent of up to 2,000 ft. Price notes that caliche deposition functions as an agent of weathering in semi-arid to arid environments owing to the disruption of strata; it also tends to retard erosion by the process of recementation of rock fragments.

Price, W. Armstrong. 1933, Reynosa problem of South Texas, and origin of caliche: American Association of Petroleum Geologists Bulletin, v. 17, no. 5, p. 488-522.

Price defines “caliche” as a genus of soil-mineral accumulations, including calcareous, siliceous, ferruginous, aluminous, and nitrogenous varieties in young, mature, and aged stages. Included within this overly expansive definition are travertines, sinter/tufa, quartzite, chalcedony, opal, iron oxides, and hydrated iron oxides, kaolinite, bauxite, and laterite deposits. Price attributes formation of caliche as a leaching and redeposition of materials in the soil zone (from A to C horizons) in a degradational setting. This outdated report is valuable for its presenting the geographic extent of the Reynosa Plateau, which includes a caliche caprock (p. 490).

* Price, W. Armstrong. 1958. Sedimentology and quaternary geomorphology of South Texas: Gulf Coast Association of Geological Societies, Transactions, v. 8, p. 41-75.

In this multifaceted, and far-ranging discussion of regional geology, Price reviews his three types/origins of caliche: 1) soil carbonate caliche; 2) outcrop induration caliche (case-hardening); and 3) caprock caliche formed contemporaneously with accumulating calcareous loess in a dry climate (of the kind described by Brown, 1956). Price proposes that the Reynosa caliche is of the third type, formed by coastal winds providing loess to the top of the Reynosa scarp.

((Springer LINK))

Pulido-Bosch, A., M. Machkova, M. Lopez-Chicano, M.L. Calvache, J.M. Dimitrov, J.M Calaforra, B. Velikov, P. Pentchev. 1997. Hydrogeology of the upper aquifer, Dobrich Region, Northeastern Bulgaria. Hydrogeology Journal v. 5, i 2, p. 75-85.

The upper aquifer of the Dobrich region, northeastern Bulgaria, is composed of limestone, calcarenite, sand and probably dolomitic limestone, of Messinian age; total thickness is 40-200 m. Most of the area is underlain by surficial deposits that include slightly permeable loess and highly permeable sand and alluvium. The nearly impervious substratum comprises marl and clay of varying age. In the aquifer as a whole karstic processes are not very pronounced, based on observations of the small variations in the discharges of the springs that have been monitored. The lithology of the Quaternary-age surficial deposits strongly influences the hydrochemistry of groundwater in the aquifer. The main sources of pollution are related to agricultural activities, corralled livestock, and urban wastewater, as indicated by the high nitrate contents of the water in numerous wells. Seawater intrusion is occurring in some eastern parts of the region.

Rabenhorst, M.C., L.T. West, L.P. Wilding. 1991. Genesis of calcic and petrocalcic horizons in soils over carbonate rocks. Soil Science Society of America special Publication no. 26.

The formation of calcic and petrocalcic horizons in unconsolidated materials has generally been attributed to processes related to the translocation and net accumulation of pedogenic carbonates that have been derived from a variety of sources. Where soils have formed over carbonate-rich rocks (hard or soft limestones), the formation of calcic and petrocalcic horizons may involve fundamentally different processes. Under these conditions, processes of translocation are relatively minor in comparison to the alteration of lithogenic (inherited) carbonate to pedogenic (soil formed carbonate through in situ dissolution and recipitation of carbonates. This has been confirmed through a variety of microscopic and isotopic studies. These horizons may thus be lower in carbonate than the underlying horizons. These processes cause changes in the soil fabric, and presumably in the nature of the carbonates. The origin of laminar caps at the upper surfaces of petrocalcic horizons is presently under debate. Laminar caps have traditionally been attributed, by pedologists, to inorganic processes of carbonate precipitation over an impermeable substrate. Some workers, however, have described biological features in the laminar materials, and suggest a biogenic (i.e., stromatolitic) origin. Because such differences in the interpretation of these structures have important ramifications on the theories of pedogenesis, diagnostic criteria are needed, which allow the orgin of these laminar features to be determined conclusively. Soil scientist are probably most familiar with calcic or petrocalcic horizons that have probably formed under semiarid or arid conditions, and in unconsolidated sedimentary deposits that are low in carbonates. Under such conditions, the formation of these horizons has generally been attributed to processes related to the translocation and net accumulation of pedogenic carbonates of varied sources (derivied directly from calcareous parent materials, neoformed from Ca-rich minerals, or carbonates in dust). This model was earlier described by Hawker (1927) used by many workers (Bretz & Horbeg, 1994; Harper, 1957; Buol, 1964; Flach et al., 1969), and then more throughly elaborated in the classic paper by Gile et al. (1966). At least in pedological circles, somewhat less attention has been directed toward carbonate-rich horizons as they occur in soils that overly carbonate rock (R or C horizons). Limestone rocks and sediments (including chalks and dolomites) are quite extensive on a worldwide scale. Many of these exposures also occur in regions of arid or semiarid climate, which are conductive to calcic horizon formation. Calcic and petrocalcic horizons, which occur in this setting, might exhibit both similarities and differences in properties and genetic pathway when compared with those formed in more pervious materials. Where parent materials are carbonate rocks, carbonates in calcic horizons need not come from an external source such as dust, because they are abundant in the parent material. Carbonate contents may be greater in the underlying parent materials. In such cases, calcic and petrocalcic horizons may form through in situ alteration of the parent carbonate, with only ancillary translocation or redistribution. In this chapter we hope to elucidate those conditions unique to calcic and petrocalcic horizons formed over carbonate rocks.

Rabenhorst, M. C., L. P. Wilding. 1986. Pedogenesis on the Edwards Plateau, Texas: I. nature and continuity of parent material. Soil Science Society of America Journal, 50: 3, 678-687.

Of 15 pedons sampled on the Edwards Plateau of Texas, four were evaluated to determine the relative contribution of limestone weathering and airborne dust additions to soil formation. Although dusts were collected at measurable rates, silt grain morphology by scanning electron microscopy indicates that dusts are not accumulating on stable land surfaces. Euhedral, prismatic quartz grains were prominent components of residues from hard crystalline limestones. These grains were used as marker minerals in identifying parent material discontinuities. Quartz grain morphology, particle size distribution, elemental assay, and mineralogical data indicate lithologic discontinuities between the solum and subjacent limestone. Noncarbonate residues from petrocalcic horizons show varying degrees of similarity to the overlying sola and subjacent limestone. These soils appear to have formed from overyling limestone residuum, rather than from the underlying rock, which is different in character.

Rabenhorst, M. C., L. P. Wilding. Pedogensis on the Edwards Plateau, Texas: II. formation and occurrence of diagnostic subsurface horizons in a climosequence. Soil Science Society of America Journal, 50: 3, 687-692.

Following reconnaissance efforts to minimize differences in parent materials, 15 pedons were sampled across the Edwards Plateau of Texas, which spans a pronounced moisture gradient. Care was taken to minimize differences in topography by choosing sites on relatively stable landscape positions. Statistically significant positive relationships exist between depth to bedrock or petrocalcic horizon and Thornthwaite's P-E index. Negative relationships occur between carbonate contents and this index. Petrocalcic horizons are common and most strongly expressed in the dry western part of the study area, while argillic horizons are observed in the more humid eastern portion. High shrink swell activity in the argillic horizons (coefficient of linear extensibility [COLE] values 0.09-0.23) caused difficulty in distinguishing illuvial clay from stress oriented clay, both in the field and in thin section. Well-oriented illuvial clay was best preserved within interconnected pores of sand and gravel size chert fragments.

Rightmire, Craig Turner. 1967. A radiocarbon study of the age and origin of caliche deposits: the University of Texas, M.S. Thesis (unpublished) 67 p.

Rightmire applies isotope geochemistry (carbon-14 and stable-isotopes of carbon) to caliche deposits in the Finlay area, Hudspeth County, Texas. He notes that data support a pedological origin of the caliches in Hudspeth County. The isotope data spans 1700 years and indicates decreasing aridity with age.

((Compendex))

Runnells, D. D. 1976. Wastewaters in the vadose zone of arid regions. Geochemical Interactions: Ground Water 3rd, Sep 15-17 1976, 1976, v 14, n 6/Spec Issue v 1, Nov-Dec, p 374-385.

The author shows that in the subsurface the process of oxidation may be of little value in significantly reducing the concentration of discharged contaminants; in contrast, oxidation plays an important role in purifying surface waters. Eleven physical-chemical processes are identified as having potential value for purifying wastes discharged to the subsurface, as follow: dilution, buffering of pH, precipitation by reaction, hydrolysis, oxidation or reduction, filtration, volatilization, biological assimilation, radioactive decay, membrane filtration, and sorption.

Sayre, Albert Nelson. 1937. Geology and ground water, Duval County, Texas: U.S. Geological Survey, Water-Supply Paper 776, 116 p.

In reporting on the occurrence of caliche deposits in Duval County, Sayre reviews literature bearing on formation of caliche. Much attention is given to the hypothesis that caliche precipitated from ground water, but Sayre accepts the thesis, proposed by O.E. Meinzer, in oral communication, “that caliche is characteristically formed near the surface in aggrading areas by deposition of calcium carbonate through evaporation of the soil moisture and that it is not generally related to the ground-water table.” (p. 69) Thus, Sayre proposes what is the modern acceptance of caliche as a pedologic material. He correctly notes that “caliche is not all formed by identical processes.” Sayre concludes that three criteria are needed for the formation of caliche: 1) subhumid to arid climate; 2) underlying formation must be calcareous; and 3) substrate must be of a texture to allow capillary movement of subsurface waters. Subsequent research casts doubt on his second criteria, especially.

((Compendex))

Scandura, J.E. and M.D. Sobsey. 1997. Viral and bacterial contamination of groundwater from on-site sewage treatment systems. Water Science and Technology , v 35, n 11-12, Proceedings of the 1996 IAWQ 8th International Symposium on Health-related Water Microbiology, 1997, Elsevier Science. Oxford, Eng. p 141-146

On-site septic tank-soil absorption systems treating domestic wastewater have contaminated groundwaters with enteric viruses and other pathogens and caused drinking waterborne outbreaks. The factors influencing pathogen transport, survival and fate at on-site wastewater treatment systems remain inadequately characterised. we studied the survival and transport of a model enterovirus (be-1) and faecal coliform bacteria in four on-site wastewater treatment systems (three conventional and one low pressure, small pipe diameter, pumped system) located in sandy soils typical of the coastal plains. septic system wastewaters were seeded seasonally with known amounts of be-1 and the fate of be-1, faecal coliforms and other wastewater constituents were followed for three months in seeded wastewaters and groundwaters of drainfield monitoring wells. be-1 levels in seeded wastewaters declined exponentially by kinetics consistent with a 3d hydraulic residence time. be-1 was detected in ground waters of monitoring wells as early as 1d after seeding and persisted up to two months. virus detection in ground water was greater in winter than in summer and was positively associated with proximity to septic effluent distribution lines, drainfield soils with the lowest clay content, elevated ground water ph and shallower vadose zones. viruses were not strongly associated with either distance from septic tank or faecal coliform levels in groundwater. under optimum conditions, virus reductions were as high as 9 log10, but in systems with the most coarse (sand) soils and highest water tables (most shallow vadose zones), there was extensive ground water contamination by viruses and other wastewater constituents. under some conditions, septic systems in sandy coastal plains soils can contaminate ground water with viruses and other wastewater constituents.

((NSFC Bibliographic Database))

* Sherman, K.M., P. Hextell, and J.L. Massicotte.1994. Evaluation of drainfields in Florida using recycled crushed concrete aggregate. On-Site Wastewater Treatment: Proceedings of the 7th Int'l Symposium on Individual & Small Community Sewage Systems.

The authors conducted a field evaluation of 45 drainfields using recycled crushed concrete (RCC) instead of conventional aggregate. The field evaluation consisted of a soils evaluation and obtaining samples of the infiltrative surface and aggregate samples at various depths within the drainfield. Excessive aggregate erosion or cementation did not occur. Two systems (4.4 percent) met the definition of failure (greater than five percent). The five pH measurements taken from ponded systems fell near the normal range of septic tank effluent. The failing systems had RCC of small average size and had excessive particles less than 4.75 mm. When properly sized and thoroughly washed, this aggregate functions as well as other approved materials (for example, limestone). Scrupulous quality control must occur daily at the production facility to make certain that extraneous materials (for example, plastics, asphalt, wood) do not contaminate the aggregate. The best motivation for this vigilance is the certain knowledge that materials that do not meet standards will be quickly and without exception disapproved at time of inspection.

((CAB Abstracts))

Shukla, N., G.S. Pandey. 1991. Biogenic reduction of some oxo-anions by domestic sewage sludge. Journal of Ecotoxicology & Environmental Monitoring v.1: 4, 325-328.

The removal of oxalate, sulfate, phosphate, thiosulfate, nitrate and chromate by bacterial communities present in domestic sewage sludge was investigated. The kinetics of the reduction were in the order: oxalate more than sulfate more than thiosulfate more than nitrate more than phosphate more than chromate. Prior deactivation of the bacteria by thermal treatment resulted in a substantial decrease in the reduction process. The reduction process was optimal at pH 8.10, the natural pH of the sewage sludge.

((NSFC Bibliographic Database))

Sikora, L.J., J.C. Converse, D.R. Keeney, R.C. Chen. 1977. Field evaluation of a denitrification system. Proceedings of the Second National Home Sewage Treatment Symposium. ASAE Publication 5-77.

The use of a denitrification tank packed wth limestone medium for treating nitrified septic tank effluent was tested. Nitrate removal rates were found to be over 80 percent during 24- and 12-hour retention times. Methanol was added as an energy source. The system was operated for two years in the laboratory, and the pilot plant evaluations were performed for seven months. Tabulated results of nitrate removal and schematic diagrams of the denitrification system are included. (SWF)

((NSFC Bibliographic Database))

** Simon, J.J., R.B. Reneau, M.J. Degen. 1986. Suitability of limestone-derived soils for onsite wastewater disposal. Virginia Polytechnic Institute and State University, Bulletin 86-6, Fall.

Results of this study indicate that clayey soils developed in limestone residuum are suitable for disposal of STE. Where the soil structure is weak blocky to massive, but soil colors indicate good drainage, flux densities of 0.5 cm/day may be suitable with LPD. ST-SAS installed in fine textured soils with 15 to 30 cm of soil having moderate to strong blocky structure beneath them may be dosed at 1 cm/day. Where more than 60 cm of soil with strong structure, but no other apparent restrictions underlies a ST-SAS, loading rates of 2 to 3 cm/day may be suitable. Presence of > 25% coarse fragments in otherwise well structured soils may result in lower effluent acceptance rates; hence, a maximum rate of 1 to 2 cm/day may be suitable in these soils, depending on other soil properties. If effluent is continually ponded in ST-SAS, nitrification may be mini-

mal. However, nitrification was predominant both below ST-SAS which were not continuously ponded and below trenches which were rested. Concentrations > 60 mg/l of NO_3 may be present in water leaving the immediate trench bottom area below ST-SAS. The density of ST-SAS placement and loading rate should be determined in part by the area required to dilute NO_3 concentrations to the U.S. Public Health Service standards of 10 mg/l.

((NSFC Bibliographic Database))

** Smith, C.R., and K.F. Steele.1990. Nitrate concentrations of ground water Benton County, Arkansas. Arkansas Water Resources Research Center, n. 73.

Because ground water in fractured carbonate aquifers is particularly susceptible to contamination from surface sources, there is concern about nitrate contamination of ground water supplies in northwest Arkansas. Surface application of animal wastes, commercial fertilizers, animal impoundments, septic systems, and municipal sewage collection and treatment systems represent potential sources of contaminants, especially nitrate. A survey of ground water nitrate concentrations was conducted in Benton County, Arkansas during 1990. Sixty-eight randomly selected ground water samples were collected from springs and wells during successive wet (5-19 to 6-5-90) and dry (7-19 to 8-3-90) seasons. Fifty-two samples were collected from the shallow, unconfined Boone-St. Joe limestone formations of the Springfield Plateau aquifer. Sixteen wells were completed in the more productive Ozark aquifer. Owner reported well depths and Mg/Ca ratios were used to determine the source aquifer for each sample. Nitrate concentrations for wells and springs of the Springfield Plateau aquifer were higher than those of the Ozark aquifer during both seasons. Mean concentrations for the shallow aquifer are 2.63 mg/L NO_3-N in the wet season, and 1.80 mg/L in the dry. The nitrate concentrations are higher during the wet season: a period of maximum recharge. Wells producing from the Ozark aquifer had significantly lower mean values as a population. Mean values for this confined aquifer were 0.11 and 0.15 mg/L for the wet and dry seasons, respectively.

((Compendex))

Smith, R. B. 1984. On nomenclature and classification of calcretes: Australian Road Research v 14, n 4, Dec, 1984, p 197-204.

A diversity of terms is used in Australia to name the products formed by the secondary cementation of soils or rock by calcium carbonate in the surficial environment. Terms used include calcrete, travertine, secondary limestone, kunkar, caliche and nodular calcium carbonate. Even the one term may have different meanings for different workers; for instance, 'kunkar' means calcareous gravel to some workers and sheet-like layers to others. It is proposed that 'calcrete' be adopted for all the products, indurated or not, which are formed in soils by the secondary cementation of calcium carbonate and have in excess of about 50 per cent calcium carbonate present. Calcretes could be classified according to the system of Netterberg which is based on the secondary (chemical) structure and sequence of development of calcretes.

* Stricklin, F.L., Jr., C. I. Smith, and F. E. Lozo. 1971. Stratigraphy of lower cretaceous Trinity deposits of Central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations no. 71, 63 p.

This detailed study of depositional environments of the basal Cretaceous strata in Central Texas discloses widespread caliche deposits that are part of the rock record (and are not results of modern processes). Thus, these paleo-caliche deposits are used to characterize ancient environments at the time the various units were deposited along the margins of the Cretaceous seas.

((ArticleFirst))

Takeuchi, M., M. Komada. 1998. Phosphorus removal from hoggery sewage using natural calcium carbonate. Japan Agricultural Research Quarterly 32, no. 1, (1998): 23.

For the treatment of hoggery sewage, an attempt was made to develop a phosphorus removal technique by using natural calcareous materials whose products can be restored to farmland as phosphate materials with minimal waste, at a low cost and with easy management. The results of tests on packed materials passing through a water column under the same conditions revealed that the efficiency of phosphorus removal characteristics was in the order of Sakhalin surf clam > oyster seashell, scallop seashell > coral sand > fossilized seashell > dolomite for twice the daily amount of passed water. In brief, young calcareous sources originating from marine Conchifera were superior as dephosphorization materials. The mechanism involved in phosphorus removal of natural calcareous materials was neither absorption to materials nor crystallization but a direct replacement reaction from carbonates to phosphates. Since the produced salts were $CaHCO_3$ and $Ca_4H(PO_4)_3$ with low Ca/P and OH/P ratios, highly valuable phosphates for fertilizer were obtained. Since the pH of effluents was 8.5 at the maximum and lies within the legal standard range, the dissolution of carbonates and the production of phosphates prevent clogging and the total cost is low. If the TOC and TIC concentrations of influents are high, the TIP concentration in the effluents easily increases. However, it was demonstrated that 24 h aeration in the presence of sludge results in a decrease of pH due to accelerated nitrification and that the release of supersaturated CO_2 into the atmosphere can lower TIC significantly.

((Soil Science Society of America))

Tarchitzky, J., Y. Golobati, R. Keren, Y. Chen. 1999. Wastewater effects on montmorillonite suspensions and hydraulic properties of sandy soils. Soil Science Society of America Journal, 63, p. 554-560.

Recycled wastewater effluent is an important source of irrigation water in arid and semiarid regions. In these regions, however, irrigation water quality is one of the main factors limiting plant growth. Wastewater effluents generally contain high concentrations of suspended and dissolved solids, both organic and inorganic. Inorganic dissolved solids are only minimally removed from the effluent during conventional sewage treatment (secondary or tertiary). As a result, most of the salts added during domestic and industrial usage remain in the irrigation water and may eventually reach the soil. A number of researchers have reported reduced hydraulic conductivity for soils to which treated wastewater has been applied. In this research, the influence of dissolved organic matter (DOM) contained in reclaimed wastewater effluents (mainly humic substances) on the flocculation of montmorillonite and on the hydraulic properties of soils was studied. Flocculation values (FVs) for Na-montmorillonite increased with increasing concentration of DOM at all pH levels analyzed (5.5, 7.0, and 8.5). Maximum FV levels were exhibited for Na-montmorillonite at the highest DOM concentrations. The effect of DOM on FV can be explained by the mechanics of edge-charge reversal and mutual flocculation. The hydraulic conductivity (HC) of a sandy soil was determined in the laboratory by leaching columns with an electrolyte solution chemically similar to that of the wastewater effluent (but without DOM). In columns treated with wastewater effluent, the HC exhibited a sharp decrease to only 20% of its initial value. The adverse effect of DOM on HC was evident for this soil despite a relatively low exchangeable sodium percentage (ESP). The reduction in HC is likely to be the result of decreased soil pore-size, which reflects two processes; (I) retention of parts of the DOM during water percolation; and (ii) a change in pore-size distribution due to swelling and dispersion of clay particles. The later may result from a higher percentage of absorbed sodium combined with the presence of humic substances from the wastewater effluent.

Waltz, David Henry. 1974. Sewage renovation and surface-water quality, Lakeway resort community, Travis County, Texas: The University of Texas at Austin, M.A. Thesis, 91 p.

Strictly speaking, this citation does not deal with “caliche” (at least as reported in the thesis). But it does deal with wastewater application and remediation on Glen Rose Limestone terrain in western Travis County. Waltz injected sewage with an average of 130,000 total coliforms and 11,000 fecal coliforms/100 ml into a borehole 150 cm deep. Movement of bacteria-laden water was monitored by collecting water samples from nearby observation wells—all within the zone of aeration. After the injection of 300 liters of sewage and a cumulative rainfall of 3.17 cm, a sample from a well 10.6 m from the injection well contained 4,500 total coliforms and 30 fecal coliforms/100 ml. Water movement was controlled by fractures. Surface water samples in Lake Travis showed a range of total coliforms ranging from 26 to 1,100/100 ml and fecal coliforms 10-18 fecal coliforms/100 ml. The data show attenuation of wastewater, yet suggest the possibility for overloading of the capabilities of the land to mitigate septic tank effluents

with increasing densities on such a limestone terrain.

Weeks, Albert W. 1933. Lissie, Reynosa, and upland terrace deposits of Coastal Plain of Texas between Brazos River and Rio Grande: American Association of Petroleum Geologists Bulletin, v. 17, no. 5, p. 453-487.

This review of stratigraphy presents the “Reynosa Limestone” comprises the caliche caprock that is discussed more fully by Price (1933).

West, L. T., L.R. Drees, L.P. Wilding, and M.C. Rabenhorst. 1988. Differentiation of Pedogenic and Lithogenic Carbonate Forms in Texas. Geoderma, 43, p. 271-287.

Sixteen pedons, representing soils developed from limestone and fluvial/deltaic sediments, were sampled in central and western Texas (300-800 mm annual precipitation) to differentiate pedogenic (secondary) and lithogenic (inherited) carbonate forms by field and laboratory techniques. Lithogenic carbonate forms identified in the field include indurated limestone bedrock and coarse limestone fragments (lithorelicts). Field identified pedogenic forms included petrocalcic horizons, thin laminar cappings on indurated limestone, carbonate joint seams, pendants on pebbles, and carbonate films and threads on ped faces. Small (<10 mm)glabules were also consideredpedogenetic in the field, but micro fabriuc analysis indicated that this group of carbonates was composed of pedogenic concentrations, pedogenic nodules, and lithorelicts. Soft tubular segregations were field identified as pedogenic, but these forms had many properties that could be mistaken for those of lithogenic carbonates. Micromorphology and stable C isotope analysis indicated that the soft tubular segregations were pedogenic, but their formation was through recrystallization of marine carbonates rather than through translocation and accumulation. Stable C isotope analysis also indicated that as much as 80% of the disseminated carbonates in the limestone-derived soils were pedogenic. These disseminated carbonates are not currently considered to meet calcic horizon criteria although they comprise a significant portion of the carbonates in these soils.

West, L. T., L. P. Wilding, C. R. Stahnke, C. T. Hallmark. 1988. Calciustolls in Cental Texas: I. parent material uniformity and hillslope effects on carbonate-enriched horizons. Soil Science Society of America Journal, 52: 6, 1722-1731.

Most soils associated with soft Cretaceous limestones in Texas occupy moderately to strongly sloping erosional landforms and are underlain by interbedded weakly to strongly indurated limestone. Fourteen pedons from four hillslopes in these landscapes were sampled to evaluate soil parent materials and the effect of hillslope position on genesis of the soils and carbonate-enriched horizons. Clay-free, carbonate-free particle size distribution and elemental analysis of the residue silt fraction show that the soils

had developed from stratified parent materials. Calcareous microfossils observed in thin section and siliceous micofossils observed with scanning electron microscopy indicate the soil parent materials to be limestone of composition similar to that underlying the soils. Dust is being added to the soil surface at a rate of 1 to 2 mm/100 yr but has not been an important parent material amendment. The main effect of hillslope position on genesis of soils and carbonate-enriched horizons is through site stability. No consistent relationships were observed between soils on backslope and summit positions, and expression of carbonate-enriched horizons.

((Compendex))

Whelan, B. R. 1988. Disposal of septic tank effluent in calcareous sands. Journal of Environmental Quality v 17, n 2, Apr-Jun, 1988, p 272-277.

This study investigated the suitability of calcareous sands (Xeropsamment) for treatment of septic tank effluent. Most of the NH_4-N in the effluent was oxidized to NO_3-N in the unsaturated zone just below the slime layer. Nitrate (NO_3^-) was present in the soil solution up to a concentration of 50 mg L^{-1} down to the maximum depth sampled of 8 m. The acidity produced during nitrification of the NH_4, dissolved carbonates from the soil changing the soil pH. The soil P was increased by sorption and precipitation of P from the soil solution until it reached an equilibrium. At equilibrium the soil solution P was at the same concentration as in the effluent and the P sorbed on the soil was at a maximum for that concentration. Further down the profile where the sorbed soil P was not at its maximum, all the P was sorbed from the soil solution in a vertical distance of 0. 5 m. Additional study results and conclusions are discussed.

** Wilding, L. P., L.R. Drees, and C.M. Woodruff, Jr. 1997. Minerology and microfabrics of limestone soils on stepped landscapes in Central Texas. Soil Microbiology: Studies on Soil Diversity, Diagnostic, Dynamics, Moscow-Wageningen 1997.

In the Hill Country of Central Texas, strongly calcareous, loamy skeletal, soils are derived from Cretaceous age, interbedded dolostone/limestone strata of the Glen Rose Formation. These soils ocupy stepped terrain in gently to strongly dissected landforms. Soil distribution patterns, pedogenetic development, biogeochemical properties, and hydrolological function are controlled locally by riser and tread repeating microtopographic units (1-4 m high and 10-20 m long). Crystalline dolostones are composed primarily of interlocking and interwelded euhedral dolomite rhombs. Softer marls are predominately composed of anhedral, micitric calcite with secondary amounts of dolomite, quartz, and non-carbonate silt and clay seperates. Marly limestones are more easily weathered than hard dolostone strata and thus, the thickest soils occur on the steepest parts of the microtopography. The formation of calcic versus petrocalcic horizons in these formations is controlled by local hydological environments within steps, which function essentially as independent hydological units. Micromorphological features indicate that petrocalcic horizons are polymorphic and polygenectic. The 2Bk and 2Bk/Cr calcic horizons also exhibit multiple microfabric and DEM forms. 2Cr materials are dense, micritic clasts. 2Bk materials consist of spongy, porous, micritic, micromasses, wavy, laminar, micritic pendants on lower clast surfaces; nodules composed of recemented lithic clasts; needle pore linings; and interwoven tubular masses. Clcic horizons also appear to be polymorphic and polygenetic. All plasmic fabrics are crystic with s-matrixes porphyroskelic. Occassionaly, sparry pedogenetic calcite cements fill joint planes.

((Texas A&M Library)

** Wilding, L.P., C.M. Woodruff, Jr.1994. Soils and landforms of the Central Texas Hill Country: implications for wastewater application. Insights v. 3, n. 1: Spring.

Much of the Central Texas Hill Country is comprised of disected landscapes that were formed on the Glen Rose limestone formations west of the Balcones Escarpment. A key attribute of the Hill Country is its "stair-step" topography, in which hard limestone and dolomite strata commonly crop out as flat trends and ledges. Marly beds rise from risers, which slope below the ledges. The risers function as local water retention and storagedevices, although subsurface flows are impeded by stacked sequences of strata with varying permeability. This often forms a sries of locally perched aquifers and aquitards. Traditionally, this terrain has been used for rangelands. Recently, landuse patterns have changed. The Texas Hill Country is now highly prized for homesites and development pressures are pronounced in urban-fringe areas near Austin and San Antonio. An environmental concern is the adequacy of on-site wastewater systems to treat wastes in this setting without causing ground or surface water pollution. Many people believe that soils are too thin and slopes are too steep across most of the Hill Country to allow adequate infiltration and remediation in on-site wastewater systems.

Since August 1991, we have conducted soil, landform, vegetation and hydrology studies in two small waresheds that drain part of the Glen Rose limestone terrain of Austin. The study area is part of a 3,346 acre-tract that has been proposed for mixed use development and includes watersheds that drain into Barton Creek, which is recognized for its environmental sensitivity. The study area and the development are upstream of the recharge zone of the Barton Springs segment of the Edwards Aquifer. Our research has focused on how the hydrology, landforms and soil, chemical, physical and biological properties affect the quality and quantity of waters within the study area.

** Wilding, L. P. and C.M. Woodruff. 1996. Soils and microtopography of the Central Texas Hill Country: implications on vadose zone hydrology. 1996 GSA Meetings.

In the hill Country of Central Texas, strongly calcareous, loamy skeletal, soils are derived from Cretaceous age, interbedded hard and soft limestone strata of the Glen Rose Formation. The soils occupy stepped terrain in gently to strongly dissected landforms. The quality, thicness, pedogenic development and hydrological function of soils are controlled locally by a series of riser and tread microforms (1-4 m high and 10-20 m long).Contrary to conventional wisdom, the thickest soils (1-3 m) are set to disjunct wedges along steep-gradient risers are developed from a thin veneer of limestone-rubble colluvium superposed over partially-weathered, marly bedrock; downslope on the nearly level treads, soils become thinner (<0.5 m) and are formed in loamy pedisediment clastics mixed with weathered marls that abruptly overlie caliche-sealed (petrocalcic), or weakly jointed limestone or dolomite ledge-former strata. Based on the infiltometer, piezometer, tensiometer, shallow access wells, soil morphology, microfabric porosity, and microwatershed responses to natural rainfall events, the riser/tread microforms were shown to be essentially independent hydrological units. Ephermeral multiple wter tables are perched within among marly strata that exhibit limited interconnectivity. Locally, the risers serve as the recharge zone and the treads as the interflow or discharge zone within these microform couplets. Discharge of incident water to downslope positions is retarded by cascading processes of water flow through multiple steps.

** Wilding L. P., C.M. Woodruff, Jr., and W. Gabriel. Caliche Soil—What is is It? Wastewater Treatment Research Council Conference.####### DATE????

The term “caliche” is highly ambiguous. It has multiple definitions depending on the context and professional disciplines involved. It is derived from the Latin root cal meaning lime. However in the glossary of Geology (Jackson, 1997) the term carries two definitions, [eco-geol] and soil contexts. The former implies: gravel, soil, or alluvium cemented with soluble salts of sodium in nitrate deposits of deserts in northern Chile and Peru; thin layer of clayey soil capping a gold vein; (Peru; whitish clay in veins along a fault zone (Chile); feldspar, white clay, or compact transition limestone (Mexico); and a mineral vein recently discovered or a bank composed of clay, sand, and gravel in placer mining (Columbia). At the extreme caliche has been compared to loess deposits (Reeves, 1970 and Brown, 1956), bog iron ore by Price (1933), and bauxites (Swineford et al., 1958).

In the [soil] context, the glossary of Geology (Jackson, 1997) gives the term caliche as a synonym for calcrete. It has been applied broadly in the Southwestern U.S. as the “reddish brown to buff or white calcareous material of secondary accumulation, commonly found in layers on or near the surface of stony soils of arid and subarid regions, but also occurring as subsoil deposit in subhumid climates”. Sometimes caliche has been reserved for just the cement in calcareous and non-calcareous host gravels, sands, silts, and clays. Compositionally, it is mostly calcium carbonate but may include magnesium carbonate, silica or gypsum in various degrees of induration and in different morphological forms. Hard crusts, plates, nodules, soft porous masses, and massive strongly indurated zones are common. Theses distinctive materials have been called: hardpan, calcareous duricrust, calcareous crust, croute calcaire, nari, sabach, and tepetate in various parts of the world. In more recent years pedological literature, calcic and petrocalcic are the terms commonly in vogue as substitutes for caliche (Soil Taxonomy, 1975). Caliche is considered obsolete by soil scientist because of its unrestricted usage. For the purpose of this paper the following working definition is proposed for the term caliche. It is defined as pedogenically altered parent material that contains more than 40% calcium carbonate equivalent and has sufficient accumulation of pedogenic carbonates to meet the minimum requirements of a calcic or petrocalcic diagnostic horizon as defined in the Keys to Soil Taxonomy (Soil Survey Staff,1998). These materials may either be indurated (petrocalcic) or non-indurated (calcic); they have variable morphology, thickness, and origin; however, they are differentiated from soft and hard limestones, or sediments derived from them, by sufficient weathering to form accumulations of pedogenic carbonates equivalent to at least 5% by volume identifiable forms. Likewise, there has been sufficient weathering that at least 50% of the parent material or “rock structure” has been obliterated. In most cases the minimum thickness of altered zone should be about 6 inches for a calcic and four inches for petrocalcic horizon.

((Compendex)

Wilhelm, S. R., S.L. Schiff, W.D. Robertson. 1996. Biogeochemical evolution of domestic wastewater in septic systems: 2. Application of conceptual model in sandy aquifers. Ground Water v 34, n 5, Sept-Oct, 1996 Ground Water Publ Co, p. 853-864.

Aqueous geochemical data from unconfined sand aquifers beneath two operating domestic septic systems are used to illustrate and evaluate a conceptual model of septic-system geochemistry. This model emphasizes the changing redox and alkalinity conditions in the septic system and the subsurface. The septic-tank effluents flow as distinct plumes downward through the unsaturated zones and then primarily laterally in the ground-water zones. The composition of the effluent was measured at several points in each system. At each site, the septic-tank effluent underwent aerobic oxidation in the unsaturated zone, which caused conversion of NH_4^+ to NO_3^-, organic C to CO_2 and organic S to SO_4^{2-}. At the first site, calcium carbonate dissolution in the unsaturated zone buffered the acidity released by the redox reactions. In contrast, the second system was poorly buffered and the pH dropped from 6.7 to 4.9 as aerobic oxidation occurred. Below the water table a small amount of aerobic oxidation occurred at each site. Nitrate-N concentrations in the cores of both plumes were above 25 mg/l as the plumes traveled from the septic systems. At the second site, the ground-water plume discharges to a river at the edge of the property. As the effluent flowed through the organic C-rich sediments of the river bed, NO_3^- disappeared and alkalinity increased, presumably due to denitrification. Differences in sediment composition at the two sites also led to different behaviors of Fe, Al, and possibly PO_4^{3-}. The conceptual model offers an organized approach to interpreting the major geochemical trends observed in the two systems, which are determined mostly by the well-aerated unsaturated zones below the drain fields and the amount of buffering material present in the sediments.

((NSFC Bibliographic Database))

* William C., P. E. Allanach, and Becky Johnson-Richards, R.P.G. 1995. Water infrastructure study Saltillo, Mexico. Groundwater Management, Proceedings of the International Symposium sponsored by the Water, Resources Engineering Division, American Society of Civil Engineeers, San Antonio, Texas, I. August 14-16.

The city in this case study, Saltillo, Coahuila, Mexico, is a prime example of a city which supports its entire community and sizeable industrial population solely through groundwater resources in limestones of the Sierra Madre Oriental. The city has experienced industrial growth and a population expansion to almost 500,000 and has great potential for continued growth and prosperity. Both the local and state governments endorse and support the expanding economic sector, but realize that they must plan for sustainable development in both industry and the community. This sustainable development includes water supply, distribution and wastewater treatment. In addition, they must secure a reliable surface water supply. To ensure continued prosperity, the governor of Coahuila established a commission, FIDAGUA, whose purpose is to modernize the water and wastewater systems of the area in a manner which could serve as a model for other cities in northern Mexico. FIDAGUA's goals for Saltillo's future water needs are: study alternatives to meet future water supply needs, evaluate infrastructure and management of water and sewer conveyance systems for modernization and operational changes, evaluate construction of wastewater treatment facilities and study water re-use alternatives, and design an implementation program to execute new initiatives. Currently, wastewater is discharged into dry arroyos without any treatment. Therefore, construction of a wastewater treatment plant will be required. In general, the wastewater drainage system in Saltillo is currently functioning well. However, increased supply and more efficient distribution will require the wastewater system to handle increased flows. A wastewater flow rate analysis was performed and used in conjunction with an area contribution analysis to determine possible flaws in the collection system with respect to the flow carrying capacity of the pipes. The comparison indicated that several collectors were flowing near ultimate capacity, dictating the need for expansions and parallel lines. As water needs of the industries increase, a treated wastewater reuse program will be imperative.

((NSFC Bibliographic Database))

Willman, B.P., G.W. Petersen, and D.D. Fritton. 1981. Renovation of septic tank effluent in sand-clay mixtures. Journal of Environmental Quality v. 10, n.4.

Sand required by Pennsylvania code for use in elevated sand mounds is not specified by sand mineralogy but does require 5-15-% clay by weight. Since this required sandy material is expensive and research elsewhere would suggest that a specific clay percentage is not required, the objective of this research was to test the validity of the clay content requirements and the effects of sand mineralogy on septic tank effluent renovation. Limestone, sandstone, and shale sands were used with clay added to give 0, 3, 6, and 12% clay. Septic tank effluent was applied at the rate of 1.5 cm/day to the surface of each sand-clay mixture for 23 weeks. The effluent was analyzed at regular intervals before and after flowing through 60 cm of the sand for the following 16 chemical and biological variables: pH, chemical oxygen demand (COD), fecal coliforms, fecal streptococci, total Kjeldahl N, NH_4^--N, NO_3^-N, NO_3^- NO_2-N, PO_4^-P, total P, Cl, Ca, Na, K, and specific conductivity. All the sand-clay combinations (including the 0% clay samples) removed over 99% of the fecal coliforms and streptococci. The removal of P and COD and the transformation of N were highly efficient in the limestone and shale sands regardless of clay content. Renovation in the sandstone sand, which is a relatively inert material, was increased by the addition of small amounts of clay. It was concluded that sand type influences the renovation of effluent and is more important than the amount of clay. The results of this study indicate that limestone is the most desirable sand type, although long-term dissolution may be a problem, followed by sandstone with a small percentage of clay, and then by shale. Although shale was a relatively efficient renovator of effluent over the time period studied, it is anticipated that the susceptibility of shale to weathering would lead to early clogging.

APPENDICES

Cherepon, Alan. Personal Communication 23 May 2001. South Texas Caliche.. Texas Natural Resource Conservation Commission.

In South Texas, there is considerable caliche. From my experiences, the South Texas caliche is probably different from other caliche in the state, having some to most of the minerals present by leaching out of the tuffaceous materials, notably in the Jackson Group, and Catahoula-Frio, and I believe up into the Goliad formation. Some areas are more enriched in zeolite minerals, which may be useful for your study application. The area, which has more zeolite mineralization, is if I recall correctly, primarily in the Catahoula (see Galloway's papers) in and around Duval/McMullen Counties. There are also zeolites as well as other "exotic" mineralization in and around many of the uranium areas, especially on the Karnes/Atascosa County border (some of the old uranium deposit papers by Eargle and Weeks mention the zeolites in this area, and , having worked in the area, as well as having collected mineral specimens there since the mid-1970's, I can tell you there are some thick concretion zones overlying the uranium deposits, in what appear to be possible super-, or hyper-calichified layers.

Owens, P.R. 2001. Sand lined trenches to renovate septic system effluent in structured soils. Technical Note.

Increasingly, structured soils are being evaluated for their potential to transmit water and contaminants through bypass flow. Recently several studies utilizing dye tracing techniques have shown that the majority of water is transmitted along structural units and biopores (Morgun et al., 2000). A study by Keys, 1998 showed that 75%-95% of water moved through 10-15% of the soil. This phenomenon is a potential mode of contamination of groundwater through soils especially where soils are highly permeable due to high stone content and shallow to bedrock. One method to improve water quality below septic trenches, are sand lined trenches. Many states require 30 cm of medium to coarse sand surrounding the trenches where the soil is permeable and shallow to bedrock. The sand grains in the bottom of the trench are in direct contact with the soil and serve as a plug to clog the larger pores. The effluent is forced to travel through the smaller pores, which increases the residence time of the effluent and provides a physical filter for suspended solids and an increase in surface area to provide more cation and anion exchange. A study conducted by Wolf et al. (1998), placed a filter field with sand lined trenches in an Alfisol with tile drains 100 cm from the trench. The soil had a structured argillic subsurface horizon with a clay content around 30%. The trenches were lined with 8 cm of sand. The tile effluent was sampled twice a month for three years. The researchers found the water quality of the of the tile drain effluent was significantly higher than the background control samples; however, the NO_3-N was 3.1 mg L^{-1} in the tiles below the septic trenches. This meets the NO_3-N limit established for drinking water standards. The NH_4-N was an average of 1.0 mg L^{-1} and the ortho-P was 0.86 mg L^{-1}. The fecal coliforms were reduced to 18 CFU/100mL. Another similar study conducted by Goff et al. (2001) on a similar soil yielded much different results without the sand lined trenches. The tile drains were placed 91 cm from the unlined trenches. The tile effluent was sampled twice per month for 1 year. In this study, only fecal coliforms were reported. Background samples were taken before sewage was introduced to the system and the coliforms averaged 20 CFU/100 mL. After effluent was introduced to the system, the fecal coliforms ranged from 2 CFU/100 mL to 2000 CFU/100 mL with an average of 393 CFU/100 mL. The comparison of the two systems show that in similar soils, the fecal coliforms were 18 CFU/100mL with sand lined trenches and 393 CFU/100 mL with unlined trenches. This demonstrates the effectiveness of sand lined trenches in structured soils to provide a better filter for septic tank effluent.

References

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Wolf, D.C., M.A. Gross, K.E. Earlywine, E.M. Rutledge. 1998. Renovation of onsite wastewater in a poorly drained soil. Onsite wastewater Treatment. Proceeding of the 8th National Symposium on Individual and Small Community Sytems. ASAE. St. Joseph, MI p. 320-325.

Owens, P.R. 2001. Design of septic tank filter field trenches for climatic stress periods. Technical Note.

Soils serve to store and renovate septic effluent as it returns to the hydrologic cycle. The focus of design of septic system filter fields is to provide storage to keep the effluent below ground. Many states rely on the percolation test and minimum separation distances from a perched seasonal water table to keep the effluent below the soil surface. The percolation test has only limited success and depends on the soil moisture at the time the percolation test is conducted (Gross et al. 1998). A system of design based on soil morphology was developed at the University of Arkansas to store effluent during climatic stress periods (Rutledge et al., 1992). This method estimates the volume of effluent coming out of the house and matches the liquid volume from the house with pore volume in the soil for a given duration during the stress period. Although soil porosity is around 50%, the soil porosity in this model is assumed to be 20%, which is similar to values reported for effective porosity. The soil surface provides the upper boundary for storage volume. The side constraints for the effluent storage volume are assumed to be a 20% slope away from the trench. The bottom of the effluent storage volume is limited by the presence of a seasonal water table, which is determined by the presence of redoximorphic features. According to a study by Franzmeier et al. (1983), the free-water usually occurs about 20 cm above the redoximorphic features and in this model is the lower boundary for storage. These constraints form a trapezoid shape of which 20% of that volume will effectively store effluent. The length of time the soil must store the effluent is determined by the duration of the water table, which is inferred by the intensity of the redoximorphic features (Owens et al., 2001). A soil with only iron concentrations and iron depletions which are not chroma 2 or less are assigned a category of brief and requires that above this perched seasonal water table the effluent must be stored for 6 days. In a soil with chroma 2 or less iron depletions is assigned the category of moderate and the effluent must be stored for 18 days. And finally, a soil horizon where the entire matrix is chroma 2 or less the duration is assigned the term long and must be stored in the soil above the perched seasonal water table for 36 days. Assuming the effluent coming from a house were 600 liters/day and the soil contained a brief seasonal water table, the soil volume needed would be 3600 m^3. The 20% volume within the trench trapezoid must match the soil volume. As a seasonal water table gets closer to the surface, the trapezoid get smaller therefore there is less storage volume. To make up for the lost volume, the length and number of trenches must be increased to match the volume of effluent coming from the house. In well drained soils, the presence of a water table is not a limiting design factor so the loading rate is limited by the soil clogging mat at the trench soil interface (Rutledge et al., 1997). This upper limit is commonly estimated around 3.0 cm/d. In some soils, the texture is limiting the transfer of effluent from the trench to the soil. Clay soils transmit water slowly therefore, this method of design is not applicable.

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