REUSE OF DRINKING WATER TREATMENT PLANTS SLUDGES IN AGRICULTURE: PROBLEMS, PERSPECTIVES AND LIMITATIONS

VERLICCHI P.*, MASOTTI L.*

*Department of Engineering, University of Ferrara, Via G. Saragat 1, I-44100 Ferrara, Italy

ABSTRACT

The paper deals with the disposal of the coagulation-flocculation-filtration sludges from water work plants, which treat surface water ("drinking sludges"). It reports their characteristics, discusses the problems connected with their disposal - in particular by land-application for agricultural or ecological purposes - and analyses what Italian Legislation prescribes, promotes and makes possible for their disposal.

Accounts are given for some case studies in Europe and in the USA.

In the end, the paper compares the future trends in Italy, in Europe and in the USA, and points out how in Italy land application of these sludges for agricultural reuse is not adequately considered as a valid and economic possibility, as in other Countries is occurring.

INTRODUCTION

Quantities and chemical-physical characteristics of Water Works residuals, mainly sludges and brine, depend on the source water type (surface or groundwater) and on the treatments to which water is subjected (coagulation-flocculation-filtration, lime softening, membrane separation, ion exchange, powdered or granular activated carbon adsorption, stripping, etc...).

Treatment, disposal and reuse methods are different for the various residuals.

In this paper, only the problems connected with the disposal of coagulation-flocculation-sedimentation and filtration sludges ("*drinking sludges*") are considered, with particular attention to the reuse for agricultural purposes.

This topic is of particular relevance in many Countries, as well as in Italy, where it can be estimated that about 15% of the local population uses surface water, with a total yearly production of wet sludge of approximately 15 000 000 m^3, that, after dewatering, reduces to 750 000 t/year. This residual is normally disposed in landfill, with a total cost roughly estimated in about 50 million euro/year.

Similar to drinking sludges disposal problems are those related to sludges from iron and manganese removal plants, very common in Italy, especially in small units for the treatment of groundwater. Finally, it is remarkable that in the USA as well as in France, Germany and the Netherlands, also lime sludges, from water softening treatments, are usually used for agricultural purposes, due to the high pH value, which is beneficial to an acid soil.

MATERIAL AND METHODS

Fig. 1 depicts the general flow-sheet of a surface Water Treatment Plant, and specifies where drinking sludges are produced and their treatment and disposal routes, in the "liquid" and "solid" forms; the sludges produced from the backwashing of sand filters, are normally sent in front of the settling compartment (just to recuperate water), but there is a tendency to treat them separately.

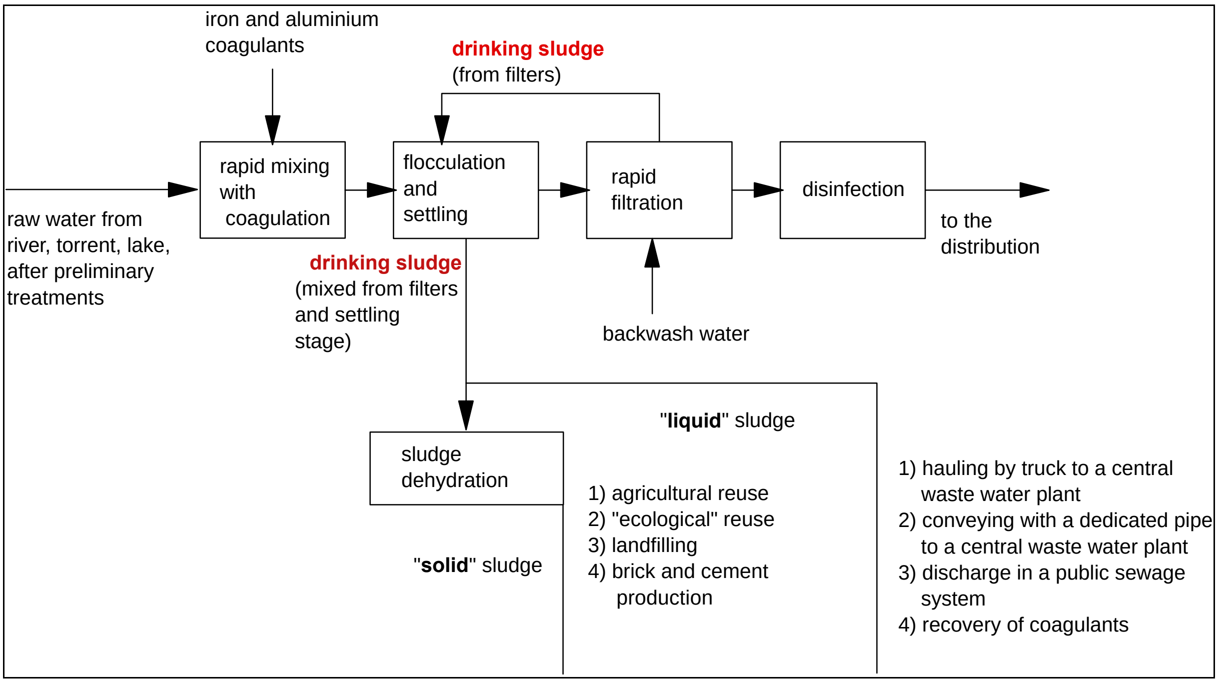

Fig. 1. Production and disposal of solid and liquid "drinking sludges" in a Water Treatment Plant

Drinking sludges contain colloidal iron and alum hydroxides (alum and iron are the most used coagulant (Conio et al. 1994), colloidal or dissolved organic matter, clay, silt and microorganisms. Due to the presence of metal hydroxides, they are often called hydroxide sludges. Tab. 1 reports the average chemical composition of coagulation sludges referring to different Water Treatment Plants in Northern Italy, which draw water from Po, Adige, Sile and Bacchiglione Rivers (Navazio et al., 1990).

Sludge	L.I.*	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	CO_2	Fe^{2+}	Metals
Alum	38%	9.3	0.26	23.3	27.2	1.31	0.33	18.6	absent	trace
Iron	26%	33.6	13.9	5.8	15.1	3.16	0.16	13.9	absent	trace

* Lost on ignition at 550°C

Tab.1 Average chemical composition of hydroxide sludges, [mg/l] except for L.I.

Till some year ago, the main disposal method for these residuals was to return them into surface waters without any further treatment - and some small water Companies still go on with this practice - but now, quite all the Regulations prohibit that.
At present, the possibilities, as pointed out in Fig. 1, are: hauling by truck or conveying through a dedicated pipeline to a wastewater treatment plant with immission into the water or the sludge line; discharge into the public sewage system (mixing the water sludge with sewage, with final unified treatment); landfilling; agricultural reuse; "ecological" land reuse; dedicated land application; industrial reuse for the brick and cement production; recovery of coagulants.
The availability of drinking sludges at a wastewater treatment plant is a beneficial one, as the residual coagulating capacity can be useful to improve the settling effectiveness, to contribute to the phosphorous abatement, to improve the dehydration stage of sludge (Culp et al., 1986; Report, 1998). In this case, the final biological sludge of the wastewater treatment plant ("biosolids") can be used - mixed with drinking sludge - for agricultural purposes.

As to agriculture reuse of drinking sludges, this method includes applications on pasture and cropland, forests, public parks, plant nurseries, roadsides, golf courses, lawns and home gardens.
"Ecological" reuse includes eutrophic lake recovery (capping of the sediments, with immobilisation of phosphorus), pit filling and reclamation, capping of waste landfills.
Dedicated land applications are "intensive" application of sludge (100-200 t/ha per year), designed in order to treat and dispose of *large* quantities of residuals, mobilizing the action of soil microorganisms, sunlight, and/or oxidation, with binding and fixing effects of metals by soil.
Successful application of drinking sludges on land for agricultural reuse, requires an evaluation of the effects of these residuals on soils physical properties (cohesion, aggregation, strength and texture which affect hydraulic properties of the soil), on plant growth and on groundwater quality (Elliott et al. 1990). It is worth noticing that alum and iron hydroxides present in the sludge, favour the fixation of available phosphorus (PO_4^{-3}), thus making it less easily available to vegetation. This can be negative, and can be contrasted adding phosphorous to the sludge, but can be positive, if the soil is subjected to an excessive phosphorous load due - for example - to the spreading of farm organic wastes (Report, 1998; Sequi, 1989).
Anyway, experiments made with the aim of evaluating the possibility of reusing drinking sludge in agriculture, were substantially positive (Lucas et al. 1991; Navazio et al., 1990, Croker et al., 1995).

Italian legislation - the possibility of using drinking sludges in agriculture and for "ecological" purposes

Decreto Legislativo 22/1997 (Ronchi Act) considers all kinds of water industry wastes as *special* wastes (art. 7, comma 3). On disposing of wastes, control Authorities favour all the actions aiming to reuse or recycle wastes, without causing damage or risk for human health or for the environment (art. 2, comma 2, art. 4, comma 1). Possible reclamation actions, which are of interest for drinking, as indicated in Annex C of the Act 22/1997, are land application for *agricultural* and *ecological* purposes, but the Act does not specify what agricultural and ecological reuses are. On the contrary, a former Act (Delibera del Comitato Interministeriale 4.2.1977) specified that agricultural land is an area where vegetable production is utilised for human or animal nourishment, and non agricultural land is a surface excluded from the above reported definition. Agricultural land application was allowed only if sludges can act as a soil fertiliser, amendment or conditioner.
According to Ronchi Act, every waste disposal must be authorised, but *simplified* procedures are allowed for the recovery of some non-hazardous waste categories. Decreto Ministeriale 5.2.1998 admits only reuse in the cement and brick industries as simplified procedures for water industry softening and coagulation sludges.
As to application on agricultural land, Decreto Legislativo 99/92 regulates sludge types and rates of application that may be utilised: drinking sludges are not explicitly included, as the Act takes in consideration in general sludges from civil and industrial settlements. It admits - for agricultural uses - just the application of sludges which can produce "*manure*", "*amendment*", and “*corrective*" effects on the soil. This type of sludges may be mixed with other residuals of the same nature or other wastes which have a natural organic matrix or a composition similar to that of fertilizers, regulated by Law 748/84 (art 12).
Thus, by the Italian Law, it is not so explicit that drinking sludges can be used on the land for "agricultural" purposes. Anyway, the possibility of using them on land to be benefited by "ecology" - as it is stated in the "Decreto Ronchi" - appears to be evident, and so it appears

that they can be used for eutrophic lake recovery, pit filling and land reclamation in general, capping of waste landfills.
On the contrary, it is not clear that "*intensive*" land application of sludges, without agricultural or "ecological" purposes, is still granted, as previously was admitted in the "Delibera del Comitato Interministeriale del 4.2.1977".

Disposal and reuse methods of drinking sludges in italy, in europe and in the usa: case studies

Italy
In Italy, at present - clearly due to the very stiff and unclear Legislation which discourages agricultural applications - drinking sludges are generally landfilled, with very high costs of transportation and final disposal supported by the Water Companies (on the average, about 70 euro/ton). Just in some cases, they are reused in the cement industries (e. g. Ravenna, Ferrara).

European Countries
In the Nineties, different studies have been carried out in France (Forzini, 1990), in Great Britain (Skinner et al., 1996) in Sweden (Report, 1998) and in Denmark (Report, 1998) about agricultural and ecological reuse of drinking sludges. They concluded that:

- these residuals may be effectively applied to land for agricultural purposes, as they have no pathogens, heavy metals concentrations less than law limits for land application, and high concentrations of lime, which improve physical-structural properties of the soil, increasing its fertility (Forzini, 1990);
- on applicating on grassland, the maximum application rate at a time should not exceed 55 m^3/ha, and 3 application per year are the the maximum recommended, (Skinner et al., 1996); moreover also the mixing of these sludges with natural soil represents a feasible practice (Report, 1998)

USA
In many States of the USA, land application must be in general authorized: chemical and physical sludge characteristics have to respect analytical requirements set by local Regulations. Sometimes they are the same as biosolids (Florida Administrative Code, 1998). Tab. 3 reports the limits fixed in Florida and Pennsylvania for heavy metals contents, PCBs and pH.

	pH	As	Cd	Cr	Cu	P	Hg	Mo	Ni	Se	Na	Zn	PCB
PA	5.5-8.5	41	25	1200	1500	300	17	18	420	36	3500	2800	2
FL		75	85		4300	840	57	75	420	100		7500	

Tab. 3. Analytical requirements for land application in Pennsylvania and in Florida, [mg/kg] except for pH.

Usually these sludges are directly applied to the land as either a top dressing or incorporating into the soil. In Pennsylvania, local regulation (Permit no. WMGR017) prohibits mixing of water sludges with other types of solid wastes, including wastes or special handling wastes.
No phosphorus is in general added: actually, in Florida binding phosphorus by drinking sludge alum could have a desirable effect, because it appears that in some places long term use of manure has resulted in an excess of phosphorus in the soil, leaving the land with rain surface runoff and contributing to eutrophication problems in adjacent water bodies (Florida Department of Environmental Protection, 2000).

Some State has fixed the amount of residual which may be applied: Pennsylvania sets 37 t/ha year and for each individual application 50 m^3/ha d; in Georgia at Marietta Facility (ASCE, 1995), the most important case of agricultural reuse, where drinking sludges are conditioned with lime before dewatering and land spreading, the maximum application rate ranges between 11-35 t/ha year and is set by the lime requirements of the field and the lime content of the plant residuals.
Some States, for instance Arkansas, (Arkansas Department, 2000) requires details about the types of vegetation where the residuals will be land-applied, in others (among them Georgia) no restriction has set on the types of crops or pasture, except for the agronomic pH requirements of the cultivations involved.

Future trends in italy, in europe and in the USA

Due to the high disposal costs especially for landfilling (60-300 euro/t depending on the Country) (Verlicchi et al., 2000), more economic alternatives have been evaluated.
In Italy, particular relevance is given to the reuse in the brick or cement industries, for whom simplified procedures are allowed by current legislation (Verlicchi et al. 2000). Some experiences have been carried out for utilizing residual flocculant capacity of drinking sludges, by mixing with wastewater sludges ("biosolids"), and the cost-benefit analysis has shown that one parameter which makes this feasible is a distance less than 5-6 km between the Water Work and Wastewater Plant (Moruzzi, 1990).
In European Countries (Report, 1998), land application for agricultural reuse will be a promising practice for Water Companies in France, Sweden and Great Britain, restoration of eutrophic lakes in Denmark and Great Britain, reuse in the brick or cement industries will have a greater number of applications in Belgium, Denmark, Ireland, Portugal, the Netherlands and Great Britain, drinking sludges transfer in wastewater plants will be realized in many Water Companies in Finland, Luxembourg and the Netherlands, and recovery of coagulant will be practised in Ireland and in the Netherlands.
In USA, National and State Regulations tend to increase the reuse of drinking sludges for agricultural, ecological and industrial purposes, on the basis of experimental studies which are becoming more and more frequent (Lucas et al. 1991; Van Benschoten, 1991; Croker et al. 1995; Lee et al. 1995; Murray 1995, Neukrug, 1995).

CONCLUSIONS

At present, in Italy, the preferred way of disposing of drinking sludges is landfilling after dewatering at the water treatment plant. It is a very costly practice, and it can be roughly estimated that the cost for transport and disposal is about 50 million euro/year.
Keeping this in mind, cheaper alternatives will be greatly appreciated, including the possibility of reusing drinking sludge, according to the most recent tendencies in Europe and in the USA.
Drinking sludge alone or mixed with “biosolids”, that is the organic matter in wastewater sludges, can be a very good amendment and soil fertilizer for many agricultural uses. But, at present, in Italy, long and complicated bureaucratic procedures must be followed by Water Companies in case of drinking sludges reuse with the exception of reuse in the cement and brick industries. Direct land application seems to be a promising disposal way, according to USA current practices as well as the tendency of some European Countries, while indirect land application of sewage-drinking sludges (when drinking sludges are discharged into the public sewage systems) is allowed without any restriction.

Finally, it is worth noticing that, in accordance with the current Italian Laws, Ronchi Act, it does not appear that there is no limitation on the "ecological" use of this residual (eutrophic lakes recovery, pit filling and reclamation, capping of waste landfills).

REFERENCES

ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY, 1999. General Permit for land application of water treatment plant residuals.

ASCE, 1996. Technology Transfer Handbook: Management of Water Treatment Plant Residuals, *Asce and AWWA Ed. NY*.

CONIO O., LASAGNA C., RANIERI M., RIGANTI V., 1994. I prodotti chimici utilizzati nei processi di potabilizzazione. Nota II: Ruolo, problematiche correlate e prima valutazione del loro impiego in Italia, *IA Ingegneria Sanitaria*. (XXIII, 11-12, 637-644)

CROKER R.A., PANKIEWICZ R. J., 1995. An Overview of Residual Management Alternatives and Solutions for a Multi-Plant Pennsylvania Water Utilitily, *Conference Paper AWWA* ACE95239.

CULP/WESNER/CULP, 1986. Handbook of Public Water Systems, Ed. Williams Culp *Van Nostrand Reinhold, NY*

ELLIOTT H.A., DEMPSEY B.A., 1990. Land application of water trestment sludges: impact and management. Final report. Denver CO, *AWWA Research Foundation*.

FLORIDA ADMINISTRATIVE CODE, 1998, Chapter 62-640, Domestic wastewater residuals.

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION, 2000. Private communications.

FORZINI Y., 1990. Analyse des diverses utilisations possibles pour les boues des stations d'eau potable, en particulier l'emploi en agriculture, *Journées techniques Fribourg*, (55-69)

LEE V.G., STEPHENS T., 1995. Establishing NPDES Limitations for residuals from three Phoenix Water Treatment Plants, *Conference Paper AWWA ACE95283* (741-749).

LUCAS J.B., KUPER J., NOVAK J., KNOCKE W., RENEAU R.B., DILLAHA T.A. 1991. Impact of Land application of Alum Sludge on the Growth of Tail Fescue at Lobiolly Pines. *Conference Paper AWWA ACE91090* (745-756).

MORUZZI L., 1990. Un example de stratégie synergique comprenant le traitement des eaux usées, leur potabilisation et leur réutilisation, *Journées techniques Fribourg*, (25-37).

MURRAY K., SECKINGER S., STOOPS R., HUGHES D., ASHE C.R., TRAN T., KIM J., 1995, Pilot Scale Evaluation of Residuals Management Options, *Conference Paper AWWA ACE95045* (177-190).

NAVAZIO G., ALBERTIN P., BARTOLOZZI P., 1990. Smaltimento di fanghi di potabilizzazione, *Giornate di studio Protezione e controllo della qualità delle acque per uso potabile*, Centro Scientifico Internazionale, Milano.

NEUKRUG H.M., 1995. New constraints in Residuals Management: Quantity, quality and Economic Reality, *Conference Paper AWWA ACE95282* (723-738).

LEBOUCHER G., PATRIA L., 1998. Pennsylvania Department of Environmental Resources, Beneficial Use Permit for land application n. WMGR017. Report on Drinking Water Sludges, Lisbon.

SEQUI P., 1989. Chimica del suolo, *Patron Ed. Bologna*.

SKINNER R.J., LEWIS J.G., CARDIFF A., ROAD A., 1996. Testing iron water treatment sludge on grassland 1992-1995. *Summary report*.

Van Benschoten J. E, Stuart G.R., Nensen J.N., 1991. Recovery and reuse of polyaluminum chloride sludges, *Conference Paper ACE91075*, (461-476)

Verlicchi P., Masotti L., 2000. Lo smaltimento dei fanghi di potabilizzazione in Europa e negli Stati Uniti, in press.

Delibera del Comitato dei Ministri per la tutela delle acque dall'inquinamento 4.2.1977 *Criteri, metodologie e norme tecniche generali di cui all'art. 2, lettere b), d) ed e), della Legge 10 Maggio 1976, n. 319, recante norme per la tutela delle acque dall'inquinamento* Gazzetta Uff. della Repubblica Italiana, 21 Febbraio 1977

L. 19 ottobre 1984, n. 748, *Nuove norme per la disciplina dei fertilizzanti*, Gazz. Uff. della Repubblica Italiana n. 305 del 6.11.1984

Decreto Legislativo 27 gennaio 1992, n. 99, *Attuazione della direttiva 86/278/CEE concernente la protezione dell'ambiente, in particulare del suolo, nell'utilizzazione dei fanghi di depurazione in agricoltura*.

Decreto legislativo 5 Febbraio 1997, n. 22, *Attuazione delle direttive 91/156/CEE sui rifiuti, 91/686/CEE sui rifiuti pericolosi e 94/62/CE sugli imballaggi e sui rifiuti di imballaggio* (Ronchi Act), Gazzetta Uff. n. 38 del 15 febbraio 1997

Ministero dell'Ambiente. Decreto Ministeriale 5 Febbraio 1998, *Individuazione dei rifiuti non pericolosi sottoposti alle procedure semplificate di ricupero ai sensi degli articoli 31 e 33 del decreto legislativo 5 Febbraio 1997, n. 22*. Gazzetta Ufficiale n. 88 del 16 aprile 1998